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Assessment of freshwater fish seed resources for sustainable aquaculture

Cover photos:
Left: Freshwater fish seed production activities: hapa system used in fish seed nursery, Cambodia (courtesy of So Nam).
Right, top to bottom: Sacrificing male catfish to obtain milt, Cameroon (courtesy of Randy Brummett); careful selection of broodfish for spawning, Viet Nam (courtesy of Pham An Tuan).

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Preparation of this document

Under the Aquaculture Management and Conservation Service (FIMA) Regular Programme (RP232A1001409), a project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was undertaken from 2005–2006. The project consisted of a desk study (country-level assessment, regional syntheses and thematic reviews on freshwater fish seed resources and production) and an FAO Expert Workshop on Freshwater Fish Seed as Global Resource for Aquaculture (held in Wuxi, China, from 23 to 26 March 2006). The project culminated in the publication of this document which is presented in two parts.

The study and expert workshop were technically supervised by Dr Melba B. Reantaso, Fishery Resources Officer of FIMA, Fisheries and Aquaculture Management Division (FIM) of FAO Fisheries and Aquaculture Department.

Twenty-one aquaculture experts contributed to Part 1 of this document which contains the proceedings and recommendations of the expert workshop. Thirty-five specialists on various aspects of aquaculture contributed to Part 2 of this publication comprised of 21 country case studies, three regional syntheses and eight thematic reviews and contributed papers. The country case studies followed a template and include: (a) introduction, (b) seed resources and supply, (c) seed production facilities and seed technology, (d) seed management, (e) seed quality, (f) seed marketing, (g) seed industry, (h) support services, (j) legal and policy framework, (l) information or knowledge gaps, (m) stakeholder and (n) future prospects and recommendations.

Abstract

Four of the most important resources to aquaculture, outside human and technological resources, are land, water, seed and feed. Efficient use of these resources are necessary to guarantee optimum production from aquaculture. A number of regional and international events highlighted some of the most pressing issues concerning seed in global aquaculture development. These include inadequate and unreliable supply of quality seed, genetic quality, inadequate hatchery technology and facilities for rearing fry/fingerlings, distribution mechanisms, impacts of releases of cultured seed stocks, the need for more hatcheries with business orientation and others. In order to secure stable seed supply for major freshwater aquaculture species, factors affecting seed availability, seed quality, seed production technologies and support services, seed distribution networks, breeding technologies, genetic improvement and domestication need to be understood well if resources are best to be targeted and policy decisions on future investment and management options improved.

Recognizing these issues, a project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was undertaken by the Aquaculture Management and Conservation Service of FAO's Department of Fisheries and Aquaculture. The project was implemented through a desk study and an expert workshop to assess the status of freshwater fish seed resources and supply and its contribution to sustainable aquatic production. The desk study, undertaken between July 2005 and April 2006, consisted of: (i) country-level assessment, (ii) regional syntheses and (iii) thematic reviews. The FAO Expert Workshop on Freshwater Seed as Global Resource for Aquaculture, held in Wuxi, China, from 23 to 26 March 2006 and hosted by the Wuxi Freshwater Fisheries Research Center, Chinese Academy of Fisheries Sciences, was aimed at analysing the current status of the freshwater seed sector used in aquaculture with special emphasis on rural aquaculture and evaluating the current constraints and challenges as basis for identifying measures and generating action that will contribute to the sustainable development of this sector.

This publication is presented in two parts. Part 1 contains the proceedings and major recommendations of the expert workshop which tackled three major themes: (1) seed quality, genetics, technology and certification; (2) seed networking, distribution, entrepreneurship and certification; and (3) how rural fish farmers can benefit from the freshwater aquaseed sector. Part 2 contains the detailed outcomes of the desk study consisting of three regional syntheses (Africa, Asia and Latin America) based on 21 country case studies (Bangladesh, Brazil, Cambodia, Cameroon, China, Colombia, Cuba, Ecuador, Egypt, Ghana, India, Indonesia, Mexico, Nigeria, Pakistan, the Philippines, Sri Lanka, Thailand, Uganda, Viet Nam and Zimbabwe), five thematic reviews (seed quality, genetics and breeding in seed supply for inland aquaculture, seed networks and entrepreneurship, role of seed supply in rural aquaculture, farmer innovations and women involvement in seed production) and three invited papers (self-recruiting species, decentralized seed networking in Bangladesh and establishment of national broodstock centres in Viet Nam).

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Executive summary

A project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was implemented through a desk study and an expert workshop to assess the status of freshwater fish seed resources and supply and its contribution to sustainable aquatic production. The study, undertaken between July 2005 and April 2006, consisted of: (i) country-level assessment, (ii) regional syntheses and (iii) thematic reviews on issues affecting the freshwater fish seed production sector. The project included the FAO Expert Workshop on Freshwater Seed as Global Resource for Aquaculture aimed at analyzing the current status of the freshwater seed sector used in aquaculture with special emphasis on rural aquaculture and evaluating current constraints as basis for identifying measures and generating action to address such challenges. The expert workshop was held in Wuxi, China from 23 to 26 March 2006 and hosted by the Wuxi Freshwater Fisheries Research Center of the Chinese Academy of Fisheries Sciences.

This publication is presented in two parts. Part 1 contains the proceedings and recommendations of the expert workshop which tackled three major themes, namely: (1) Theme 1 on seed quality, genetics, technology and certification; (2) Theme 2 on seed networking, distribution, entrepreneurship and certification and (3) Theme 3 on how rural fish farmers can benefit from the freshwater aquaseed sector. Part 2 presents the detailed outcomes of the desk study consisting of three regional syntheses (Africa, Asia and Latin America) based on 21 country case studies (Bangladesh, Brazil, Cambodia, Cameroon, China, Colombia, Cuba, Ecuador, Egypt, Ghana, India, Indonesia, Mexico, Nigeria, Pakistan, the Philippines, Sri Lanka, Thailand, Uganda, Viet Nam and Zimbabwe), five thematic reviews (seed quality, genetics and breeding in seed supply for inland aquaculture, seed networks and entrepreneurship, role of seed supply in rural aquaculture, farmer innovations and women involvement in seed production) and three invited papers contributed during the expert workshop (self-recruiting species, decentralized seed networking in Bangladesh and establishment of national broodstock centres in Viet Nam).

On key issues concerning Theme 1, the expert workshop recommended for concerned authorities and FAO to: (a) assist member countries in the development of national broodstock certification programs (at national level) including provision of guidelines on development of national broodstock certification systems for public and/or private sector seed suppliers; (b) support the development of guidelines for establishing standardized protocols to optimize seed quality and certify hatcheries at national level; (c) review models used for certification in the livestock sector (and possibly agriculture sector in general) particularly on processes involved in developing certification systems for seed quality; (d) support regional multi-disciplinary reviews of broodstock quality of key freshwater aquaculture species being transferred regionally and internationally; (e) develop species- and/or system-specific checklists on seed quality for use by purchasers at the point of sale and (f) review the potential impact of past and current culture-based fisheries on genetic diversity of wild stocks in major regional watersheds.

Concerning Theme 2, major recommendations to concerned authorities and FAO include: (a) development of technical guidelines on registration, licensing and/or certification and provision of assistance in the implementation of such guidelines; (b) compile a set of best practices implemented in various countries, including models and options for networking and partnerships, based on lessons learned; (c) encourage the establishment of international networks for collaboration in genetic improvement, sharing of information and genetic material; (d) support the development and/or updating

of training and extension materials related to seed production and distribution and (e) conduct livelihood analysis of people in rural communities involved in various activities of seed production and distribution to generate information for policy development.

On key issues pertaining to Theme 3, major recommendations include: (1) provision of capacity building activities in the following areas: (i) seed nursing, entrepreneurship and credit and savings management (targetting women); (ii) simple hands-on and practical training on various aspects of seed production (e.g. breeding; nursing; stress tests; simple seed quality test, basic health checks; conditioning, packaging and transporting; record keeping and basic accounting or simple bookkeeping and simple understanding and managing of risks) for rural fish farmers and hatchery/nursery operators and traders; (2) support a regional project to focus on enhancing the role and empowerment of women in aquatic food production with emphasis on skills development and organization of women into Self-Help Groups (SHG); (3) conduct sustainability studies using Farmer Participatory Research (FPR) in places where Farmer Field Schools (FFS) have been practiced in rural aquaculture (e.g. Bangladesh, Indonesia and Viet Nam), taking experiences and lessons learned and particularly incorporating seed production in the system; (4) review and compile all relevant published materials on indigenous knowledge and farmer innovations and document other unpublished practices; and (5) create a database of farmer innovations and make it accessible to all.

The desk study revealed that harvests from freshwater aquaculture will continue to substantially contribute to global aquatic production. The 21 country case studies were unanimous in their findings that the freshwater seed sector is one of most essential and profitable phase in aquaculture production. Efficient use of freshwater fish seed resources will be necessary to guarantee optimum production from aquaculture.

In Africa, availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture. Government hatcheries have generally failed to achieve sustainability and the private sector is impeded by the lack of marketing information and appropriate technological assistance. At present, the main aquaculture species in the continent are Nile tilapia (*Oreochromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*). While the tilapias are easy to reproduce on-farm, poor broodstock management had resulted in reduced growth rates in many captive populations. Catfish are mostly reproduced in hatcheries, but availability of broodstock and high mortality rates in larvae are key problems still requiring research. Of the countries reviewed, Egypt (1.2 billion tilapia and 250 million carp fingerlings produced) and Nigeria (30 million fingerlings produced) report the highest number of modern private commercial hatcheries, although most of these are unregulated and lack accreditation and certification systems. Ghana, Cameroon, Uganda and Zimbabwe rely almost entirely on semi-commercial systems producing unreliable quantities and quality of seed. Interventions to improve the quality of extension services, make credit more available and build partnerships between public and private sectors to address key researchable topics are recommended to improve the availability of fish seed to African fish farmers.

In Asia, even though seed of major cultivated species are produced in sufficient quantities in hatcheries, poor quality is perceived as a major constraint to expansion of freshwater aquaculture. Several approaches ranging from institutional to farmer-managed decision-making tools have been adopted by countries and farmers to assure fish seed quality. The regional focus has shifted from centralized to decentralized seed production, a strategy which offers opportunities for poor farmers to enter into the fish seed business. Decentralized fish seed production should be supported by appropriate breeding strategies to maintain the genetic quality of broodstock. Building support services at the local level is crucial in expanding fish seed supply. With basic technologies for small-scale fish breeding and fry nursing largely in place, future support should now focus on extension of knowledge and building of institutional support for rural households where there is potential for fish breeding and fry nursing. Information sharing mechanism on hatchery breeding and fry/fingerling production as an agribusiness will also help enhance capacities in countries where these technologies are still not well-developed.

In Latin America, Chile, Brazil, Mexico and Ecuador produce more than 80 percent of the total regional aquaculture production. The overall growth of the freshwater aquaculture industry demands for an increasing and stable supply of reliable and traceable seed to sustain regular production. Such factors are critical to sector sustainability and the issues have been approached firstly by governments and later by farmers themselves. As the aquaculture sector grew and turned into an export-oriented industry, private investment has been channeled into seed production, either as an exclusive activity, or as a part of vertically-integrated aquaculture ventures. Seed quality parameters (i.e. survival, growth rate, disease resistance, size homogeniety) within countries, have historically been indirectly measured through the level of satisfaction of seed buyers and are not regulated by governments. However, with increasing international seed trade, regional hatcheries are slowly introducing quality assurance measures, both as part of hatchery operation procedures and genetic manipulation of their broodstock. The only type of certification that is common to all countries of the region is an official zoosanitary certificate that is mandatory before domestic and international movement of organisms can take place. Given the rapid expansion of export-oriented culture of high-value species, it is expected that both volume of high quality seed and quality certification procedures will gradually be in place throughout the region.

In order for the sector to develop in a sustainable manner, an enabling environment will be required in terms of basic production and human infrastructure, financial/business/marketing support and policy and legal frameworks. Severe challenges will be faced concerning water allocation and land use for general aquaculture production and as such the following areas below need careful consideration to enhance the development of the freshwater seed production sector to support aquaculture sustainability.

Seed quality is an essential attribute to optimize the potential for aquaculture production (better yield and good returns) and is related to the quality of the broodstock used and the seed produced. Genetic quality and good hatchery/nursery management are two main factors affecting seed quality. It is important to understand the factors that contribute to poor quality seed and to develop interventions (e.g. better management practices) to address the problem. In many aquaculture systems, stocking quality seed does not necessarily ensure a successful crop. Seed certification and accreditation of practices should be continuously explored.

Approaches to genetic improvement using successful research findings (e.g. selective breeding, application of genetic markers, sex control techniques, chromosome set manipulation, crossbreeding and transgenesis) should be integrated with good genetic management during domestication and translocation of aquaculture stocks. In addition, such approaches should be supported by efficient and equitable dissemination and technology transfer strategies coupled with awareness and/or certification programs. Strengthening awareness and institutional capacity to deal with ecological risks associated with introductions of alien and/or genetically improved fish will be essential. Use of indigenous species and their domestication for freshwater aquaculture production should be promoted.

Seed certification is a quality assurance system aimed to produce and supply high quality seed to farmers. It is a system which meets certain minimum pre-determined quality standards and criteria, e.g. genetic purity, appropriate husbandry, high grow-out performance, freedom from major diseases, other market needs, etc. A process which adds value to the potential of aquaculture production, seed certification will outweigh the anticipated increased costs when done properly. Seed certification is part of a wider programme on genetics and breeding, biodiversity conservation and international trade.

There are various levels of success on seed certification used for freshwater aquaculture seed. There is value in reviewing certification models used in the livestock and plant sectors to determine which processes can be adapted for use in aquaculture.

The main actors in a freshwater seed network are the breeders, hatchery and nursery operators, traders, growers and other input/service providers (e.g. water suppliers, transport providers, hormone sellers, nightsoil traders, extension workers, etc.). Seed networking has become an important component of the sector that enabled accessibility and delivery of fish seed in areas distant from traditional sources, thus, stimulating aquaculture development in marginal and remote rural areas. Seed networking should be promoted and supported with enabling policies and required infrastructure.

Broodstock management will be a key issue in meeting the projected fingerling requirement to 2020. To meet this challenge, there is a need for a shift in freshwater aquaculture technology from intensive-water use of land-based systems to water-saving and water productivity-enhancing interventions. Integrating fish seed production with agriculture and optimizing the use of irrigated agricultural land, as seen in several countries, can be further explored. The use of cages and *hapas* for fry- to fingerling-rearing is becoming increasingly popular in some countries, particularly those which have large numbers of perennial water bodies. Such initiatives contribute to the enhancement of productivity of irrigation water bodies and enable landless households to generate income and animal protein from fish culture activities provided there is equal access to such resources.

Many rural farmers have developed technology innovations and applied indigenous knowledge in order to meet their livelihood necessities. In aquaculture seed production sector, some examples include the following: (1) hatchery technology (bamboo/wood-based circular technology), (2) breeding techniques (Bundh breeding in India), (3) nursing techniques (removal of egg stickiness by washing with milk prior to nursing in jars, application of fermented manure including oil cakes, stunting fish technology), (4) local methods for fish collection and transportation and others. Many such innovations and indigenous knowledge remain undocumented. Reviewing and compiling all relevant published materials on indigenous knowledge and farmer innovations, documenting other unpublished practices, creating a database on farmer innovations and making it accessible to all, replicating and promoting fully-tested innovations in other countries/regions and giving recognition to successful farmer innovators are suggested actions to enhance available human capital.

Private-public sector partnership can be tapped by improving integration and linkages of inputs and efficient delivery of services of the broad spectrum of the freshwater fish seed production sector, for example: (a) large-scale hatchery operators supporting small-scale operators on training, information sharing, broodstock exchange and provision of high quality seed; (b) promoting government-private sector (large hatcheries) partnership for broodstock development and (c) promoting contract growing for fingerling production as practiced in China.

Aside from enabling policies, there are many strategic elements and approaches which can be promoted to enhance the benefits to and participation and contribution of small-scale farmers. These include: (i) practical application of the concepts of FFS, FPR and training of trainers; (ii) providing good access to rural microfinancing programmes; (iii) supporting formation of SHGs and producer associations; (iv) harnessing farmer innovation and indigenous knowledge; (v) building capacity on community-based aquatic resource management; and (vi) communicating the various risks in aquaculture production.

Contents

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Acronyms and abbreviations

AAI	Aquaculture Authority of India
ABRACOA	Brazilian Association for the Culture of Aquatic Organisms
ABRAQ	Brazilian Aquaculture Association
ABRAS	Brazilian Supermarket Association
ACIAR	Australian Centre for International Agricultural Research
AD	Aquaculture Division (Department of Fisheries, Cambodia)
ADB	Asian Development Bank
ADP	Agricultural Development Programmes
AEO	Aquaculture Extension Officers
AFFAN	Association of Fish Farmers and Aquaculturists of Nigeria
AFLPs	amplified fragment length polymorphisms
AFGRP	Aquaculture and Fish Genetic Research Programme
AFP	anti-freeze protein gene
AGCD	General Administration for Development Cooperation
AGIP	Azienda Generale Italiana Petroli
AIFP	Aquaculture and Inland Fisheries Project
AIMS	Aquaculture of Indigenous Mekong Species (Cambodia)
AIT	Asian Institute of Technology
AKVAFORSK	Norway Institute of Aquaculture Research
AOFFN	Association of Ornamental Fish Exporters of Nigeria
APFON	Association of Fingerling Producers of Nigeria
APHEDA	Australia People for Health Development Abroad
APIP	Agriculture Productivity Improvement Project (Cambodia)
AQDC	Aquaculture Development Center (Sri Lanka)
ARDQIP	Aquaculture Resource Development and Quality Improvement Project (Sri Lanka)
AREX	Agriculture and Rural Extension
ASA	Association for Social Advancement
AUSAID	Australian Agency for International Development
BAU	Bangladesh Agricultural University
BCIS	Beijing Consensus and Implementation Strategy
BDT	Bangladesh Taka
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BFRI	Bangladesh Fisheries Research Institute
BFSPRC	Bati Fish Seed Production and Research Center (Cambodia)
BMPs	Better management practices
BRAC	Bangladesh Rural Advancement Committee
BRL	Brazil Real
CAFAN	Catfish Farmers Association of Nigeria
CaO	calcium oxide, quicklime
CARD	Collaboration for Agriculture and Rural Development Programme
CARE	Cooperative for Assistance and Relief Everywhere
CARFSPS	Chak Ang Rae Fish Seed Production Station (Cambodia)
CARITAS	Catholic Agency for International Aid and Development
CAUNESP-UNESP	Aquaculture Center of the São Paulo State University

CBFM	Community-based Fisheries Management
CBOs	Community-based Organizations
CCFRS	Chrang Chamres Fisheries Research Station (Cambodia)
CCRF	Code of Conduct for Responsible Fisheries (of FAO)
CDRMP	Community Development and Resource Management Project
CENIACUA	National Center of Investigations in Aquaculture (Colombia)
CEPAM	Aquaculture Training Centre of Mamposton (Cuba)
CEPTA	Aquaculture Research and Training Center (Brazil)
CFA	Central African Franc
CGIAR	Consultative Group on International Agricultural Research
CGHV	Grass carp hemorrhagic virus
CIFA	Central Institute for Freshwater Aquaculture
CIFE	Central Institute of Fisheries Education
CIFRI	Central Inland Fisheries Research Institute (India)
CLSU	Central Luzon State University (CLSU)
CMFRI	Central Marine Fisheries Research Institute (India)
CNY	China, Yuan Renmindi
COA	Commission on Audit
CoC	Code of Conduct
COD	Carbon oxygen demand
CODEVASF	Company for the Development of the São Franscisco Valley (Brazil)
CONAMA	National Council for Environmental Affairs (Brazil)
CoP	code of practice
COP	Colombian peso
CP	Charoenpokaparn Company Ltd.
CP	culture pond
CRS	Catholic Relief Services
CSIR	Council of Scientific and Industrial Research (India)
CY	Calendar Year
CUC	Cuba Convertible Peso
DANIDA	Danish International Development Agency
DMMSU	Don Mariano Marocs Memorial State University
DNA	deoxyribonucleic acid
DNOCS	National Department of Engineering Against Droughts
DFID	Department for International Development of the United Kingdom
DFRRI	Directorate of Food, Roads and Rural Infrastructure
DOCA	deoxycorticosterone acetate
DoF	Department of Fisheries (Cambodia)
DOF	Department of Fisheries (Bangladesh)
DOF	Department of Fisheries (Thailand)
DoF/AIT-AARM	DoF/AIT Aquaculture and Aquatic Resources Management
DoF/MRC-READ	DoF/MRC Rural Extension for Aquaculture Development
EED	Exuvia entrapment disease
EEZ	Exclusive Economic Zone
EGP	Egypt Pound
EIA	environmental impact assessment
ELISA	Enzyme-Linked Immunosorbent Assay
EOS	Extension Officers
EPC	Extract of Pituitary of Carp
ESALQ-USP	Superior School of Agriculture Luis de Queiroz from the University of São Paulo in Piracicaba

ESC	Exotic Species Center
ESPC	Exotic Species Production Center
EU-PRASAC	EU-Pole regional de recherche appliquee au developpement des savanes d'agriculture centrale
EUS	Epizootic ulcerative syndrome
F1	Filial 1, the first filial generation seed/plants or animal offspring resulting from a cross mating of distinctly different parental type
FAC	Freshwater Aquaculture Center (CLSU)
FAG	Farming Guaranty Funds (Colombia)
FAIEX	Freshwater Aquaculture Improvement and Extension Project (Cambodia)
FAO	Food and Agriculture Organization of the United Nations
FAO-RAF	FAO Regional Office for Africa
FAO-RAP	FAO Regional Office for Asia and the Pacific
FARMC	Fisheries and aquatic resource management councils
FAO-RLC	FAO Regional Office for Latin America and the Caribbean
FASA	Faculty of Agronomy and Agricultural Sciences
FaST	FAC-Selected Tilapia
FDA	Food and Drug Administration (United States of America)
FDAP	Fisheries Development Action Plan
FDF	Federal Department of Fisheries (Nigeria)
FEDEACUA	Colombian Federation of Aquafarmers
FFDA	Fish Farmers Development Agency
FFS	Farmer field schools
FIES	Fisheries and Aquaculture Information and Statistics Service
FIMA	Aquaculture Management and Conservation Service
FINAGRO	Financing Funds of Sector Agropecuario (Colombia)
FISON	Fisheries Society of Nigeria
FLD	Farmer Livelihood Development (Cambodia)
FMAS	farmer-managed aquatic systems
FMRT	Fisheries and Marine Resource Technology
FSPRS	Fish Seed Production and Research Stations (Cambodia)
FSPS	Fishery Sector Programme Support
FRSS	Fisheries Resource Survey System (Bangladesh)
GAFRD	General Authority for Fish Resources Development
GAP	Good Aquaculture Practices
GAVS	General Authority for Veterinary Services
GBC	Genetic Breeding Center
GCHV	Grass carp hemorrhagic virus
GDP	Gross domestic product
GEF	Global Environmental Facility
GET EXCEL	Genetically Enhanced Tilapia – and Excellent strain that has Competitive advantage for Entrepreneurial Livelihood projects
GFSMF	Government Fish Seed Multipying Farms
GH	growth hormone gene
GHC	Ghana Cedi
GIAN	Grassroots Innovation Augmentation Network (India)
GIFT	Genetically Improved Farmed Tilapia
GIFT FI	GIFT Foundation, Incorporated
GMF	Grammen Matsha Foundation
GMT	Genetically Male Tilapia

GMO	genetically modified organisms
GOV	Government of Viet Nam
GSI	Genetic stock identification
GST	Genomar Supreme Tilapia
GTZ	German Technical Cooperation
GURT	genetic use restriction technologies
HACCP	Hazard Analysis and Critical Control Point
HCG	Human Chorionic Gonadotropic
HH	High Health
HHP	household pond
IAGA	International Association for Genetics in Aquaculture
IAS	Institute of Aquaculture, Stirling University
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
ICA	Colombian Institute of Agriculture and Livestock
ICAR	Indian Council of Agricultural Research
ICES	International Council for the Exploration of the Seas
ICLARM	International Center for Living Aquatic Resources Management
IDA	International Development Association
IDR	Indonesian Rupiah
IDRC	International Development Research Centre (Canada)
IFReDI	Inland Research and Development Institute (Cambodia)
IIM	Indian Institute of Management
IITA	International Institute for Tropical Agriculture
IMC	Indian major carps
IMNV	idiopathic muscle necrosis virus
INCODER	National Institute for Rural Development (Colombia)
INPA	National Institute of Fisheries and Aquaculture (Colombia)
INR	Indian Rupee
IOs	international organizations
IPM	Integrated Pest Management
IPN	infectious pancreatic necrosis
INR	Indian Rupee
IRAD	Institute of Agricultural Research for Development
IRR	Internal Rate of Return
IVA	Tax Valor Agregado (Colombia)
IVLP	Institute Village Link Programme
JICA	Japanese International Cooperation Agency
KHR	Cambodia Riel
$KMNO_4$	potassium permanganate
KVK	Krishi Vignana Kenddra
LAPAD-UFSC	Freshwater Fish Aquaculture Laboratory from the Federal University of Santa Catarina
LH-RH	Luteinizing hormone releasing hormone
LGC	Local Government Code
LGU	Local Government Unit
LHA	Lake Harvest Aquaculture
LKR	Sri Lankan Rupee
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MAPA	Ministry of Agriculture, Supply and Cattle (Brazil)
MAS	marker assisted selection
MBV	monodon baculovirus

MCAC	*Mission francaise de cooperation et d'action culturelle*
MEP	Ministry of Economy and Planning
MINEPIA	Ministry of Animal Industries and Fisheries
MINRESI	Institute for Agricultural Research for Development
MIP	Ministry of Fisheries (Cuba)
MCC	Mennonite Central Committee
MMV	*Macrobrachium* muscle virus
MINSAP	Institute of Hygiene and Epidemiology of the Ministry of Public Health (Cuba)
MOA	Memorandum of Agreement Ministry of Agriculture (China)
MOFI	Ministry of Fisheries (Viet Nam)
MoFL	Ministry of Fisheries and Livestock (Bangladesh)
MPEDA	Marine Products Export Development Authority
MRC-AIMS	Aquaculture of Indigenous Mekong Species of the Mekong River Commission
MrNV	*Macrobrachium rosenbergii* nodavirus
mtDNA	mitochondrial DNA
MS 222	tricaine methane sulfonate
MSc	Master of Science
MXN	Mexican Peso
NA	Northern Areas
NAADS	National Agriculture Advisory Services (Uganda)
NABARD	National Bank for Agriculture and Rural Development
NABWSS	National Aquatic Bred and Wild Seed System (China)
NACA	Network of Aquaculture Centres in Asia-Pacific
NACRDB	Nigeria Agricultural Cooperative and Rural Development Bank
NAFEC	National Fishery Extension Centre
NAQDA	National Aquaculture Development Authority of Sri Lanka
NARS	National Agricultural Research Systems
NASPS	National Aquatic Seed Production System
NAWCP	National Aquatic Weed Control Project
NBC	National Broodstock Center (Philippines)
NBC	National Broodstock Centre (Viet Nam)
NBFGR	National Bureau of Fish Genetic Resources
NCCA-WBV	National Certification Committee of Aquatic Wild and Bred Varieties
NCDC	National Cooperative Development Cooperation
N_e	effective population size
NEPAD	New Partnership for Africa's Development
NET	northeast Thailand
NGOs	Non-governmental Organizations
NGN	Nigerian Naira
NEFP	Northwest Fisheries Extension Project (Bangladesh)
NFFTC	National Freshwater Fisheries Technology Center (Philippines)
NIF	National Innovation Foundation (India)
NIFFR	National Institute for Freshwater Fisheries Research (Nigeria)
NIOMR	Nigerian Institute for Oceanography and Marine Research
NORAD	Norwegian Agency for Development Cooperation
NPK	Nitrogen, Phosphorus, Potassium

NPRS	National Poverty Reduction Strategy
NRCCF	National Research Center for Coldwater Fisheries
NSPFS	National Special Programme on Food Security
NUFASD	Nigeria Union of Fishermen and Seafood Dealers
NWFP	North West Frontier Province
NWP	North West Province (Sri Lanka)
OIE	World Animal Health Organisation (Office International des Epizooties)
OPIP	Provincial and National Fisheries Inspection Services (Cuba)
PADEK	Partnership for Development in Kampuchea
PAS	Philippine Aquaculture Society
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCARRD	Philippine Council for Agricultural Resources Research and Development
PCR	polymerase chain reaction
PDA	Prawn Culture Project (Bangladesh)
PDAFF	Provincial Department of Agriculture, Forestry and Fisheries (Cambodia)
PFD	Provincial Fisheries Divisions (Cambodia)
PG	pituitary gland
PhD	Doctor of Philosophy
PHP	Philippine Peso
PKR	Pakistan Rupee
PL	Post-larvae
PMA	Plan for Modernization of Agriculture (Uganda)
PNVRA	National Agricultural Research and Extension Program
PPO	Private pond operator
PRA	participatory rural appraisal
PROSPER	*Procedure optimisee de selection individuelle par epreuves repetees*
QAAD	quarterly aquatic animal disease
QTL	quantitative trait loci
RA	Republic Act
RAPD	random amplified polymorphic DNA
RDRS	Rangpur Dinajpur Rural Services (Bangladesh)
RF	rice field
RFLP	restriction fragment length polymorphisms
RIA	Research Institute for Aquaculture
ROI	return on investment
ROS	Regional Outreach Stations (Philippines)
RRD	Red River Delta
RVDB	River Vallies Development Board
SAEP	Society of Aquaculture Engineers of the Philippines
SCA	Aquaculturists Association (Cuba)
SCALE	SAO Cambodia Aquaculture Low Expenditure
SEAFDEC-AQD	Southeast Asian Fisheries Development Center – Aquaculture Department
SEAP	Special Secretariat of Aquaculture and Fisheries
SEAPB	*Service d'Etudes et d'Appui aux Populatuons a la Base*
SEAP/PR	Special Secretariat of Aquaculture and Fisheries from the Presidency of the Republic of Brazil
SEC	southeast Cambodia

SEDPII	Second Five-Year Socio-economic Development Plan 2001–2005 (Cambodia)
SFD	States Fisheries Division (Nigeria)
SHG	Self-help Groups
SMC	San Miguel Corporation
SNPs	single nucleotide polymorphisms
SQIC	Seed Quality Inspection Centers
SPDC	Shell Petroleum Development Company
SPF	Specific pathogen free
SPR	Specific pathogen resistant
SPS Agreement	Sanitary and Phytosanitary Agreement of the World Trade Organization
SRS	self-recruiting species
SRT	Sex reversed tilapia
STREAM	Support to Regional Aquatic Resources Management
SUDA	Sustainable Aquaculture Development
SUFA	Support to Freshwater Aquaculture
SUMA	Support to Brackishwater and Marine Aquaculture
TCDC	Technical Cooperation Among Developing Nations
TCP	Technical Cooperation Programme
THB	Thailand Baht
Tk	Bangladesh Taka
TKFSPS	Toul Krasang Fish Seed Production Station (Cambodia)
TP	trap pond
TPCL	Tata Power Companies Limited
TSP	Triple super phosphate
TSV	Taura syndrome virus
UEM	University of Maringá in Paraná
UFAN	United Fisheries Association of Nigeria
UGX	Ugandan Shilling
UMATA	Unidades Municipales de Asistencia Técnica Agropecuaria
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UPMSI	University of the Philippines Marine Science Institute
UV	ultraviolet
VCDL	Vorion Chemicals and Distilleries Limited
VND	Viet Nam Dong
WB	World Bank
WBVA	Wild Bred Variety Amplifier
WFC	World Fish Center
WMD	White muscle disease
WRI	Water Research Institute
WSD	white spot disease
WSSV	white spot syndrome virus
WTD	white tail disease
WTO	World Trade Organization
WVCC	Wild Variety Collection Center
XAF	Cameroon CFA Franc BEAC
XSV	extra small virus
ZWD	Zimbabwe Dollar

Fish and other species

SCIENTIFIC NAME	COMMON NAME/LOCAL NAME
Acipenser schrenckii	Amur sturgeon
Acrossocheilus hexagonolepis	mahseer
Aethiomastacembelus praensis	spiny eel
Amur pikc	pikes
Anabas testudineus	climbing perch, Thai koi
Araipama gigas	Pirarucu
Argyrosomus regius	meagre
Arichthys aor	singhari
Aristichthys nobilis	bighead carp
Astronotus ocellatus	apaiari
Astyanax altiparanae	lambari
Bagarius bagarius	catfish
Barbodes gonionotus	silver barb
Barbonymus altus	red-tail tinfoil barb
Barbonymus gonionotus	silver barb
Barbus subinensis	minnow, carp
Brycon amazonicus	matrinxa
B. hilarii	piraputanga yamú
B. henni	sabaleta
B. orbignyanus	piracanjuba
B. siebenthalae	yamú
Botia birdi	Birdi loach
Carassius auratus	ornamental goldfish
Carassius auratus pengzesis	Pengze crucian carp
C. carrasius	crucian carp
Catla catla	catla
Chana obscura	tilapia
Channa asiatica	Chinese snakehead
C. gachua	murrels
C. marulius	saul
C. micropeltes	giant snakehead
C. punctatus	murrels
C. striata	giant snakehead
Chrysichthys nigrodigitatus	tilapia
C. walkeri	Bagrid catfish
Cichla ocellaris	tucunare
Cirrhinus cirrhosus	mrigal
C. molitorella	mud carp
Cirrhina mrigala	mrigal
Clarias x Heterobranchus	hybrid catfish
Clarias batrachus	Asian catfish
Clarias gariepinus	African catfish
Clarias macrocephalus	walking catfish
Clarias macrocephalus x C. gariepinus	hybrid catfish
Clarias gariepinus x C. batrachus	hybrid catfish
Clarias lazera	sharptooth catfish

Clarias sp.	catfish
Colisa lalia	dwarf gourami
C. macropomum	tambaqui
Colossoma macropomum	black cachama
Cristaria placata	river shell, winkle shell
Ctenopharyngodon idella	grass carp, *Carpa herbivora*
Cyclocheilichthys enoplos	cyprinid
Cyprinus carpio	common carp, *Carpa comun*
Cyprinus carpio singuomensis	common carp
Cyprinus carpio var. jian	Jian carp
Cyprinus carpio var. specularis	mirror carp
Cyprinus carpio var. wuyanensis	common carp
Dicentrarchus labrax	European seabass
Erythroculter ilishaeformis	topmouth culter
Fenneropenaeus chinensis	fleshy prawn, Chinese white shrimp.
Fugu obscurus	pufferfish
Fugu xanthopterus	pufferfish
Gadusia chapra	clupeid
Glossogobius giurus	goby
Glyptothorax kashmirensis	catfish
G. reticulatum	catfish
Gymnacus niloticus	tilapia
Hemibagrus wyckioides	*Hemibagrus* catfish
Hemichromis elongates	banded jewelfish
Hemosorubim platyrhynchos	juropoca
Heterobranchus bidorsalis	African clariid catfish
H. longifilis	Vundu catfish
Heteropnuestes fossilis	Asian catfish, shing
Heterotis niloticus	kanga
Hilsa ilisha	clupeid
Hoplis malabaricus	trairao
Hypopthalmichthys harmandi	Vietnamese silver carp
H. molitrix	silver carp, *Carpa plateada*
Hyriopsis cumingi	triangle mussel
H. schlegeri	pearly mussel
Ictalurus nebulosus	bullhead brown catfish
I. punctatus	channel catfish
Labeo bata	Ilsha bata
L. calbasu	kalbaush
L. chrysophekadion	black sharkminnow
L. dero	carp
L. fimbriatus	carp
L. gonia	Kurio labeo
Lates niloticus	tilapia
Labeo calbasu	kalbaush
L. rohita	rohu, rui
Leiarius marmoratus	yaque
Lepomis macrochirus	bluegill
L. amblyrhynchus	chimbore
L. elogantus	piapara
L. friderici	piau
L. macrocephalus	piauvucu, piaucu
L. obtusidens	piava

Leptobarbus hoevenii	hoven's carp
Liza ramada	thin-lipped grey mullet
Macrobrachium brimanicu m	freshwater prawn
M. malcolmsoni	freshwater prawn
M. rosenbergi	freshwater prawn
M. vollehonvenii	freshwater shrimp
Mastacembelus spp.	mahseer
Megalobrama amblycephala	blunt snout bream
Megalobrama terminalis	black Amur bream
Micropterus salmoides	black bass, *Trucha americana*
Misgurnus mizolepis	Korean mud loach
Morone chrysops x M. saxilis	hybrid striped seabass
Morulius chrysophekadion	black shark
Mugil cephalus	mullet
Mugil sp.	mullet
Mystus cavasius	Gangetic mystus
Mylopharyngodon piceus	black carp
Myxocyprinus	Chinese high fin banded shark
Notopterus chitala	featherback
N. notopterus	Notopterus, featherback
Ompok bimaculatus	catfish
O. pabda	Pabda, butterfly catfish
Oncorhynchus mykiss	rainbow trout
Ophiocephalus micropeltes	snakehead
Oreochromis aureus	tilapia
O. leucostictus	mbiru
O. macrochir	tilapia
O. mossambicus x O. niloticus	red tilapia
O. mortimeri	tilapia
O. niloticus	tilapia, Nile tilapia, GIFT tilapia
O. nilotics x O. aureus	hybrid tilapia
Osphronemus goramy	giant gourami
Osteobagrus aor	catfish
O. seenghala	catfish
Osteochilus melanopleura	local name krom, cyprinid
Oxyeleotris marmoratus	sand goby
Pangasianodon hypophthalmus	pangasiid catfishes (river catfish, sutchi catfish)
Pangasius conchophilu	pangasiid catfishes
P. larnaudiei	pangasiid catfishes
P. bocourti	pangasiid catfishes
Pangasius sutchi	Thai pangas
Patinopecten yessoensis	Japanese scallop
Parachanna obscura	snakehead
Piaractus brachypomus	black cachama
Piaractus mesopotamicus	pacu
P. brachypomus	pirapitinga
Pimelodus blochii	nicuro
P. grosscopfii	capaz
Plagiognathops microlepis	Smallscale yellowfin
Plecoglossus altivelis	Japanese ayu
Phractocephalus hemioliopterus	pirarara
Prochilodus lineatus	curimbatá, curimba
Prochylodus magdalenae	bocachico

Pseudoplatistoma fasiatum	bagre rayado
P. tigrinum	bagre rayado
Pseudoplatystoma spp.	Pintado, surubim, cachara
Puntius sarana	Olive barb
P. conchonius	rosy barb
Rita pevimentata	catfish
R. rita	catfish
Rana heckstheri	frog
Rhandia spp.	jundiá
Rhinomugil corsula	Indian mullet
Salminus brasiliensis	dourado
S. maxillosus	dourado
Salmo fario	brown trout
S. trutta	brown trout
Sarotherodon galilaeus	tilapia
S. melanopleura	tilapia
Schizothorax spp.	carp
Semaprochilodus sp.	jaraqui
Setipina phasa	clupeid
Silonia silondia	catfish
Sorobim lima	jurupenses
Sparus aurata	gilthead seabream
Spinibarbus sinensis	barbodes
Steatocranus irvinea	bream or mango fish
Synodontis arnoulti	squeakers or upside-down catfishes
S. macropthalmus	squeakers or upside-down catfishes
S. velifer	Eupterus
Takifugu flavidus	towny puffer
Tenualosa ilisha	Indian chad
Tilapia aurea	blue tilapia
T. guineansis	tilapia
T. nilotica	Nile tilapia
T. rendali	tilapia
T. sparmanni	tilapia
T. zilli	tilapia
Tor khudree	Deccan mahseer
T. macrolepis	Golden mahseer
T. mosal	mahseer
T. mussulla	mahseer
T. nelli	mahseer
T. progenies	mahseer
T. putitora	Putitor
T. tor	mahseer
Trichogaster pectoralis	snakeskin gourami
Trionyx sinensis	soft-shell turtle
Valamugil seheli	bluespot mullet
Wallago attu	catfish
Xenocypris argentea	yellowfin
Xiphophorus helleri	green swordtail

Annexes, boxes, figures, plates, tables

6.3 AQUACULTURE SEED RESOURCES IN LATIN AMERICA: A REGIONAL SYNTHESIS

7.1 FRESHWATER FISH SEED RESOURCES IN BANGLADESH

7.4 FRESHWATER FISH SEED RESOURCES IN CAMEROON

7.5 FRESHWATER FISH SEED RESOURCES IN CHINA

7.6 FRESHWATER FISH SEED RESOURCES IN COLOMBIA

7.7 FRESHWATER FISH SEED RESOURCES IN CUBA

7.8 FRESHWATER FISH SEED RESOURCES IN ECUADOR

7.9 FRESHWATER FISH SEED RESOURCES IN EGYPT

7.10 FRESHWATER FISH SEED RESOURCES IN GHANA

7.11 FRESHWATER FISH SEED RESOURCES IN INDIA

7.12 FRESHWATER FISH SEED RESOURCES IN INDONESIA

7.13 FRESHWATER FISH SEED RESOURCES IN MEXICO

7.14 FRESHWATER FISH SEED RESOURCES IN NIGERIA

7.15 FRESHWATER FISH SEED RESOURCES IN PAKISTAN

7.16 FRESHWATER FISH SEED RESOURCES IN THE PHILIPPINES

7.17 FRESHWATER FISH SEED RESOURCES IN SRI LANKA

7.18 FRESHWATER FISH SEED RESOURCES IN THAILAND

7.19 FRESHWATER FISH SEED RESOURCES IN UGANDA

7.20 FRESHWATER FISH SEED RESOURCES IN VIET NAM

7.21 FRESHWATER FISH SEED RESOURCES IN ZIMBABWE

8.1 SEED QUALITY IN FRESHWATER FISH PRODUCTION

8.2 GENETICS AND BREEDING IN SEED SUPPLY FOR INLAND AQUACULTURE

8.3 SEED NETWORKS AND ENTREPRENEURSHIP

8.4 ROLE OF FRESHWATER SEED SUPPLY IN RURAL AQUACULTURE

8.5 FARMER INNOVATIONS AND WOMEN INVOLVEMENT IN SEED PRODUCTION

8.6 SELF-RECRUITING SPECIES (SRS) FROM FARMER-MANAGED AQUATIC SYSTEMS (FMAS) – THE CONTRIBUTION OF NON-STOCKED SPECIES TO HOUSEHOLD LIVELIHOODS

8.7 DECENTRALIZED SEED – POORER FARMERS PRODUCING LARGE SIZE FINGERLINGS IN IRRIGATED RICE FIELDS IN BANGLADESH

8.8 ESTABLISHMENT OF NATIONAL BROODSTOCK CENTRES IN VIET NAM

PART 1

PROCEEDINGS AND RECOMMENDATIONS OF THE FAO EXPERT WORKSHOP ON FRESHWATER FISH SEED RESOURCES FOR SUSTAINABLE AQUACULTURE

Officials and experts participating at the FAO Expert Workshop on Freshwater Fish Seed Resources for Sustainable Aquaculture held at the Freshwater Fisheries Research Center in Wuxi, China from 23 to 26 March 2006

Seated (left to right): C.V. Mohan (NACA), Magdy Saleh (Egypt), Graham Mair (Australia), Mohammad Hasan (FAO Rome), Simon Funge-Smith (FAO Bangkok), Wei Shaofen (China), Hu Honglang (China), Xu Pao (China), Melba Reantaso (FAO Rome), Arlene Nietes-Satapornvanit (United Kingdom), So Nam (Cambodia), Miao Weimin (China).

Standing (second row, left to right): Sunil Siriwardena (United Kingdom), Alex Nava-Flores (Mexico), Nguyen Cong Dan (Viet Nam), Basilio Rodriguez (Philippine), Jack Morales (United Kingdom), M.C. Nandeesha (India), Agus Budhiman (Indonesia), Melchor Tayamen (Philippines), Md. Rafiqul Islam Sarder (Bangladesh), Kamchai Lawonyawut (Thailand), Benoy Barman (Bangladesh), Nagappa Basavaraja (India), Yuan Xinhua (China), Pham Anh Tuan (Viet Nam), Zhou Xiaowei (NACA).

1. Background

Land, water, seed and feed constitute four of the most important resources to aquaculture outside human and technological resources. Efficient use of these resources are necessary to guarantee optimum production from aquaculture. Availability of quality fish seed is a pre-requisite for adoption of sustainable aquaculture especially for smallholders.

A number of regional and international events have highlighted some of the most pressing issues concerning seed in global aquaculture development.

The proceedings of a special session on "Rural Aquaculture" convened during the Fifth Asian Fisheries Forum, International Conference on Fisheries and Food Security Beyond the Year 2000, held in November 1998 in Chiang Mai, Thailand, Edwards *et al.* (2002)[1] identified seed as one of the five major issues affecting rural aquaculture development and considered two aspects: (a) role of the private sector and (b) types of hatcheries (i.e. large, centralized government or small, decentralized hatcheries – which need further consideration in seed production. As part of the same publication, Little *et al*. (2001)[2] reported poor quality seed as a major constraint to the success of fish culture, especially for new entrant farmers and poorer smallholders.

Regional reviews (Asia, Africa and Latin America) from the Conference on Aquaculture in the Third Millemium (NACA/FAO 2001)[3], held in Bangkok, Thailand in February 2000, recognized important issues concerning seed as a significant resource for aquaculture. In the Asian region, Kongkeo (2001)[4] emphasized that one of the technical constraints in Asian aquaculture is the inadequate and unreliable supply of quality fish seed. Machena and Moehl (2001)[5] identified the lack of fish seed as a serious restriction to aquaculture development in sub-Saharan African region. In Latin America, Hernandez-Rodriquez *et al.* (2001)[6] reported that for tilapia culture, maintenance of high genetic quality within the stock as well as development of disease-resistant strains are important issues for consideration as they adversely affect growth, harvest size and profitability. In general terms, broodstock and seed supply have been identified as representing a major constraint to production increases not only in terms of availability but also health management. Several major initiatives are underway to

1 Edwards, P., Little, D.C. & Demaine, H. 2002. Rural Aquaculture. UK: CABI Publishing. 385 pp.

2 Little, D.C., Satapornvanit, A. & Edwards, P. 2002. Freshwater fish seed quality in Asia, pp. 185-195. In P. Edwards, D.C. Little & H. Demaine. Rural Aquaculture. UK: CABI Publishing. 385 pp.

3 NACA/FAO. 2001. Aquaculture in the Third Millenium. Subasinghe, R.P., Bueno, P., Phillips, M.J., Hough, C., McGladdery, S.E. & Arthur, J.R. (eds). 2001. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. Bangkok, NACA and Rome, FAO. 471 pp.

4 Kongkeo, H. 2001. Current status and development trends of aquaculture in the Asian Region. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 267-293. Bangkok, NACA, and Rome, FAO.

5 Machena, C., & Moehl, J. 2001. African Aquaculture: A regional summary with emphasis on Sub-saharan Africa. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 341-356. Bangkok, NACA and Rome, FAO.

6 Hernandez-Rodriguez, A., Alceste-Oliviero, C., Sanchez, R., Jory, D., Vidal, L. & Constain-Franco, L.-F. 2001. Aquaculture development trends in Latin America and the Caribbean. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 317-340. Bangkok, NACA and Rome, FAO.

develop methods for the use of specific-pathogen-free (SPF) and high-health (HH) seed production. Such strategies involve domestication allowing the development of commercial breeding programmes for the establishment and maintenance of desirable traits. El-Gamal (2001)[7] in a review of the status and development trends of aquaculture in the Near East concluded that availability of seed is a crucial technological constraint to future development of aquaculture in the Near East region. In Egypt, insufficient numbers of tilapia fingerlings are produced in governmental hatcheries and do not match fish farm requirements. He concluded that promotion of aquaculture should not be made unless there is an assured supply of seed from hatchery sources. De Silva (2001)[8], in his global perspective of aquaculture in the new millenium, suggested that in culture-based fisheries one of the major limitations is the lack of suitably sized fingerlings for stocking due to inadequate hatchery technology, inadequate facilities for fry to fingerling rearing and distribution mechanisms.

During the ASEAN-SEAFDEC Conference on "Sustainable Fisheries for Food Security in the New Millenium" held in Bangkok in November 2001, Mair (2002)[9] identified four major elements affecting quality of seed resources for sustainable aquaculture. These are: (a) seasonality and inconsistency of seed supply; (b) inadequate support for seed production; (c) deterioration in quality of seed stocks and (d) impacts of releases of cultured seed stock.

The report of the second session of the Sub-Committee on Aquaculture (Norway, 2003) highlighted the lack of seed as an important issue in culture-based fisheries (Section xxii, para. 53) and which requires further work in order to promote this important sector of aquaculture (FAO, 2003)[10].

Most recently, the thirteenth session of the Committee for Inland Fisheries of Africa (CIFA) held from 27 to 30 October 2004 highlighted two important points: (a) lack of quality seed as one of the important factors limiting the contribution of aquaculture to food security and economic growth and (b) availability of strong and disease-free seed as one of the major constraints to aquaculture development in the region; that seed shortage represents the failure of government hatcheries to meet the expressed demand; noted the progressive involvement of the private sector to revive the seed production industry and the need for more private hatcheries with business orientation.

OUTLOOK AND PROSPECTS

The above-mentioned events have repeatedly highlighted the various issues surrounding seed as an important resource for sustainable aquaculture development. Factors affecting seed availability, seed quality, seed production technologies and support services, seed distribution networks, and etc. need to be understood well if resources are best to be targeted and policy decisions on future investment and management options improved. The development of breeding and hatchery technology, genetic improvement and domestication are additional key objectives for securing the seed supply for major aquaculture species.

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7 El Gamal, A.R. 2001. Status and development trends of aquaculture in the Near East. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 357-376. Bangkok, NACA and Rome, FAO.

8 De Silva, S.S. 2001. A global perspective of aquaculture in the new millenium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 431-459 Bangkok, NACA and Rome, FAO.

9 Mair, G. 2002. Topical issues in genetic diversity and breeding: genes and fish: supply of good quality fish seed for sustainable aquaculture. Aquaculture Asia, VII(2): 25-27. Bangkok, Thailand, NACA.

10 FAO. 2003. Report of the Second Session of the Sub-Committee on Aquaculture, Trondheim, Norway, 7-11 August 2003. FAO Fisheries Report No. 716. Rome, FAO. 91 p.

2. Technical workshop

2.1 OBJECTIVE

The FAO Department of Fisheries and Aquaculture conducted a global analysis of the freshwater seed sector through a number of country case studies, regional syntheses and thematic reviews, the outcomes of which were presented during the FAO Expert Workshop on Freshwater Fish Seed Resources for Sustainable Aquaculture held in Wuxi, China from 23 to 26 March 2006. The objectives of the expert workshop were to analyze the current status of the freshwater seed sector used in aquaculture with special emphasis on rural aquaculture and to evaluate the current constraints and challenges faced by the sector as basis for identifying measures and generating action that will contribute to the sustainable development of this sector.

2.2 STRUCTURE AND PROCESS

The expert workshop was hosted by the Freshwater Fisheries Research Center (FFRC) of the Chinese Academy of Fisheries Sciences (CAFS) in Wuxi, China. The Opening Ceremony was graced by Mrs Wei Shaofen, Director of the Jiangsi Bureau of Marine (Annex 4.1) and Fisheries and Prof Xu Pao, Director of the FFRC/CAFS (Annex 4.2). FFRC Deputy Director Miao Weimin ably chaired the sessions.

Twenty-one experts (Annex 4.3) on freshwater aquaculture, genetics, health, rural aquaculture and aquabusiness from national institutions, universities and private sector from Australia, Bangladesh, Cambodia, China PR, Egypt, India, Indonesia, Mexico, the Philippines, Sri Lanka, Thailand, Viet Nam and the United Kingdom participated in the workshop; co-authors of the different presentations and country case studies participated remotely and provided additional information requirements that were also used during the workshop. The Workshop was facilitated by 3 FAO officers (MB Reantaso, MR Hasan and S FungeSmith).

The four-day Expert Workshop (Annex 4.4) consisted of plenary presentations of six selected country case studies (China, India, Cambodia, Viet Nam, Mexico, Egypt), three regional syntheses (Asia, Africa and Latin America), five thematic reviews (seed quality, genetics and breeding in seed supply for inland aquaculture, seed networks and entrepreneurship, role of seed supply and technology in rural aquaculture and farmer innovations and women involvement in seed production), and four invited presentations (self-recruiting species, decentralised seed networking in Bangladesh, establishment of national broodstock centres in Viet Nam, and private sector involvement in seed production and distribution).

Following the plenary technical presentations, the participants were divided into three Working Groups to deliberate on the following themes based on the Working Group guidelines:

Theme 1: Seed Quality, Genetics, Technology and Certification;
Theme 2: Seed Networking, Distribution, Entrepreneurship and Certification; and
Theme 3: How Rural Fish farmers Can Benefit from the Freshwater Aquaseed Sector.

The outcomes of the Working Group discussions were presented in plenary.

2.3 WORKING GROUP GUIDELINES

The Working Groups were requested to:

- analyse the current status of the freshwater seed sector used in aquaculture, with special emphasis on rural aquaculture;
- evaluate the current constraints and challenges faced by the sector as basis for identifying measures and generating action that will contribute to its further development;
- this will be done in due recognition of variability between regions with respect to farming systems and practices.

Key outputs from the Working Group include:

- several key recommendations to FAO for action;
- appropriate actions to address the following issues affecting the freshwater seed sector:
  - policy guidelines for the national governments/NGOs/international agencies/donors;
  - further studies and research;
  - extension and application/adoption;
  - capacity building;
  - roles of state and private sector, partnerships between private and public sectors.

3. Working Group findings and recommendations

3.1 WORKING GROUP 1: KEY ISSUES CONCERNING SEED QUALITY, GENETICS, TECHNOLOGY AND CERTIFICATION [11]

Working Group 1 Members
Rapporteur/Facilitator: Dr Simon Funge-Smith

- Dr Nguyen Cong Dan
- Dr Kamchai Lawonyawut
- Dr Graham Mair
- Dr C.V. Mohan
- Dr Magdy Saleh
- Dr Md. Rafiqul Islam Sarder
- Mr Miao Weimin

What do we mean by seed quality?

Seed quality is that which optimizes the potential for aquaculture production and is related to the quality of the broodstock used and the seed produced. "Seed" can mean eggs, milt fry, fingerlings or nursed animals. The quality considerations are those which meet the expectations and demands of the producer (grow-out operations) and the final consumer of the end product. There are marked differences in priority and importance of quality criteria according to the systems for which they are intended (e.g. intensive system of small-farmer, extensive systems). There are also specific differences between the major aquaculture groups such as finfish, crustaceans and molluscs, this will inevitably mean that certification system for quality assurance will need to be done with specific relevance to parts of the sector and in consultation with the producers and hatchery operators. The parameters for quality assurance may include the following:

(i) Conforms to market needs, e.g.
- colour
- body shape (meat yield)
- safe (free of human disease causing organisms)

(ii) Meets producers needs and expectations, e.g.
- uniformity of size and age
- fast growing
- consistency
- genetic potential
- purity
- minimizes risk to the farmer, e.g.
  - high survival
  - disease resistance
  - healthy (nutritionally fit and free of disease)

[11] Working Group 1 findings and recommendations were put together by G. Mair.

How do we achieve quality seed?

The Working Group discussed what were the important features of good quality seed and what factors would influence good quality. The group concluded that there were two main categories that were related to seed quality. These were:

(1) Genetic quality which concerns the following aspects: (i) genetic management of domesticated stocks, (ii) development of improved broodstock, (iii) availability of good quality broodstock and (iv) access to good quality broodstock

(2) Good hatchery and/or nursery management which concerns the following aspects: (i) good nutrition of broodstock, larvae and fry, (ii) good record keeping, (iii) bio-security, (iv) financing, (v) disease control, (vi) standardization of protocols, (vii) implementing of technology (e.g. 3n and monosex), (viii) human resource capacity (training, skills development) and (ix) knowledge base/ information resources.

Tables 3.1.1 to 3.1.3 describe different seed quality features as they relate to threat and opportunities Table 3.1.1), scoring and ease of assessment of overall quality (Table 3.1.2) and monitoring points (Table 3.1.3).

Certification of seed quality

A certification system for seed production can cover the following four areas:

- assurance that the genetic status of the seed is correct;
- assurance that the seed has been produced under appropriate husbandry conditions;
- handling and transportation of the seed;
- final measurable quality features of the seed at the point of sale.

The first two categories relate to management practices of the hatchery that produces seed and the broodstock provider. In this case, the seed itself is not certified but the hatchery and/or the broodstock provider is certified or accredited. Certified hatcheries are those hatcheries which adhere to a plan of production under a "code of practice" or similar system for ensuring the quality of their product and/or those who produce seed from certified or verified quality broodstock. Monitoring for certification can take place during several stages of seed production through third party monitoring, self-monitoring and record keeping).

The quality features that are monitored relate principally to whether the product is to be certified or the production operation is to be certified (or accredited). The quality checks at point of sale (POS) serve as guidelines to the buyers, although they can be used as part of the monitoring process (when used in conjunction with records relating to the production process). This gives some indication of the quality of the production process, but cannot be used to establish the genetic quality features or traits.

Point of sale checks

The final measurable quality of the seed is its status at POS. In this case, sample of the seed for sale can be checked using a number of criteria. If this is done for each batch, then the seed can be called a 'certified seed'. The measurable quality features can be divided into those which are possible to be undertaken at POS and those which are possible through light microscopy. These features include:

– regular size (uniform sizes);
– free from fouling or external parasites/fungi, etc.;
– no obvious external damage;
– no obvious deformities;
– full gut (evidence that the animal is feeding);
– body shape (evidence of good feeding, not overlarge head, muscle wasting, etc.);
– free of specific disease (that can be tested using rapid methods, e.g. light microscopy on fresh tissue smears, gene probe or PCR test kit);

TABLE 3.1.1

Table of seed quality features and the issues that relate to them in terms of threat to the operation or opportunity to improve the product (Number of + refers to order of importance)

Quality factor (of seed)	Genetic Factors	Seed husbandry/ process including transport	Threat to producer	Opportunity to producer	Strategy to ensure/mitigate against result
Features that are mainly related to the genetic quality of the stock or genetic management of the stock					
Colour	++++++			Exploit colour preference in market	Use correct species or strain or breed for desired colour
Genetic purity[12]	++++++		Introgression, poor performance, reduced yields		Good broodstock management; Control hybridisation
Shape (conformity)	+++++	+		Exploit shape preference in market	Use correct species, strain or breed for desired shape
Sterility	+++++	+	Unwanted reproduction and environmental impact	Enhanced growth, environmental safety, better meat yield	Develop and apply triploidy by direct induction or 4n x 2n, also hormonal sterilization in common carp
Growth potential	++++	++	Poor performance = higher costs (e.g. high FCR), lower value, late harvest	Good performance = lower costs (e.g. lower FCR), higher value, early harvest	Responds well to strain selection & selective breeding
Disease resistance and/or immunity	++++	++	Poor survival, poor quality, need for treatment (use of chemicals)		Breed for disease resistance and utilize immune-prophylactic practices (e.g. disease challenges, vaccination, immunostimulation)
Advanced maturation	++++	++	Reduced growth after maturation, unwanted reproduction and recruitment	Early availability of over-wintered seed	Selection for late maturation, early or late season spawning of broodstock, stunting of seed by overstocking
Features that more or less equally influenced by genetic quality and management of the hatchery production process (depending upon species or method)					
Deformity	+++	+++	Poor performance, low marketability		Use good lines, avoid inbreeding. Good husbandry, nutrition, DO, etc.
Environmental tolerances	+++	+++	Mortality at stocking or later	Can culture in different environments	Selection for increased environmental tolerance and appropriate acclimation (e.g. temp, DO, salinity)
Monosex	+++	+++	Not monosex = variable growth, recruitment etc.		e.g. hormones, temperature treatments, breeding
Features which are principally influenced by the hatchery production process					
Uniformity of size and age	+	+++++	Cannibalism, differential growth, regular grading	Reduced management costs and improved efficiency & more marketable product	Grading, avoid mixing batches, good feeding, maintain optimum temperature
Disease status	+	+++++	Poor survival, poor growth, disease transmission, need for treatment (use of chemicals)		Provide better biosecurity (e.g. broodstock, seed , hatchery free of notifiable pathogens, hygienic practices)
Nutritional health	+	+++++	Poor survival, poor growth, deformities		Ensure/provide good larval and juvenile nutrition
Weaning off live feed onto artificial diet	+	+++++	Mortality of unweaned stock or costs of live feeds, poor marketability		Good management
Transportation and handling stress	+	+++++	Transit mortality, reduced survival at stocking and poor disease resistance		Optimize transportation condition (conditioning, packing, density, temperature, DO, etc.)
Species/strain purity/hybrids		++++++	Poor or unexpected performance, predation, lower stocking densities, reduced yields		Good broodstock management, screening of hatchery ponds, etc.

[12] To ensure that stock is genetically pure, i.e. for pure species/stocks that they are not introgressed with other species/stocks or that hybrids are indeed F1 hybrids between target parental species

– fish weaned onto pellet feeds (this can usually be observed in the hatchery);
– swimming behaviour.

Scoring of quality features for ease of monitoring and degree of importance on overall seed quality

Table 3.1.2 shows possible scoring to determine the relative ease of assessment for a number of quality features of seed at two levels, i.e. hatchery and point of sale.

Hatchery production process monitoring

A second set of features are those which could be tested as the basis for regular monitoring of the hatchery for the purpose of certifying or accrediting that hatchery. These would be more comprehensive and cover issues such as health and internal physical characteristics, e.g.:

– freedom from specific diseases (through microscopy, gene probe, etc.);
– normal pathology of major organs (gut, liver, etc.);
– evidence from records of appropriate genetic management of broodstock;
– evidence from records that the broodstock originated from a certified supplier;
– records that the hatchery activities follow a code of practice or better management protocols (BMPs) (particularly if a specific technical intervention is used such as sex reversal or vaccination).

For process monitoring of hatchery production, the existence of protocols or BMPs can be used as basis for hatchery certification. Hatcheries that source their broodstock from accredited suppliers are also easier to certify in terms of the genetic quality of their animals. The requirement for record keeping is important in this situation, since this would be an important part of the monitoring process that would enable the renewal of certificates.

TABLE 3.1.2

Possible scoring for quality features, ease of assessment of overall seed quality (Number of + relate to relative ease of assessment of quality traits via process monitoring or monitoring seed at the point of sale)

Quality features (of seed)	Relative ease of assessment		Main control point
	Process/ monitoring of hatchery	Seed at point of sale (POS)	Either Point of sale (POS) or Monitoring hatchery production process
Principally monitored during production and difficult to check at point of sale			
Monosex	+++	+	Monitoring hatchery production process
Sterility	+++	+	Monitoring hatchery production process
Weaning off live feed onto artificial diet	+++++	++	Monitoring hatchery production process
Species/strain purity[13]	++++	+	Monitoring hatchery production process
Genetic purity	+++	+	Monitoring hatchery production process
Growth potential	+++	+	Monitoring hatchery production process
Disease resistance/immunity	++++	+	Monitoring hatchery production process
Environmental tolerances	++	+	Monitoring hatchery production process
Advanced maturation	+++	+	Monitoring hatchery production process
Can be checked during production and also rechecked at point of sale			
Disease status	+++	+++	Both
Colour	++++	+++++	Both
Nutritional health	+++	+++	Both
Transportation and handling stress	++	++++	Both
Easily checked at point of sale			
Uniformity of size & age	+++++	++++++	POS
Deformity	++	++++	POS
Shape (conformity)	+	+++++	POS
Swimming behaviour			POS

[13] To ensure that species/stocks are not contaminated with individuals of other species/stocks

TABLE 3.1.3
Seed quality features and the critical monitoring points at which they could be applied

Quality feature	Critical process point within hatchery	Point of sale check?
Mainly related to broodstock genetics		
Species/strain purity	Evidence of broodstock source or broodstock certification. Feedback from buyers	Contaminants from fish that are visibly different can be detected
Sterility*	Feedback from buyers Verification of triploidy protocols	
Genetic purity*	Evidence of broodstock source OR Broodstock certification	
Colour*	Feedback from buyers	POS checklist. Readily detected in many cases
Shape (conformity)*	Feedback from buyers	POS checklist. Detectable in some cases
Growth potential*	Feedback from buyers	
Advanced maturation*	Feedback from buyers	
Broodstock genetics and hatchery production process		
Monosex*	Feedback from buyers Evidence of broodstock source OR Broodstock certification OR BMP of sex reversal.	
Environmental tolerances*	Record of acclimation process OR Evidence of broodstock source or broodstock certification	
Deformity*	Evidence of broodstock source OR Broodstock certification	POS checklist. Detectable in some cases
Disease resistance/ immunity*	Record of vaccination and/or use of immuno-stimulation	
Disease status	Records of monitoring of batch health	POS checklist External inspection detectable in some cases.
Nutritional health	Feed quality & feeding regime	POS checklist
Weaning off live feed onto artificial diet	Records on feeding	POS checklist. Detectable soon after POS.
Uniformity of size & age	Records on management and grading	POS checklist. Readily detectable.
Transportation & handling stress	Adherence to protocol	POS checklist

* indicates those quality features which could potentially be certified at the level of the broodstock if they were traits from breeding programs.

There are several quality features which are desired by the grow-out producer, but which can only be indicated by the genetic source and quality of the stock and cannot be monitored at the hatchery level. These features would only become apparent after the grow-out period.

There are a number of specific technical interventions which can be applied during the hatchery production process which are also difficult to monitor. Fish vaccination and the use of hormonal sex reversal techniques are two such examples.

In this case, the buyer has to trust that the hatchery has produced the seed with the desired quality features and this can be partly guaranteed by the hatchery being certified as adhering to specific good practices. The monitoring point for whether the hatchery has adhered to these protocols or practices is problematic. Typically, farmer feedback or monitoring at the grow-out level is the only way to determine if the product has reached the expected performance.

Farmer feedback may be in the form of complaints to the hatchery or to local government offices responsible for monitoring. The inevitable result of the supply of seed that does not perform as expected or advertised is subsequent purchase of seed from other hatcheries. Monitoring the genetics related performance of the stock is a critical aspect of the certification process for broodstock.

A few examples are presented below.

Monosex fish produced by hormone reversal. If the process is not undertaken properly, there will be an unacceptably high proportion of non-sex reversed animals. In this case, it is too late for the producer to do anything about it but would either seek compensation from the hatchery for the mistake or change to a different supplier.

Good genetic stock with good growth potential. This would only become apparent during grow-out. The farmer has little recourse to the hatchery if strain performance is unsatisfactory. The solution is usually to seek hatcheries that have a particular strain (branded strain) or purchase from a hatchery that is certified as having good genetic quality stock (or which is purchasing broodstock from an accredited supplier).

Vaccination of stock against specific disease. Typically this could be tested using gene probes but may be expensive and impractical. If the stock was affected by the disease against which it was supposed to have been vaccinated, this would be a strong indication that that there is a problem with that hatchery's vaccination process.

Certifying seed traders

The effect of traders on the quality of a product needs to be considered as transportation and handling issues. This relates to the actual POS with respect to the certification of seed. For some systems, this will be when the animal leaves the hatchery, but in other cases, hatcheries will deliver the seed to the farm or to the growers. Thus, the transport method is another part of the production and management chain that can be certified and subject to a "code of practice" or "better management practice" and would be certifiable. Either the hatchery is certified if it is transporting or seed traders are certified.

Other issues related to quality of hatchery produce seed

Stocking of open waters

This issue can be divided into two main concerns: (a) stocking of waters with species that are unable to breed in the environment in which they are placed and (b) stocking of species which are able to breed in the environment inn which they are placed.

For those species which are unable to breed in the environment to which they are released, the quality assurance aspect is related largely to the health of those animals and the need to avoid introducing disease organisms that may impact wild populations.

For those species which are able to breed, there are three sub-issues relating to the likely impact of that breeding activity. These are:

- if the species stocked are able to breed but not with wild fish, there may be an issue of competition for niches (this is not an issue of seed quality but relates to the choice of species to be released);
- if the species are exotic, there maybe an issue with hybridization with indigenous species and subsequent loss of genetic diversity;
- if the species released are indigenous, then there is a direct competition with the wild relatives; if the genetic diversity of the stocked species is narrow (as a result of captive broodstock or using domesticated broodstock), this may also impact the genetic diversity of the wild stock.

There are clear examples where the genetic diversity of wild populations has been modified. Although the genetic effects of the release of hatchery-bred animals to the wild can be demonstrated in some cases where very large-scale releases have taken place, the actual effects on the populations and the fisheries for these animals are less clear.

A cautionary note here is that in the case where there is a programme of large-scale release of fish to the wild, then it is important to take the precaution that the genetic diversity of the fish to be stocked should reflect that of the wild population into which it is to be stocked. The stocking of open waters with domesticated stock or stock with narrow genetic diversity should be discouraged if there is a likelihood that they will breed with local populations.

The costs of ensuring 'wild type diversity' for stocks to be released to open waters can be quite high. Therefore, stocking with a less diverse stock can be considered in the case where the diversity of the wild population has already been severely compromised as a result of loss of habitats or other environmental factors (or even due to long-term restocking programmes).

Recommendations on the identified issues

1. Broodstock genetics and broodstock supply are fundamental and need to be addressed at various levels including the promotion of basic genetic management of broodstock in all aquaculture systems and the conservation of wild genetic resources.
2. At national level, governments should promote public and private selective breeding as the core of genetic improvement programs of species for which sustainable aquaculture industries have developed (see fuller recommendation in Section 8.2 (Mair, 2007, this volume).
3. There is value in reviewing the models used for certification in the livestock sector (and possibly agriculture sector generally), for processes of developing certification systems for seed quality.
4. The benefits of hybridization are minimal and risks of introgression and contamination of domesticated and wild stocks are significant and hybridization should be avoided in seed production with specific exceptions (e.g. tilapia and *Clarias*).
5. Emerging genetic technologies such as transgenic fish, genetic use restriction technologies (GURTs) and marker assisted selection/quantitative trait loci (MAS/QTL) were not considered to be of current significance with respect to quality assurance but developments should be monitored. The use of these technologies would be covered under any certification or labelling system if they were introduced.
6. There is a need to continue investigation on indigenous species for their potential to be used in aquaculture or to be further domesticated. The closing of life cycles, maintenance of broodstock and development of economic hatchery systems for these species is a technical constraint.
7. Caution should be made in reintroducing broodstock from the wild due to potential loss of benefits of domestication selection and disease transmission.
8. There is a strong need for certification or accreditation of practices to validate seed quality at various levels:
   i. at the broodstock/genetic level
   ii. level of production
   iii. during transportation
   iv. point of sale
9. There is a need for assistance in the development of national broodstock certification programs (at national level) including provision of guidelines on development of national broodstock certification systems for public and/or private sector seed suppliers.
10. There is a need for the development of policies and legislation governing the production and supply of quality fish seed including incentives for private hatcheries (see also outcomes of Working Group 2).
11. There is a need for assistance on the development of guidelines for establishing standardized protocols for optimizing seed quality and hatchery certification at the national level. Certifying hatcheries for international trade may be necessary in cases where broodstock or seed are shipped between countries.

12. There is a need for regional multidisciplinary reviews of broodstock quality of key freshwater aquaculture species that have a high likelihood of international/regional transfer.
13. There is value in reviewing the potential impact of past and current culture-based fisheries on genetic diversity in wild stocks in major regional watersheds such as:
    i. risks of disease transmission
    ii. hybridization with indigenous species
    iii. genetic diversity of wild populations
14. Hatchery-based breeding for release to enhance fisheries should utilize indigenous (local) stock with large effective population sizes, to minimize potential negative impacts on wild populations.
15. There is a need for species and/or system-specific checklists for seed quality for use by purchasers at the point of sale.
16. It is necessary to investigate the potential for regional level sharing of knowledge on national broodstock management and genetic improvement schemes and the potential for improving these through intergovernmental organisations such as the International Network of Genetics in Aquaculture (INGA) or the Network of Aquaculture Centres in Asia-Pacific (NACA). Many national initiatives are not well known outside of the country and this information could also be made available through a web-based resource.

Recommendations to FAO

1. Assist member countries in the development of national broodstock certification programs (at national level) including provision of guidelines on development of national broodstock certification systems for public and/or private sector seed suppliers.
2. Support the development of guidelines for establishing standardization of protocols for optimizing seed quality and certifying hatcheries at national level.
3. Review the models used for certification in the livestock sector (and possibly agriculture sector generally), for processes of developing certification systems for seed quality.
4. Support the development of guidelines for establishing standardization of protocols for optimizing seed quality and certifying hatcheries at a national level.
5. Support regional multidisciplinary reviews of broodstock quality of key freshwater aquaculture species.
6. Develop species and/or systems specific checklists for seed quality for use by purchasers at the point of sale.
7. Review the potential impact of past and current culture based fisheries on genetic diversity in wild stocks in major regional watersheds.

3.2 WORKING GROUP 2: KEY ISSUES CONCERNING SEED NETWORKING, DISTRIBUTION, ENTREPRENEURSHIP (AND CERTIFICATION) [14]

Working Group 2 Members:

Rapporteur/Facilitator: Dr Mohammad Hasan

- Dr Benoy Kumar Berman
- Mr Agus Budhiman
- Ms Hu Honglang

[14] Working Group 2 findings and recommendations were put together by B. Rodriguez and A. Nietes-Satapornvanit

- Mr Basilio Rodriguez, Jr.
- Ms Arlene Nietes Satapornvanit
- Mr Melchor Tayamen
- Mr Zhou Xiaowei

In order to be effective and efficient, aquaculture seed production and distribution, especially when undertaken by the private sector, depend on a number of key factors. These key factors can be classified according to the following categories: basic infrastructure, production support, business and marketing support, financial support and the policy environment. These are the basic elements of an enabling environment for agriculture.

Basic infrastructure includes roads and transportation, communications, electricity, water access and regulation and products from agricultural research. In the case of aquaculture seed distribution, the most important research products include genetically improved breed, hatchery technologies and other information for efficient production. Production support providers include input (feed, seed, etc.) suppliers, equipment manufacturers and suppliers, extension services providers and others. Market and business support services include information, market intelligence, market promotion and technical and business training services. Such services can be provided by consultants, traders, chambers of commerce/industry associations, cooperatives and other support groups. Financial support services include credit, insurance and banking services. The policy environment consists of the body of laws and regulations that support the aquaculture and aquaculture seed enterprises. The lack of certain services and other factors may be common among the different parties involved in seed production and distribution. However, not all needs and concerns across the parties are the same.

The parties involved in seed production and distribution can be described according to the functions they fulfill in the supply chain. These include the following:

1. The breeder – the individual or the enterprise that develops and produces broodstock for use in the further production of broodstocks or in the production of seedtock (animals that will be grown for eventual use as food). In the livestock industry, broodstock that are used to produce animals for growing are called parent stock. Broodstock that are used to produce such parent stocks are called grandparent stocks. Animals bred to produce grandparent stocks are called great-grandparent stocks and onward up (or down) the breeding chain. The breeder's main line of business is to produce parent stocks which are sold/distributed to hatchery operators.
2. The hatchery operator – the individual or the enterprise that produces seedstocks for sale/ distribution to growers. Seedtock can be in the form of eggs, fry or fingerlings.
3. The nursery operator – the individual or the enterprise that purchases seedtock from the hatchery and grows the seedtock for a certain period and sells/distributes more advanced seedtocks to growers.
4. The trader – the individual or the enterprise that purchases seedtock from the breeder, the hatchery or the nursery and sells these to growers. Very often traders sell seed along with other inputs such as feeds. Traders may also provide these inputs to growers on credit terms.
5. The grower – the individual or the enterprise that raises the seed to market size. The grower is the end-customer of the aquaculture seed supply chain.

It is important to note that there are other actors in the seed networks but they do not handle seed directly. Depending on the country, these actors include water providers for traders in fish seed markets, transport providers, sellers of hormones, supplies and equipments related to seed production, nightsoil traders, extensionists and project staff. Some of their issues may be similar to the seed traders especially for those in the trading business.

In countries where species for which the aquaculture seed industry is not yet fully developed, government agencies may be the only provider of the above services. A single party, government or private, may also be responsible for carrying out two or more of the above functions. For example, a government agency may serve as breeder, hatchery/nursery operators and distributor while it is promoting a specific type of aquaculture. In addition, this government agency will also be responsible for providing extension and other services until the number of farmers who adopt the technology reaches critical mass. When such critical mass is reached, private individuals or enterprises may recognize a potential market and begin to provide the needed products and services. Aside from the market situation, technology also serves as a factor in determining how the above functions are carried out. As an example, the transport and distribution of tilapia eggs to nurseries only became possible with the advancement of artificial incubation technologies.

Each party involved in carrying out a specific function in the aquaculture seed supply chain will have issues and concerns along the key factors described above. Such a matrix of issues and concerns is presented in Table 3.2.1 .

Summary of issues and recommendations

This section summarizes five major issues followed by general recommendations and specific recommendations to FAO and governments to address the issues identified.

Issue 1: Poor quality and accessibility of breeding materials, parent stock and seed stock

Many countries do not have regulations governing aquaculture seed production, distribution, monitoring and surveillance.

General recommendations:

Governments should be encouraged to develop, with the participation of stakeholders, appropriate regulations, including registration, licensing and/or certification schemes for

a) aquaculture breed/strain development and quality improvement,
b) aquaculture seed production (hatcheries and nurseries),
c) aquaculture seed distribution,and
d) collection and distribution of wild-caught brood and seed stock for aquaculture.

Recommendations to FAO:

- International organizations such as FAO can develop technical guidelines for such registration, licensing and/or certification and provide assistance in the implementation of such guidelines.

Issue 2: Poor capacity in terms of technology, facilities, infrastructure, human resources, extension, information, business environment and government support/ incentives, including weak linkages between public and private sectors related to seed production, distribution and networking

Despite recent advances in fish seed production technologies, there are still gaps in the capacity of stakeholders in the seed sector, specifically:

- inadequate or lack of know-how/technology, facilities, trained staff and resources for breeding centers and hatcheries, infrastructure, extension services;
- quality, availability, and cost of inputs other than seed;
- absence of production and market information;
- lack of or inability to access business services, including business and entrepreneurship training;

- lack of government incentives/support/weak linkages with private sector (producers, traders, other interested entities).

General recommendations:

- Governments are encouraged to carry out a careful system-level assessment of the seed sector's capacity to provide the volume and quality of seed needed by the entire aquaculture industry of their respective country. Such a system-level capacity assessment is expected to highlight strategic interventions (policies, institutional strengthening, infrastructure development, investments, etc.) to improve seed production and distribution.
- Governments are encouraged to seriously consider options for collaboration with the private sector in broodstock development, seed production and seed distribution.
- Governments are encouraged to establish national networks for genetic improvement, seed production and seed distribution. Such networks should be tasked with initiating programs and projects that promote the development of the aquaculture seed sector.
- Governments, especially in countries where there are numerous institutions involved in seed production and distribution, are encouraged to develop a national inventory or directory of institutions involved in seed production and distribution to guide hatchery and nursery operators (and even growers) in the procurement of quality broodstock, seedtock and technical advisory services.
- Governments are encouraged to strengthen extension services and to develop, whenever and wherever appropriate, new channels (e.g. through private sector participants) for more effective delivery of such services. In addition, training and extension materials related to broodstock management, seed quality management and assurance and distribution should be developed, updated and disseminated.
- Parties involved in genetic improvement, seed production and seed distribution should organize themselves into networks/clusters/clubs to share information/technology and other resources, to undertake appropriate collective action and, for greater efficiency and effectiveness, consider alliances and collaboration to vertically integrate seed production and distribution functions.
- Governments are encouraged to promote, facilitate and provide incentives for the formation of such networks/clusters/clubs, including the setting up of local information centers or one-stop aqua shops.

Recommendations to FAO

- There will be value in conducting an international review on the experiences and status of aquaculture seed production and distribution and the effectiveness of strategies (including seed networking and public-private sector partnerships) implemented in various countries in order to come up with a set of best practices, including models and options for networking and partnerships, based on lessons learned.
- Encourage establishment of international networks for collaboration in genetic improvement, information sharing and sharing of genetic materials.
- Support for the development and/or updating of training and extension materials related to seed production and distribution, incorporating development issues with technical inputs.

Issue 3. Negative perceptions on the role of traders in seed distribution and small-scale seed producers (e.g. local or decentralized seed production systems)

Seed traders are important conduits between seed producers/wholesalers and the growers, not only for seed distribution but also for information on seed market

TABLE 3.2.1

Issues and concerns in aquaculture seed production and distribution

	Breeder	Hatchery	Nursery	Seed trader	Grower
Basic Infrastructure	• Inadequate infrastructure (roads, communications, water, electricity, etc.) • Lack of breeding know-how/ technology, facilities, trained staff and resources • Inability to obtain or have access to breeding materials • Poor quality of breeding materials	• Inadequate infrastructure (roads, communications, water, electricity, etc.) • Lack of hatchery knowhow/ technology, facilities, trained staff and resources. • Inability to obtain or have access to parent stock • Poor quality of parent stock	• Inadequate infrastructure (roads, communications, water, electricity, etc.)	• Inadequate infrastructure (roads, communications, water, electricity, etc.)	• Inadequate infrastructure (roads, communications, water, electricity, etc.)
Production/ Technical Support	• Quality, availability and cost of other inputs (feeds, tags, etc.) and equipment	• Quality, availability and cost of other inputs (feeds, etc.) and equipment • Lack/absence of extension services	• Inability to obtain seed • Poor quality seed • Quality, availability and cost of other inputs (feeds, etc.) and equipment • Lack/absence of extension services	• Inability to obtain seed • Poor quality seed • Lack of skills specific to their roles	• Inability to obtain seed • Poor quality seed • Quality, availability and cost of other inputs (feeds, etc.) and equipment • Lack/absence of extension services
Business and Marketing Support	• Absence of production and market information • Lack of or inability to access business services, including business and entrepreneurship training	• Absence of production and market information • Lack of or inability to access business services, including business and entrepreneurship training	• Absence of production and market information • Lack of or inability to access business services, including business and entrepreneurship training	• Absence of production and market information • Negative perceptions on the role of traders in seed distribution • Lack of or inability to access business services, including business and entrepreneurship training • Lack of stability due to seasonality of trade/other alternative livelihood	• Absence of production and market information • Lack of or inability to access business services, including business and entrepreneurship training
Financial Support		• Unavailability of credit.	• Unavailability of credit	• Informal status not recognized by lending institutions limiting their access to credit	• Unavailability of credit
Policy Environment	• Lack of government incentives (i.e. tax holidays, exemptions, credit, etc.) • Absence of technology transfer policies, particularly for products of genetic improvement programs. • Actual or perceived competition of government with the private sector.	• Lack of government incentives (i.e. tax holidays, exemptions, credit, etc.) • Actual or perceived competition of government with the private sector • Lack of policies/incentives for group formation and participatory learning	• Lack of government incentives (i.e. tax holidays, exemptions, credit, etc.) • Lack of policies/incentives for group formation and participatory learning	• Lack of government incentives for traders/negative perception of public sector • Lack of policies/incentives for group formation and participatory learning	• Lack of government incentives (i.e. tax holidays, exemptions, credit, etc.)
Public Sector/ Social	• Lack of or weak linkages with public sector especially on technical issues	• Competition with government producers especially on prices • Lack of or weak linkages with public sector • Lack of venues for information sharing • Lack of initiatives related to maintenance and upgrade of broodstock quality	• Lack of or weak linkages with public sector • Lack of venues for information sharing	• Lack of understanding of field situation of actors esp the involvement of poor • Lack of support in forming advocacy groups • Lack of or weak linkages with public sector • Lack of venues for information sharing	• Lack of venues for information sharing

demand and supply. In areas where centralized seed production is the norm, the only way for growers to have access to seed is through traders, who travel long distances carrying fish seed. These informal networks involving seed traders and other business and service providers have developed because of the growing demand for seed and the development of aquaculture in remote rural areas. Public institutions in some countries have ignored the existence and the important role these traders play in seed distribution and indirectly in aquaculture development. The same is true with small-scale seed producers, who are perceived to produce low quality seed by government and large private hatcheries. In reality, these small-scale seed producers in the rural areas are producing better seed and their proximity to growers enable them to sell larger sized seed as well as reducing transportation time. It is imperative that their existence and their needs are recognized to achieve the seed sector's goal of delivering quality fish seed. Considering that most of these people are poor, their involvement in such activities should be encouraged so their livelihoods will be improved.

General recommendations:

- Governments are encouraged to consider the role and contribution of traders in their assessment of and recommendations for the strengthening of the seed sector's capacity, including providing training to develop/strengthen technical and entrepreneurial skills and programmes to meet their social/economic/health needs.
- Social marketing activities to change public perception, thereby encouraging seed producers and traders to improve the quality of their products and services.

Issue 4. Financial issues

Seed production costs money, especially for infrastructure, equipment and inputs for producers. Traders need financing of seed money for products and transport. Credit is often not available as formal financial institutions require collateral and other guarantees which being in the aquaculture and seed production and trading business may not be able to fulfill.

General recommendations:

Aside from clustering and networking, parties in the aquaculture seed sector should be encouraged to establish linkages with micro, small, medium enterprises (MSME) and microfinance development programmes.

Issue 5. Policy issues

The absence of technology transfer policies, particularly for products of genetic improvement programs has been found to limit production of good quality seed. Government hatcheries producing seed for sale to farmers is perceived by the private sector as competitor especially in terms of selling price and market.

General recommendations:

- Governments are encouraged to review their policies on technology transfer from government research institutions to the private sector.
- Governments are encouraged to establish a policy to create an environment that would encourage the participation of the private sector in broodstock development, seed production and seed distribution.
- Governments are encouraged to review their role in seed production and distribution, i.e. to support private sector seed production and not to compete by selling seed to the same group of customers but to provide seed for stock

enhancement of public waters, for charity and for public sector fish production programmes.

Recommendation to FAO:

- Conduct a livelihoods analysis of people in rural communities involved in various activities of seed production and distribution to generate information for policy development

3.3 WORKING GROUP 3: KEY ISSUES PERTAINING TO DEVELOPMENT OF THE FRESHWATER FISH SEED PRODUCTION SECTOR THAT WILL BENEFIT RURAL FISH FARMERS

Members of Working Group 3

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- Dr Mudnakudu Channabasappa Nandeesha
- Dr So Nam
- Mr Ernesto Morales
- Dr Tuan Anh Pham
- Mr Yuan Xinhua
- Dr Sunil Siriwardena

Major recommendations resulting from the deliberations of Working Group 3 on issues pertaining to benefits that will accrue rural fish farmers from development of the freshwater fish seed production sector, many of which are directed to FAO (as indicated) are briefly elaborated below.

Policy/guidelines

National programmes such as rural aquaculture development within the broader framework of poverty reduction and food security should recognize that the seed production sector is a primary pre-requisite and an integral part of sustainable aquatic food production. Governments should play a facilitating and monitoring role and ensure that appropriate policies and/or mechanisms are in place and effectively implemented that will address the needs of the rural fish farmers concerning issues such as:

- suitable species, particularly harnessing indigenous species (e.g. self-recruiting species) and using exotic species after careful assessment, appropriate for rural aquaculture development
- quality control in seed production through certification;
- improved collection and dissemination of information and statistics for better development planning;
- viable market;
- better integration of all inputs and services;
- intersectoral cooperation and other essential stakeholder consultations.

Risk communication

Typically small-scale fish farmers are risk-averse and vulnerable to losses in their systems due to a number of potential risks. These include asset, market and production/management risks which may originate from irresponsible trans-boundary movements, negative interaction between cultured and wild fisheries, use of pesticides and other chemicals, poor quality seed, unstable supply of seed and other inputs, natural disasters and other emergencies, loan diversion and non-payment, market fluctuation, etc. This can mean that transfer or start up of aquaculture technologies can be constrained by farmers' negative perceptions of the risks involved or examples of failed activities.

Communicating these risks to all stakeholders especially fish farmers is significantly essential. Suggested key actions include:

- raising fish farmers' awareness of the various forms of risk;
- evaluating the various risks faced by rural fish farmers and developing support system focussing on mitigating such risks;
- identifying and implementing risk management measures by concerned stakeholders;
- developing guidelines on risk assessments in aquaculture and making them available in simple terms for rural fish farmers.

Monitoring and evaluation of the sector

Monitoring and evaluation of the seed production sector, based on reliable statistics and information are essential for successful planning and further development of rural aquaculture. Suggested key actions include:

- improving collection and sharing of statistics and information on freshwater fish seed production sector within rural aquaculture with emphasis on the following information: number of households/individuals involved, volume of fish produced by species and contribution to household income;
- assessing and standardizing of fishfarmer's data collection methods;
- providing training for data collectors;
- appropriate analysis and management o such data/information.

Capacity building and extension

- Recognizing that small scale rural hatcheries are often located near the homes and can be managed by women, special attention shall be given to women as target recipients for capacity building especially in the areas of seed nursing, entrepreneurship and credit and savings management (FAO).
- Provision of simple hands-on and practical training on various aspects of seed production (e.g. breeding; nursing; stress tests; simple seed quality test, basic health checks; condition, packaging and transporting; record keeping and basic accounting or simple bookkeeping; and simple understanding and managing of risks) will benefit the rural fishfarmer through better decision making (FAO).
- Hatchery/nursery operators and traders as target recipients of training so they could effectively function as primary guides/service providers/extensionists for fish growers.
- Community-based capacity building on managing aquatic resources, e.g. culture-based fisheries and fish refuge pond management in floodplains (FAO).
- Relevant institutions involved in supplying services should have the necessary knowledge and skills to work with fish farmers using adaptive approaches and technologies.
- Applying important lessons learned from culture-based fisheries and stock enhancement programmes (e.g. comparative socio-economic analysis of different water bodies in Bangladesh, stocking in small lakes, commune canals, reservoir in Cambodia).

Making accessible appropriate rural microfinancing programmes for rural fishfarmers

The general benefits and varying levels of successes and failures of microfinance in aquaculture are recognized. Suggested key actions include:

- provision of access to feasible credit and microfinance services based on local needs and requirements, prudent and flexible enough (in terms of intended purpose, collateral requirements, interest rates, lending procedures and repayment period) to meet rural fish farmers' ability to effectively participate in such financial schemes;

- available guidelines as well as lessons learned from past microfinance systems be considered by such service providers in designing pertinent schemes;
- where appropriate, initial seed funds can be provided as a start up basis;
- a system of voluntary savings component may also be considered to be integrated in such programmes.

Gender issues – enhancing women's role in seed production

It is generally known that women play an important role in seed production (e.g. seed nursing and common carp breeding in Bangladesh; all stages of seed production in China and Viet Nam). However, their access to opportunities such as training, empowerment, involvement in decision-making, etc. are missing. The following key action is recommended:

- supporting a regional project to focus on enhancing the role and empowerment of women in aquatic food production with emphasis on the organization of women into self-help groups (SHG) and skills development in breeding, nursing, entrepreneurship and credit/microfinance management (FAO).

Farmer-field schools (FFS) and Farmer participatory research (FPR)

The 'farmer-field school' (FFS) concept has been successfully applied within the framework of Integrated Pesticide Management (IPM). For this concept to be applied effectively in rural aquaculture, it is important to use the systems approach and to integrate fish production as part of the rice-production system, wherever possible. A suggested key action is:

- Conducting sustainability studies using FPR in places where FFS has been practiced in rural aquaculture (e.g. Bangladesh, Indonesia, and Viet Nam), taking lessons learned and experiences and particularly incorporating seed production in the system (FAO).

Enhancing human capital through documenting indigenous knowledge and farmer innovation

Innovation is a necessary strategy which rural fishfarmers have adopted in order to meet their livelihood necessities. In the seed production sector, farmers have developed innovations on hatchery technology (e.g. bamboo/wood based circular technology), breeding techniques (e.g. Bundh breeding in India), nursing techniques (e.g. removal of egg stickiness by washing with milk prior to nursing in jars, application of fermented manure including oil cakes, stunting fish technology), local methods for fish collection and transportation and others. Even as farmers have practiced many such innovations, these remain undocumented. Suggested key actions include:

- reviewing and compiling all relevant published materials on indigenous knowledge and farmer innovations and documenting other unpublished practices (FAO);
- creating databases of farmer innovations and making it accessible to all (FAO);
- replicating and promoting fully tested innovations in other countries/regions;
- recognizing and honouring successful farmer innovators.

Farmers' indigenous knowledge and farmers' practical experiences are important and can significantly contribute to research and development. Suggested key actions include:

- implementing research in a participatory manner, involving farmers, where possible, at every stage of the process;
- making every effort be made to identify research areas based on farmer needs. Specific areas of research which are thought to benefit rural fishfarmers include: (a) improved seed (genetics and growth rates); (b) disease risk and management; (c) feed formulation using locally available materials; (d) breeding of indigenous species; (e) management of aquatic resources (for wild caught seed);

- translating research results in practical terms and wide dissemination for efficient field application by actors involved in the seed production sector;
- recognizing that there are many currently practiced farmer innovations in many countries, such practices can be further verified through appropriate research and improve such innovations for further dissemination.

Availability and affordability of suitable species of high quality and sufficient quantity

Rural fish farmers involved in the fish seed production sector as well as those engaged in culture-based fisheries will greatly benefit from suitable and locally produced seed, fry and fingerlings of high quality, in sufficient quantity and affordable price. These will not only enhance fish production but will also promote fish consumption. Suggested key actions to address this issue include:

- conducting proper diagnostics of the seed production sector in terms of suitable species and potential market;
- providing support to the initial establishment of hatcheries in strategic rural/ remote areas
- promoting decentralized seed distribution after an evaluation of the need for such system in target communities;
- establishing national broodstock centres to ensure continuous supply of high quality broodstock at subsidized costs;
- promoting price regulation through government intervention in order to protect rural farmers
- promoting the use of indigenous species, where they exist, that is supported by proper broodstock management programmes;
- forming networks of small-scale hatcheries to provide necessary service support (e.g. information sharing, marketing, etc.).

Encouraging formation of self-help groups (SHG) and other forms of farmer associations

Self-help groups and other forms of farmer association (seed clubs/network, producer club, farmer association, etc.) have effectively worked in many food production systems. They serve as important entry points for cluster management, implementation of development strategies and conservation efforts, empowerment, sharing and dissemination of information, can be key partners in delivery of services, venue for learning and skills development, serve as guarantors of loan, etc. Special attention should be given to support the organization of women SHGs. A number of key actions are recommended, such as:

- identifying social groups/networks, providing access to such networks through Information, Communication and Technology (ICT);
- providing functional linkages with financial and technology providers;
- providing a forum for interaction and consultation of all players;
- providing financial support to undertake these activities.

Private and public sector partnership

Rural fish farmers will benefit from improved integration and linkage of inputs and efficient delivery of services in the broad spectrum of the freshwater fish production sector from hatchery to seed trader to nursery operators to aquaculturists including all other services provided by various stakeholders from government and non-government. Suggested key actions include:

- taking lessons learned from the China model of contract growing for fingerling production (i.e. contracting local small farms to produce fingerlings for use of larger fish farms and for open water fisheries); such contracting systems ensure that

there is continuous supply of high quality fingerlings, good return on investment and reduced risk). Practicability of contract growing to other countries should be determined;
- encouraging large-scale hatchery operators to support small scale hatcheries for training, information sharing, broodstock exchange, provision of high quality seed;
- promoting government-private sector (large hatcheries) partnership for broodstock development and supply.

4. Annexes

ANNEX 4.1
Expert workshop programme

TIME	ACTIVITY
22 March 2006 Arrival of Participants	
23 March 2006, Thursday (Day 1)	
08.30–09.00	Opening and Welcome Remarks Madam Wei Shaofen, Director of Bureau of Fisheries and Marine Affairs of Jiangsu Province Prof Xu Pao, Director, Freshwater Fisheries Research Center, Chinese Academy of Fishery Sciences Election of Chair
09.00–09.15	Introduction to and Rationale for the FAO Expert Workshop on Analysis of Status of Freshwater Fish Seed as Global Resource for Aquaculture - Dr Melba B. Reantaso (FAO)
09.15–10.15	Selected Country Case Study Presentations
09.15–10:15	Presentations of Selected Country Case Studies • China (Mrs Hu Honglang) • India (Dr N. Basavaraja) • Cambodia (Dr So Nam) • Viet Nam (Dr Pham Anh Tuan)
10.15–10.30	Coffee Break
10.30–11.00	Presentations of Selected Country Case Studies • Mexico (Dr Alejandro Nava) • Egypt (Dr Magdy Saleh)
11.00–12.30	Regional Syntheses Presentations
11.00–11.30	Regional Synthesis: Asia (Dr Sunil Siriwardena)
11:30–12.00	Regional Synthesis: Latin America (Dr Alejandro Flores Nava)
12.00–12.30	Regional Synthesis: Africa (D. Randy Brumett) – presented by Dr Melba B. Reantaso
12.30–14.00	Lunch Break
14.00–15.00	General Discussions on Country Case Studies and Regional Synthesis
15.00–18.00	Thematic Review Presentations
15.00–15.30	Thematic Review 1: Seed quality (Dr C.V. Mohan)
15:30–16.00	Thematic Review 2: Genetic resources (Dr Graham Mair)
16.00–16:30	Coffee Break
16:30–17.00	Thematic Review 3: Seed network and entrepreneurship (Ms Arlene Nietes)
17.00–17:30	Thematic Review 4: Seed supply and technology in rural aquaculture (Dr Sunil Siriwardena)
17.30–18.00	Thematic Review 5: Farmer innovation and role of women in seed production (Dr M.C. Nandeesha)

24 March 2006, Friday (Day 2)	
08.30–09.00	General Discussions on Thematic Reviews
09:00–11:30	Invited Presentations
09.00–09.30	Invited presentation: Self-recruiting species (SRS) from farmer-managed aquatic systems (FMAS) – the contribution of non-stocked species to household livelihoods (Mr Ernesto Morales)
09.30–10.00	Coffee Break
10.00–10.30	Invited Presentation: Decentralized seed – poorer farmers producing large size fingerlings in irrigated rice fields in Bangladesh – Benoy Kumar Berman (Bangladesh)
10.30–11.00	Invited presentation: Highlights of DANIDA's Support to Freshwater Aquaculture (SUFA) Project on Establishing National Broodstock Centres in Viet Nam –Dr Nguyen Cong Dan (Viet Nam)
11.00–11.30	Invited presentation: Philippine experience on Genetically Improved Freshwater Tilapia (GIFT) Foundation – Mr Basilio Rodriquez, Jr. (Philippines)
11.30–12.30	General Discussions on Invited Presentations
12.30–14.00	Lunch Break
14.00–14.15	Mechanics and Guidelines for Working Group Discussions – Dr Simon Funge-Smith (FAO)
14:15–18.30	Working Group Discussions
15.30–16.00	Coffee Break
25 March 2006, Saturday (Day 3)	
08.30–12.30	Continue Working Group discussions and preparation for plenary presentation
10.00–10.30	Coffee Break
12.30–18.30	Lunch/Field Trip/Free Time
26 March, Sunday (Day 4)	
	Working Group (WG) Presentations in Plenary (30 minutes each)
08.30–09.00	WG 1
09.00–09.30	WG 2
09.30–10.00	WG 3
10.00–10.30	Coffee Break
10.30–11.00	WG 4
11.00–11.30	WG 5
11.30–12.30	General Discussion of Working Group Presentations
12.30–14.00	Lunch Break
14.00–16.00	Working Groups Chairpersons, Rapporteur and Technical Secretariat finalise Workshop Recommendations
16.00–17.00	Presentation of Final Workshop Recommendations in Plenary
17.00–17.30	Closing

ANNEX 4.2
Participants to the FAO Expert Workshop on FAO Expert Workshop on Freshwater Fish Seed as Resource for Global Aquaculture, Wuxi, Jiangsu Province, China, 23-26 March 2006

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ANNEX 4.3
Welcome remarks of Professor Xu Pao, Director of the Freshwater Fisheries Research Center, Chinese Academy of Fishery Sciences at the FAO Expert Workshop on Freshwater Fish Seed as Resources for Global Aquaculture, 22 March 2006, Wuxi, China

Ladies and Gentlemen, Good morning. The FAO Expert Workshop on Freshwater Fish Seed as Resources for Global Aquaculture is now commencing at the Freshwater Fisheries Research Center (FFRC), Chinese Academy of Fishery Sciences (CAFS), Wuxi, China. On behalf of the Freshwater Fisheries Research Center (FFRC), I would like to extend a warm welcome to all the experts from FAO and other countries.

The FFRC of the Chinese Academy of Fishery Sciences (CAFS) is one of the major comprehensive fisheries institutions for research, education/training and information exchange. In the research activities, FFRC has the main functions oriented toward basic and applied research. The key research emphasis are laid on fishery breeding biology and genetics, conservation of biodiversity and fishery stock resources, monitoring and protection of fishery environment, evaluation and management of fishery resources, fish disease prevention and control, carrying capacity and healthy aquaculture, fish nutrition and information exchanges.

The Asia-Pacific Regional Research and Training Center for Integrated Fish Farming is an important component of FFRC, has continuously undertaken China-TCDC training courses for 25 years. Over 30 courses have been successfully conducted for more than 1 000 participants from 80 countries. Besides, there have been also a great number of international academic workshops, visiting scholar exchanges and research collaborations taking place at the center.

The present FAO workshop is focused on freshwater fish seed development. It is generally recognized as the hottest issue for global aquaculture and essential basis for the farmers. In the 1950s, Chinese fishery specialists successfully conducted induced breeding of the Chinese carps, it is a milestone for mass seed production and a termination of wild collection from natural waters. However, greater efforts are expected in order to have better, steady and healthy supply of quality seed for farmers where aquaculture technologies are less developed.

The present FAO Expert Workshop on Freshwater Fish Seed as Resources for Global Aquaculture is highly anticipated for an appropriate orientation and practical approaches for both research people and farmers and the FFRC is pleased to carry out collaboration in any form regarding this subject for greater contribution to the aquaculture development of global freshwater fish seed resources apart from fisheries research, technical training, human resource development with all the specialists present at the workshop.

Finally, I wish in advance the successful completion of the workshop and good health to all the guests present at the workshop

Thank you .

ANNEX 4.4
Welcome remarks of Mrs Wei Shaofeng, Bureau Director, Jiangsu Provincial Marine and Fishery Bureau at the FAO Expert Workshop on Freshwater Fish Seed as Resources for Global Aquaculture, 22 March 2006, Wuxi, China

Ladies and Gentlemen, Good morning.

The FAO Expert Workshop on Freshwater Fish Seed as Resources for Global Aquaculture is now open at the Freshwater Fisheries Research Center, Chinese Academy of Fishery Sciences, Wuxi China. On behalf of the Jiangsu Provincial Marine and Fishery Bureau, I would like to extend a warm welcome to all the participants from FAO representatives and specialists from the other participating countries.

Aquaculture products are the important components for food security provision, while seed is the essential basis for aquaculture activities and assurance of sustainable development. The growth of production and the fisheries like crop production mostly demand quality seed.

Aquaculture in China is well-developed and largely dependent upon quality seed production and extension. China has laid a strong emphasis on capacity building and infrastructures for the seed development, greater efforts are made to the quality, size, standard operating procedures and scientific principles and even the quality monitoring and evaluation. Now there have been over 30 farms serving as gene banks for native and quality stocks for the whole country. The Ministry of Agriculture in China officially declares that there are about 60 quality species in China suitable for the Chinese context of aquaculture and extension. In 2004, the seed production reached 711.6 billion fry. Common carp, tilapia and shrimps are the most popular for production which largely promotes healthy aquaculture practices.

However, there have been serious degradation of the traditional fish species with limited number of quality species seed for replacement, poor use of the quality seed and even the un-effective extension systems which are the bottleneck of the national aquaculture development and demand further efforts.

Jiangsu province is a large province for aquaculture in China. In 2004, the total area reached 800 000 ha. The total production reached 3.6 million tonnes. There is a general consensus that greater efforts are needed to develop quality seed and species with higher efficiency. This province has worked hard on seed action for aquaculture as the key project particularly in the field of seed production systems. Successful results have been achieved. We would like to share this experience and carry out collaboration with all the specialists present at the workshops. Welcome to visit Jiangsu Province.

I strongly believe that the present workshop will greatly promote the aquaculture seed production in China and push forward the seed production into a new phase with mass scale and better quality.

I wish in advance that the workshop will achieve a fruitful result and wish you good health and happy stay for all the guests present in this workshop.

Thank you.

5. Country case study template

Objective:
The objective of the country case study is to collect information on the status of freshwater fish seed resources in selected countries in three aquaculture regions.

Methodology:
Country case studies (to be conducted through various ways such as literature search, actual interviews or field visits) will be commissioned through an author's contract to selected country nationals.

The following information will be collected:

(a) **Introduction.** This section contains basic information about the country in terms of : Freshwater aquaculture resources (e.g. tilapia, carps, catfish, milkfish, other important freshwater aquacultured species), contribution to aquaculture production, consumption, consumer acceptance.
(b) **Seed resources/supply.** This section includes information on resources available in terms of seed supply from hatcheries (private and government) or from wild sources.
(c) **Seed production facilities and seed technology.** This section includes information on existing number of hatcheries for freshwater fish seed production, available production figures, the number of species, available technologies (e.g. breeding, hatching, rearing), gene banks.
(d) **Seed management.** This section includes information on husbandry management of broodstock and larvae, feed management, etc.
(e) **Seed quality**. This section includes information on performance, health/ diseases, hygienic procedures in hatcheries, available set criteria for seed quality (e.g. growth rate, survival, uniformity of size at harvest, etc.)
(f) **Seed marketing.** This section includes information on supply and distribution mechanisms, types of distribution networks (e.g. organized or disorganized), flow chart or channels of distribution, people involved in the process (i.e. selling, exchange, purchase, marketing agents, etc.), market, accessibility, transportation (e.g. delivery or pick-up, what means of transportation, etc.), available financing, sales promotion.
(g) **Seed industry.** This section includes information on the scale or level of industry (i.e., small, medium or large scale (producers and suppliers) and may include a description for each level, etc., risks (socio-economic, technical and environmental risks, e.g. seed or broodstock mortality, seasonality of market, low seed price, unfavourable weather conditions, distance between seed suppliers and market, non-payment among seed buyers, impacts of naturala disasters, etc.), and other information, for example, such as women involvement, traditional knowledge of farmers.
(h) **Support services**. This section includes information on support services at the country level (extension, technical training, technology transfer, manuals, others)
(i) **Seed certification.** Does this exist in the country? For which species? If so, describe the processes and organizations involved, any recognizable impact/s?

(j) **Legal and policy framework.** This section includes information on legal and policy framework supporting the seed sector, e.g. STREAM initiative, governance, trade, etc.

(k) **Economics.** This section includes information which will determine profitability, i.e., supply and demand, prices, seasonality; what factors determine the price of seed?; contribution to household income? return of investments?

(l) **Information or knowledge gaps.** May also include other limitations or problems not covered in this outline.

(m) **Stakeholder**. Identify the various stakeholders involved in seed production, describe the number and scope and extent of activities. May include such groups as:

a. producers/farmers (seed production and exchange);
b. local institutions such as NGOs, extension services, producer associations – promotion of use of quality seed, dissemination of technology;
c. small hatcheries – to develop local market;
d. larger hatcheries – for development of new varieties/strains or innovations;
e. associations – to represent industry interest;
f. government institutions – to provide legal and policy framework for the seed industry (producers, etc.), extension services, training, start off seed;
g. researchers – information, knowledge and technology (e.g. universities, fisheries colleges, research institutes, etc.);
h. donors (funding agencies). Please provide information on existing donor-funded projects;
i. others.

(n) Future prospects and recommendations.

PART 2

REGIONAL SYNTHESES, COUNTRY CASE STUDIES AND THEMATIC REVIEWS AND CONTRIBUTED PAPERS ON FRESHWATER FISH SEED RESOURCES FOR SUSTAINABLE AQUACULTURE

6. REGIONAL SYNTHESES

6.1 Freshwater fish seed resources and supply: Africa regional synthesis

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Brummett, R.E. 2007. Freshwater fish seed supply: Africa regional synthesis, pp. 41–58. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fisheries Technical Paper*. No. 501. Rome, FAO. 2007. 628p.

ABSTRACT

The availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture in Africa. Government hatcheries have generally failed to achieve sustainability and the private sector is impeded by the lack of marketing information and appropriate technological assistance. At present, the main aquaculture species in the continent are Nile tilapia (*Oreochromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*). While the tilapias are easy to reproduce on-farm, poor broodstock management had resulted in reduced growth rates in many captive populations. Catfish are mostly reproduced in hatcheries, but availability of broodstock and high mortality rates in larvae are key problems still requiring research. Of the countries reviewed, Egypt (1.2 billion tilapia and 250 million carp fingerlings produced) and Nigeria (30 million fingerlings produced) report the highest number of modern private commercial hatcheries, although most of these are unregulated and lack accreditation and certification systems. Ghana, Cameroon, Uganda and Zimbabwe rely almost entirely on semi-commercial systems producing unreliable quantities and quality of seed. Interventions to improve the quality of extension services, make credit more available and build partnerships between public and private sectors to address key researchable topics are recommended to improve the availability of fish seed to African fish farmers.

INTRODUCTION

The availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture in Africa (FAO 2000, 2001; Moehl and Halwart, 2005). However, in most African countries, would-be hatcheries find themselves in a conundrum: achieving profitability for the fingerling producer is impossible without an adequate number of grow-out farms to purchase fingerlings while, at the same time, the profitability of grow-out depends largely on the availability of good quality fingerlings when needed. Clearly, some external interventions are needed, either in the form of cash injections to help farmers through run-in, or provision of fingerlings through externally financed

TABLE 6.1.1
Authors of country case studies

Country	Author
Cameroon	Randall Brummett, WorldFish Center, Yaoundé
Egypt	Magdy A Saleh, General Authority for Fish Resources Development, Cairo
Ghana	Patricia Safo, Crystal Lake Fish, Ltd., Akosombo
Nigeria	Akintunde Nureni Atanda, Aquaculture and Inland Fisheries Project, Abuja
Uganda	Wilson Mwanja, Fisheries Department, Entebbe
Zimbabwe	Patrick Blow, Lake Harvest Aquaculture, Ltd., Kariba

hatcheries. For many years, foreign donors have invested hundreds of millions of dollars in the construction of government-run hatcheries throughout the continent, largely to no avail. Efforts are now underway to understand past failures and generate new initiatives to overcome these key constraints. This report synthesizes country case studies executed in Cameroon, Egypt, Ghana, Nigeria, Uganda and Zimbabwe (Table 6.1.1) and strives to indicate directions for new investments on the part of governments and international development agencies.

STATUS OF AFRICAN AQUACULTURE

Although there are several indigenous aquaculture systems in Africa, what we might call modern style aquaculture based on drainable ponds, raceways or cages began under the colonial administrations of the late 1940s. Research and extension to develop culture technology for a number of species was established and hundreds of thousands of ponds were constructed. In the 1960s, most newly independent African governments dropped support to aquaculture and many of the fishponds built up to that point were abandoned. In the 1970s, 1980s and 1990s, aquaculture, as a tool in rural development, was adopted by a number of international donor agencies, the major focus being on small-scale/low-tech systems that could easily integrate into traditional farming methods. In many cases, donor-funded aquaculture projects saw important success, although most positive impacts were short-lived and ended within a couple of years after donor support was withdrawn. Currently, African aquaculture contributes less than 1 percent to global production, with only larger-scale investments in Egypt, Ghana, Nigeria and Zimbabwe producing significant quantities of fish.

While African capture fisheries have been (over) exploited to their maximum and aquaculture has languished, African demand for fish has grown. Africans are second only to Asians in the importance of fish in the diet, with 17.4 percent of total animal protein intake in the form of fish (compared to 25.7 percent in Asia). Even though total fish supplies have increased, they have not kept pace with population and Africans currently consume an average of 7.7 kg/per/yr (6.4 million tonnes total) down from a peak of over 9 kg (4.6 million tonnes total), in the early 1980s. Just to get back to 1982 consumption levels, there is a 1.3 million tonnes shortfall in supply. Nevertheless, in 15 African countries, fish represent over 30 percent of animal protein consumption (FAO, 2005) as shown in Table 6.1.2.

WATER RESOURCES FOR AQUACULTURE

Most African countries rely on surface freshwater for aquaculture, with the vast majority of the continent's many small farmponds being filled by diverting small watercourses.

TABLE 6.1.2
Animal protein consumption (percentage) of 15 African countries

Malawi (44.2 %)	Equatorial Guinea (58.2 %)	Angola (35.7 %)
PR Congo (45.3 %)	Ghana (58.6 %)	Côte d'Ivoire (36.0 %)
Gambia (47.3 %)	Sierra Leone (66.4 %)	Senegal (37.5 %)
Uganda (31.6 %)	Tanzania (32.8 %)	Togo (39.7 %)
Guinea (34.9 %)	Cameroon (49.0 %)	Nigeria (40.0 %)

Increasingly, cages placed in large waterbodies are favoured. Substantial mariculture is limited to mussel farming in South Africa and seaweed culture in Tanzania.

Cameroon is a water-rich country with some 35 000 km² of aquatic habitats representing many of the key aquatic ecosystems that prevail over the continent: large natural lakes (Lake Chad), reservoirs on dammed rivers (e.g. Lagdo, Mape, Bamindjing), crater lakes (e.g. Barombi Mbo, Nyos), large rivers (e.g. Benue, Sanaga, Cross, Mungo, Wouri, Dibamba), rainforest rivers (Nyong, Ntem, Kienke, Ndian, Lobe, Lokoundji) and thousands of kilometers of first and second order streams (representing 86 percent of total freshwater resources).

In Egypt, except for some well-based farms in the Western Desert, virtually all of the water used in aquaculture comes from the Nile River, consequently most fish farms are located in the Nile Delta, especially the northwest near the town of Kafr el Sheikh. As a generally water-poor country, Egypt prohibits the first use of water for aquaculture, requiring fish farmers to access drainage water coming out of agriculture irrigation systems, creating potential problems with purity and contamination with sewage and agricultural chemicals.

About 70 percent of the total land area of Ghana is drained by the Volta river system, including the Volta Lake, which covers some 8 500 km² plus 1 684 km of tributaries, including the Oti, Pra, White Volta, Black Volta and Asukawkaw rivers. Outside of the Volta system, the major inland water resources include the Densu, Ayensu, Okye, Kakum, Pra, Ankobra, Tano and Bia rivers and Lake Bosumtwi. Some 89 coastal, brackishwater lagoons also have potential for fish farming.

Nigeria has abundant riverine and lacustrine resources that could be used for aquaculture, but most fish farms are located in the southwest to be close to the big markets in Lagos and Ibadan. In these areas, competition for water is rampant, with many industrial and domestic users all fighting over limited resources. In response, the Nigerian aquaculture industry is intensifying with increasing use of recirculation/biofiltration systems.

Uganda also has many water resources that could support aquaculture, with 31 of 56 districts having been identified as suitable for fish farming. An estimated 650 hectares are currently under aquaculture. In addition, 43 small lakes and dams (1 476 km² total surface area) are being used for extensive, culture-based fisheries. Lakes Victoria and Kyoga have been identified as potential sites for intensive, commercial cage-based tilapia and/or Nile perch farming systems.

Zimbabwe is a generally dry country, so most of the aquaculture is based in the Eastern Highlands (Nyanga) and the large, man-made Lake Kariba. There are only six aquaculture installations, three producing tilapia and three growing trout. While some 800 tonnes of tilapia products are sold on the local market each year, aquaculture in Zimbabwe is primarily an export and/or luxury market business.

FISH SPECIES IN AFRICAN AQUACULTURE

Because of the continent's long and diverse geological history, Africa is home to a wide variety of indigenous and endemic species; at least 3 200 freshwater having been reported (FishBase, 2004). Since the 1940s, dozens of these have been evaluated as aquaculture candidates at a number of research stations:

- Djoumouna (PR Congo)
- Landjia (Central African Republic)
- Foumban (Cameroon)
- Bouaké (Côte d'Ivoire)
- Sagana (Kenya)
- Abbassa (Egypt)
- Anamalazaotra and Ampamaherana (Madagascar)
- Kipopo (DR Congo)

- Kanjasi (Uganda)
- Chilanga (Zambia)
- Henderson (Zimbabwe)
- Akosombo (Ghana)
- Domasi (Malawi)
- Port Harcourt (Nigeria)

The main indigenous species for which reproduction and practical grow-out techniques were established were the tilapias (especially *Oreochromis niloticus, O. mossambicus* and *O. aureus, Sarotherodon galilaeus, S. melanotheron, Tilapia rendalli*), the catfishes (esp. *Clarias gariepinus*, *Heterobranchus longifilis* and their hybrid often referred to as “Heteroclarias”) and the African boneytongue (*Heterotis niloticus*). In addition, most of the main international aquaculture species have been imported and tested for African aquaculture at one time or another, but only the rainbow trout (*Onchorhyncus gairdneri*) and common carp (*Cyprinus carpio*) have really stuck, probably due to their relative hardiness. A number of Chinese carps are reportedly produced in Egypt, but mostly for weed and disease control rather than as table fish.

At present, the main aquaculture species on the continent are the Nile tilapia (*O. niloticus*) and the African sharptooth catfish (*C. gariepinus*). Both of these are indigenous to the Sudano-Nilotic Ichthyological Province that dominates northern Africa, but are not naturally found elsewhere. Somewhat unfortunately, both of these are also highly invasive, “weeds” capable of taking over ecosystems when they escape from aquaculture facilities (which they always eventually seem to do). Following the publication of the Codes of Conduct for Responsible Fisheries (2002), The Nairobi Declaration on The Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species Aquaculture in Africa (2002) and the Dhaka Declaration on Ecological Risk Assessment of Genetically Improved Fish (2003), the fear that these fish will get out and ruin biodiversity has led African governments to more or less ban further imports of alien aquaculture candidates, pending more research into potential environmental impacts.

SEED RESOURCES AND SUPPLY

Since its inception in Africa, aquaculture has relied on two main sources of fingerlings: unregulated spawning in production ponds and government hatcheries. For some species, such as *Heterotis niloticus, Chrysichthys nigrodigitatus*, *inter alia,* fingerlings are captured from the wild. Lack of fingerlings where and when they are needed by fish farmers is one of the greatest constraints to aquaculture expansion in the continent. A summary of case study of countries is shown in Table 6.1.2.

Cameroon

In Cameroon, 32 national fish stations were designed with the primary objective of producing fingerlings to support the growth of aquaculture.

Although these stations are largely dysfunctional, some of the most important of them possess considerable infrastructure and potential for contributing to aquaculture development if either properly managed or transferred to the private sector. As these government stations have failed to alleviate any of the main constraints to aquaculture, fish farmers have increasingly turned to other suppliers for information and fingerlings. Over 90 aquaculture non-governmental organizations (NGOs) include aquaculture in their remit and a few have attempted to operate small hatcheries to supply their members with seed. At present, five private hatcheries (three catfish, two tilapia) are the main suppliers of high-quality fingerlings in the country, producing some 1.4 million catfish and 3.3 million tilapia per year.

Egypt

In Egypt, the large and diversified aquaculture industry makes data collection extremely difficult. Virtually all of the fish cultured in Egypt come from hatcheries. For tilapias, some farms maintain their own capacity, but the majority of seed come from private hatcheries. To reach the recorded 190 000 tonnes harvest of cultured tilapia, an estimated production of 1.2 billion fingerlings would have been produced. Production from government and licensed private hatcheries in 2004 was only 150 million fingerlings, the balance having been produced elsewhere. As current demand strongly outstrips supply, hatcheries are more and more frequently selling fry as small as 0.5-1.0 g, leaving growers to nurse them up to stocking size. Carp (*Aristichthys nobilis, Ctenopharyngodon idella, Cyprinus carpio, Hypophthalmichthys molitrix, Mylopharyngodon piceus*) seed are produced almost exclusively in government hatcheries, for stocking in ricefields and the country's extensive network of irrigation channels for control of bilharzia snails, macrophytic weeds and abundant algae blooms hatcheries and nursery stations. A total of 250 million carp seed were reportedly produced and stocked in 2004.

Ghana

In Ghana, the major constraints to successful aquaculture among producers are the poor and erratic quality of fish seed available for stocking. Two major factors influence the cost of fish seed: the high cost of production from government breeding centres and insufficient supply. Pilot tilapia hatcheries have been established in Accra (1993), Akosombo (1996) and Kumasi (1997). The Accra centre, with a target of 180 000 seed/year, produces a paltry 40 000. The Kumasi centre with a target of 100 000 seed/year produces only 4 000 seed/year. The Akosombo centre, operated by the Water Research Institute, is better regularly meeting its production target of (a very modest) 100 000 seed/year. Shortfalls in achieving production targets are attributed to predation, cannibalism theft and storms killing brooders. Though fish seed prices are subsidized by government, poor production keeps costs high.

Nigeria

The supply of fish seed in Nigeria can be from either of two sources, i.e collection from natural waters (wild sources) and from hatchery production based on controlled spawning. Fingerling collection from the wild is found to be unreliable, because it is seasonal and usually contains mixed species, some of which do not meet the criteria of good aquaculture candidates. The correct age of fish and fingerlings are difficult to determine. This has led to the dependence on hatchery-bred fish with known history. Several fish hatcheries have been established in the country with most of them in the south. The tilapias are usually allowed to spawn naturally in ponds and tanks, while the mud catfishes and carps are subjected to hormone-induced spawning. These practices require a lot of skills and these have been transferred to various interested practitioners through short courses in fish seed multiplication around the country. The earliest of such training programmes by the Federal Department of Fisheries was assisted by FAO between 1978 and 1981, when two Fish Seed Multiplication and Fish Farming Demonstration Centres were established at Panyam Fish Farm in Plateau State (north central Nigeria) and Oyo Fish Farm (southwest). Regular on-farm, hands-on training were organized for prospective fish farmers and fish seed producers at these centres. Two additional centres were later established at Umina-Okigwe (southeastern Nigeria) and Mando Road, Kaduna (north western Nigeria).

The characteristic feature of the current phase of aquaculture development in Nigeria is the emergence of private sector investors as the driving force. This is also complemented with government policy of divesting its farms to the private sector. Most recent investment in aquaculture has been targeted towards catfish farming.

Presently live catfish attract premium price in Nigeria, with a high ROI (return on investment) of between 30 to 40 percent in some very successful enterprises. This holds the major attraction to the private sector investors in Nigeria. Currently about 90 percent of farmed fish in Nigeria is catfish while in the last four years almost all hatchery infrastructure and table fish production systems have been exclusively targeted towards the production of catfish.

It is estimated that fish seed production has jumped from 3 million in 2000 to about 30 million in 2005. The emergence of high volume producers who have invested in intensive re-circulating and flow-through fish production systems have been largely responsible for the phenomenal increase in the volume of production of both fingerlings and table fish.

The total estimated total current investment in aquaculture including hatchery facilities in Nigeria is put at N$10 billion (US$75 million). There are about 30 small-, medium- and large-scale intensive, closed recirculating and flow-through systems in Nigeria especially in the southwest and south-south zones where over 77 percent of all fish farms and hatchery infrastructure are located. Investments are still growing, especially with the renewed awareness being created by the government through the Presidential Initiative on Fisheries and Aquaculture and the recent continental New Partnership for Africa's Development (NEPAD) Fish for All Summit held in Abuja, Nigeria.

Of the 2 642 private fish farms that have been inventoried by the Aquaculture and Inland Fisheries Project (AIFP) in December 2004, about 500 are commercial, although most of them are poorly managed. More than half of the 500 commercial fish farms have small- to medium-sized hatcheries built beside them and again most of these are either abandoned and at best under producing (at times not more than 5 percent of installed capacity). Abandonment has been due largely to the technical incapabilities of the hatchery managers, as most of them are either poorly trained or inadequately remunerated and in other cases, both.

Presently seed supplies from government and public sectors, hatcheries (including research institutes and universities) are about ten percent of the total. The current picture of seed supply in Nigeria is as follows: private sector farms and hatcheries about 80 percent (24 million), public sector about 10 percent (3 million), collection from the wild about 9 percent (2.7 million), importation and other sources about 1 percent (0.3 million).

Uganda

Uganda's current seed production industry can be categorized into three groups: small-scale, medium-scale and large-scale. The small-scale hatcheries produce largely for rural communities and are usually limited by capacity to supply seed to the district in which they occur. The small-scale hatcheries are those considered to produce less than 200 000 fingerlings of any one species a year or those producing not more than 300 000 fingerlings in total a year. The second category is medium-scale - this category targets emerging commercial grow-out farmers and produces seed that can be sold beyond district of production. Many of the medium-scale producers came up during the government's programme of stocking and restocking of water bodies and have since transformed into commercial hatcheries. Medium-scale hatcheries produce between 300 000 to 1 million fingerlings a year. Large-scale hatcheries are only starting to come up and they are categorized as those that produce over 1 million fingerlings a year.

Small-scale hatcheries are limited in technical capacity and resources. Normally, these category of hatcheries are rural-based and credited for bringing quality fish seed in the reach of the rural fish farmers. This category has a risk of not giving the farmer a quality product given the limited resources and remoteness of hatcheries for effective monitoring by the regulatory agencies. Medium-scale hatcheries are always careful to keep up the quality of their products as they largely depend on commercial fish farmers coming back to buy more seed from them. There is a tendency with this category of hatcheries to over produce seed to meet either the market demand and to meet deadlines. In so doing, this category of hatcheries is likely to lead to increased fish escapes, over-fertilization and failure to adhere to guidelines to ensure quality fish seed production. The large-scale hatcheries are normally well planned and designed. Initially, a single public hatchery, Kijjansi Aquaculture Research and Development Centre (KARDC) was the only large-scale fingerling producer, but in recent years the number of larger private investments have come on-line to meet growing demand for quality fish seed. Many of the large-scale hatcheries are clearly around the central administrative district and supply fish seed only to large-scale farms. One such hatchery (SUNGENOR) specializing in improved tilapia seed from the GIFT strain of Nile tilapia will be supplying seed for its out grower scheme where farmers sell back the fish to the company's fish processing and export partner (NGEGE Ltd).

On the whole, fish farming remains an alien practice, a situation that was not helped by the manner in which aquaculture was first considered and introduced into the country. The practice was considered to be non-income generating and only for fish protein provision for the rural communities who did it on subsistence with little or no input other than the fish seed. However, with time the practice has began to attract profit and income, thus generating oriented fish farmers who have started to invest commercially and expand production targeting local, regional and international markets. This level of farmers have better-constructed production units, have designed measures against predators (small reptiles and birds) and are using formulated fish feed either bought from feed firms or manufactured on farm. These fish farms are also better located and are employing technically trained persons or seeking advise from competent aquaculture service providers.

Zimbabwe

Farmed tilapia seed are available from two private hatcheries: Lake Harvest Aquaculture (Pvt) Ltd. (LHA), established in 1997 in Kariba (365 km northwest of Harare) and producing around 3 000 tonnes per annum of whole fish and 'The Bream Farm', established in the early 1980s in Kariba and producing less than 100 tonnes per annum harvest (mainly on a recreational put-and-take basis). Lake Harvest Aquaculture produces around 2 million fry per month for nine months of the year (i.e. when water temperatures are warm enough to breed outdoors). The Bream Farm produces around 1 million fry per annum. Both farms produce tilapia seed almost exclusively for their own use. Little to no seed are sold to third parties because demand is low and Nile tilapia, the only species where whose seed are produced in hatcheries in Zimbabwe, is not supposed to be moved out of the Zambezi Valley (includes Lake Kariba), except by way of permit from the government's Parks and Wildlife Authority. Such permits are difficult to obtain. There are currently no operational government hatcheries for tilapia in Zimbabwe, although attempts are being made by the government to resuscitate one or two defunct government hatcheries.

There are also three commercial trout farms:

- Clairmont Trout Farm, established in the 1970s or earlier and producing no more than 50 tonnes per annum;
- The Trout Farm, established in the 1970s or earlier and producing less than 5 tonnes per annum;
- Inn on Ruparara, established in the 1990s and producing less than 20 tonnes per annum.

Each of these has its own small hatchery for on-farm use. The Government hatchery in Nyanga produces seed for local dam stocking, essentially for recreational put-and-take fishing.

MARKETING

Unlike in parts of Asia where large numbers of middlemen buy from hatcheries and sell to grow-out farms, very little efforts are made in Africa to market fingerlings. By and large, producers either place an order with a hatchery or simply show up to buy fish. In some cases, larger orders might be delivered by the hatchery to the farm.

For the tilapias and larger catfish/carp operations, such as in Egypt, this is not a major problem as fish can be spawned most of the time and can affordably be maintained in holding facilities. However, for smaller-scale and, particularly catfish, hatcheries elsewhere on the continent, fingerlings are produced in batches. If buyers are not immediately available when needed, tilapia fingerlings often go on to reach precocious sexual maturity making them useless for commercial farming, while the catfish cannibalise each other.

Synchronisation between fingerling supply and demand is a key problem in African aquaculture. Egypt has a particular problem because of the strong seasonality of their climate, forcing hatcheries to use expensive technology to get fingerlings ready early so they can be stocked out as soon as the weather warms in the spring. Efforts on the part of hatcheries to adapt to the grow-out cycle and aggressively market their products and thus make them more easily available to producers could help in hatchery profitability, ultimately bringing prices down.

SEED PRODUCTION FACILITIES, TECHNOLOGY AND ECONOMICS

The hatchery systems employed in Cameroon, Nigeria, Ghana and Uganda are typical of small-scale hatcheries throughout the continent. In hatcheries, tilapia fingerlings are produced in open ponds of 50-50 m^2. Broodfish are randomly stocked at a rate of one male to one female. Fingerlings are captured with a dip net or fine-mesh seine net beginning at ±50 days after broodfish stocking and is repeated every 21 days until capture begins to decline (normally after about three months). Harvested fingerlings averaging about 10 g are held for two days to recover from the harvest operation and sold. Production costs vary around US$0.5 cent to US$1 per fingerling, while retail prices vary with season, size and supply/demand imbalances, averaging between US$3-5 cents 5-10 g mixed-sex fingerlings. Very few hatcheries are experimenting with hormone sex-reversal or hand-sexing to get all male populations.

Most farmers, however, do not rely on hatcheries for tilapia but instead either (a) captures them from the wild where the farmers buy the fingerlings from fishermen, or (b) some of these farms produce their own. Local fishermen usually scoop up “clouds” of fry as they school in the shallows (wild) or remove young fry from their mother’s mouth and sell to the farmers who in turn transfer them to some type of rearing container and feed them. The majority of African fish farmers use mixed-sex tilapia systems to generate their seed, i.e. they use the customary techniques where the fish is harvested in the pond after six months, selling or eating the larger fish and keeping the smaller individuals for restocking. However, since extreme care is not taken, individuals that are used for restocking are usually already sexually mature and begin reproducing almost immediately after stocking. Another alternative method used is to hold broodfish in a net enclosure (*hapa*) where their spawning is closely monitored. In this way, the age of the fingerlings are well known and the risk of stocking sexually mature individuals is eliminated. The *hapas* are usually placed in the farmer’s grow-out ponds.

Basic catfish reproduction technology has been well-established over the last 20 years as described by de Graaf and Janssen (1996). Typically, female *C. gariepinus* are injected with 4 000 IU/kg of human chorionic gonadotropine (HCG), pituitary extracts or other hormone analogs to induce final gonadal maturation and stripped after approximately 12 hrs. Eggs of all females are pooled and then dry fertilized with mixed milt from nine sacrificed males. Fertilized eggs are poured onto 70 x 50 cm wooden framed nylon-mesh screens where they adhere and are submerged to 40 cm depth in 1 m^3 *hapas* installed under the water inlet pipe (to ensure adequate exchange of fresh water) in small earthen ponds, or in indoor cement tanks. Eggs hatch within 30-35 hrs and are subsequently held in their *hapas* for two days prior to stocking, by which time they have reached an average individual weight of 2.3 mg.; hatching and survival rate to two days average 95 percent.

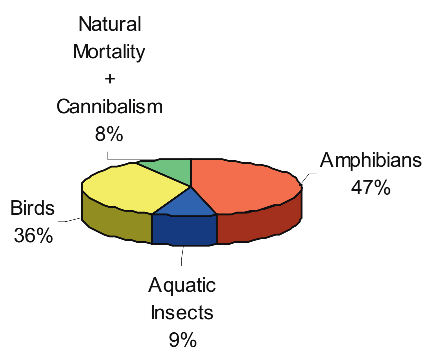
Few farmers, however, want such small seed, 7-10 g being the minimum size to insure decent survival rates. As catfish fry are susceptible to a wide range of predators (Figure 6.1.1) including cannibals, the greatest problems encountered by catfish hatchery operators concern larval survival. Three basic nursing systems are used:

Low intensity: Ponds are prepared by drying, cleaning and installing compost cribs comprised of wooden stakes driven into the mud at approximately 10 cm intervals to enclose 10 percent of the pond surface area. Ponds are then surrounded by a 1 m high fence fabricated of locally produced nylon mesh bags or aluminum roofing material to in an effort to exclude frogs, one of the most important larval predators. The compost cribs are filled with 7 kg/are[1] total dry weight (approximately 20 kg wet material) of cut grasses mixed with 0.2 kg/are of wood ash. Ponds are then filled and stocked within three days (to avoid infestation by insects) with two-day old *C. gariepinus* larvae at a rate of 7.5 per m^2. Once per week, the compost is churned using a stick and another dose of grass and wood ash added.

Medium intensity: Ponds are prepared as in System 1, but instead of compost, ponds are limed with 2.5 kg/are of quicklime (CaO), fertilized with 20 kg/are (dry weight) of chicken manure and fed a daily supplement of wheat bran at a rate of 1 kg/are. Stocking rate is 15 two-day old larvae per m^2.

High intensity: Ponds are prepared as in System 2, but from Day 11 onwards, are fed twice per day with a 1:1 mixture of wheat bran and palm nut cake at a rate of 1.0 kg/are (2.0 kg/are/day total). Two-day old larvae are stocked at 30/m^2. As in treatments 1 and 2, a frog fence and last-minute filling are the only anti-predator strategies employed.

FIGURE 6.1.1
Main predators of catfish larvae



Production cost factors vary with country, but are generally proportional to the values shown in Tables 6.1.3 and 6.1.4. A key element in profitability of all hatchery systems is intensity, with hatcheries that are able to maintain high densities making the most money. Average survival rate is about 37 percent in well-managed systems.

In Egypt, hatchery systems are more intensive than elsewhere in the continent. The most common system among industrial hatcheries is based on indoor breeding tanks to facilitate spawning one or two months earlier than that produced in outdoor systems (due to the cold winters and relatively short growing season in Egypt). Larger one-year old brooders are selected from the harvest. In late winter, broodfish are stocked at a rate of three to four females per male in each square meter of the breeding tanks. Water temperature is raised to the optimum breeding temperature (26 °C to 29 °C) by boilers. Incubating eggs are collected from females and transferred to hatching jars

[1] 1 are = 1/10 hectare

TABLE 6.1.3
Summary of fingerling supply characteristics in six African country case studies

	Cameroon	Egypt	Ghana	Nigeria	Uganda	Zimbabwe
Main Culture Systems	small semi-intensive ponds	large semi-intensive ponds; some cages in the Nile.	intensive cages in Volta Lake; intensive pond systems, small semi-intensive ponds	small, semi-intensive ponds; some new raceway systems in SW	small semi-intensive ponds; extensive small dams; planned cages L. Victoria	intensive cages in Lake Kariba; semi-intensive small waterbodies for trout.
Main Culture species	*Clarias* *Tilapia*	tilapia, mullets	*Tilapia*	*Clarias heterobranchus*	*Clarias* tilapias	*Tilapia*
Other species	*Heterotis niloticus*	carps	*Clarias heterobranchus*	*Tilapia* Ornamentals		trout
Total Reported Production (TPA)	324	471 500	6 000	50 000	15 000	3 225
Main Source of Fingerlings	hatcheries for catfish, pond residuals for tilapia.	private hatcheries	wild fishery or pond residuals for tilapia.	wild fishery, small and medium-scale hatcheries	private hatcheries	private, vertically integrated grow-out farms
Number of Hatcheries	14 private, 8 government	480 private, 10 government	4 large private, 5 government	500 small (s, 20 %) 200 medium (m, 60 %) 20 large (L, 20 %)	8 government (10 %), 45 private (90 %)	1 government (trout), 6 private (3 trout, 3 tilapia)
Main Hatchery Systems	small open ponds	hapas in ponds for tilapia, indoor tanks for carps, increasing use of greenhouses for early tilapia spawning	small open ponds or tanks	(s) small static ponds/ tanks (m) indoor flow-through tanks, small ponds (L) indoor recirculating raceways	small ponds or indoor tanks, semi-intensive	modern, pond-based
Estimated Number of Fingerlings Produced	3 300 000 tilapia 1 400 000 catfish	1 000 000 000 tilapia 250 000 000 carps	< 1 000 000 from government, unknown from private sector	30 000 000 (80 % catfish)	42 300 000 (80 % catfish)	19 000 000 tilapia, trout unknown
Estimated Future Fingerling Demand	not estimated	10 000 000 000	not estimated	500 000 000 growing to 2-3 000 000 000	450 000 000 by 2 011 + 296 000 000 for small waterbodies	not estimated
Main Problem	irregular demand not coordinated with irregular supply	strong seasonality; demand outstripping supply; decreasing size of fingerlings delivered.	inadequate hatchery capacity and poor management	inadequate water supply, poor training of technicians, poor and/or too few broodstock	lack of knowledge regarding economic performance of commercial systems	poor genetic quality of broodstock, high feed costs
Future Trends	growing steadily from a smallholder base	intensifying to reduce water requirements	growing steadily from an SME base	rapid, rather disorganized expansion	growing, with focus on medium and larger-scale investments.	unknown

TABLE 6.1.4
Average costs (US$) per square meter of pond surface area, for nursing *Clarias gariepinus* in Cameroon (Yong Sulem and Brummett, 2006)

System	Larvae	Pond Inputs	Labor	Depreciation on Predator Fence	Depreciation on Ponds and & Equipment	Total Cost per m^2
1	0.075	0.02	0.47	0.03	0.03	0.61
2	0.15	0.10	0.75	0.02	0.03	1.05
3	0.30	0.19	1.15	0.03	0.03	1.70

where they are kept until the yolk sac is absorbed. Fry are then transferred to nursing tanks (small shallow tanks each of 2-3 m^2) and fed with hormone-treated feeds for sex reversal. Hormone treatment extends to four weeks afterwhich fry are moved to outdoor nursing tanks (10-20 m^3) under greenhouses or to nursery ponds (1 000-4 000 m^2). Depending on the season and demand, fingerlings are sold as fry (0.5-1 g) or as fingerlings (3-5 g). Seeds are usually available at the beginning of the growing season in late March or early April.

Many private Egpytian farms also produce their own seed in hapas installed in ponds. Hapa spawning starts when the water temperature reaches the levels required for breeding in mid-April and continues through September. Broodfish are stocked at three to four females per male per square meter. Hapas are examined for the presence of free swimming fry which are collected by scoop nets. Collected fry are usually stocked in nursing ponds and harvested at marketable fingerling sizes by draining. A modification of this system with *hapas* installed in small ponds or concrete tanks under greenhouses is presently expanding to facilitate earlier production of fry. The increase in water temperature in the greenhouse facilitates tilapia spawning in tilapia at least one month before the natural breeding season.

Egyptian carp hatcheries are composed of three main units, namely: (a) broodstock ponds are earthen ponds each with 400-1 000 m^2 area and about 1.25-1.5 m deep, (b) indoor facilities, a building including a large hall with circular brood tanks, aquaria and hatching jars or containers, a laboratory, filters and water quality control facilities, boiler and staff rooms and (c) nursery facilities include suitable numbers of earthen ponds each of 1-1.5 acres and 1.25-1.5 m deep.

The different carp species introduced to Egypt cannot spawn naturally in the local environment. Spawning occurs through induced breeding by injecting the ripe broodfish with locally prepared common carp pituitary extract and stripping of females and males. Fertilization takes place when eggs and milt are mixed in a plastic vessel. Fertilized eggs are then incubated in hatching jars with running water from the bottom to the top. Hatched fry are collected and kept in glass aquaria and then moved to nursery ponds.

Zimbabwe is also a special case in that its tilapia production is concentrated at just a couple of larger-scale farms. They also, unlike the rest of the countries studied, grow trout commercially. Lake Harvest, Ltd. is, by far, the dominant producer in the country and uses open pond spawning and modern tilapia sex-reversal technology to produce all-male Nile tilapia fingerlings for stocking in their grow-out cages. Technology used on the trout farms is not known, but probably based on traditional trout spawning techniques.

SEED MANAGEMENT AND QUALITY

Among the countries studied in this review, only Egypt has any regulations on the maintenance of quality in fish seed production systems and this extends only to control of diseases and parasites through the use of broodstock isolation, disinfectants and prophylactic medication. However, even in Egypt, the rules are largely ignored and, anyway, only employed on an estimated 10 percent of hatcheries licensed by the government.

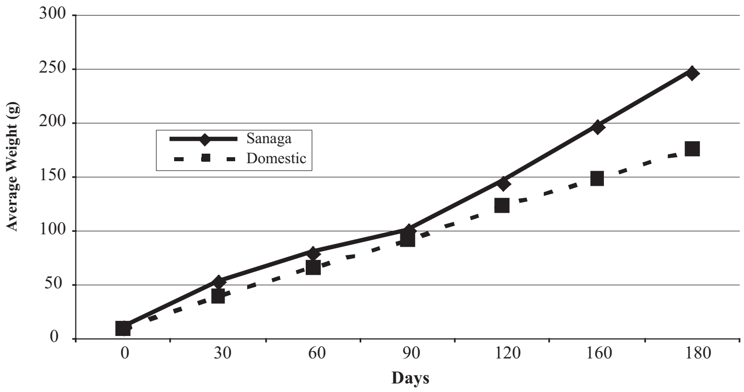
Genetic management is by far the greatest quality issue in African hatcheries and deterioration of the genetic quality of cultured populations is a serious problem. For the highly fecund carps and catfishes, there is always the temptation to use the fewest number of broodfish possible to get a certain number of eggs. For catfish, males are usually sacrificed and so are used to fertilize as many females as possible. From these, offspring of minimal numbers of parents will be selected the next generation of brooders and after several generations of mating, such bottlenecks lead to inbreeding which can reach levels sufficient to lower growth, decrease fecundity, reduce fitness and generate deformities.

Tilapia presents a somewhat different challenge, but the outcome is the same. The typical practice at harvest is to sell or eat all fish of a certain minimum size, leaving smaller individuals to be either sold as fingerlings to other farmers or continue growing in the pond. In the case of tilapia, only a part of these small fish are actually fingerlings; many being small sexually mature adults. Such selection for smaller adults amounts to inadvertent selection for slow growth and/or early sexual maturation.

In most cases, the numbers of broodfish used are far inferior to the numbers needed to maintain adequate genetic variability in the population. This is particularly troublesome for imported alien species for which new broodstock are difficult to obtain (e.g. carp populations in Egypt). Also, as male tilapia is highly territorial and competitive for mates, a relatively small percentage of males (the most aggressive, not necessarily the fastest growing) dominate the fertilization of the females. Without some methods of ensuring that most males are represented, effective breeding number (N_e) will be less than anticipated and the population can become inbred, reducing growth and viability while increasing phenotypic variation.

Genetic drift, especially the founder effect, is another mechanism that can lead to loss of genetic diversity and the potential for inbreeding. Small founder populations are more common than not in African aquaculture and, indeed, aquaculture in general. Being expensive, difficult and often illegal, individuals who seek to acquire exotic broodfish, often resort to minimal numbers, thus building low genetic diversity into their production systems from the outset. Cumulatively, these various broodstock management mistakes have induced birth deformities and reduced the growth of tilapia, carp and catfish populations held on hatcheries by up to 40 percent (Figure 6.1.2).

FIGURE 6.1.2
Comparison of growth among feral and captive populations of *Oreochromis niloticus* in Cameroon



Source: Brummett, Etaba Angoni and Piouomogne (2004)

CERTIFICATION

In Cameroon, Ghana, Nigeria and Zimbabwe, the need for some kind of seed quality certification is recognized, but no system is currently in place.

In Egypt, there are two kinds of certificates: the Health Certificate issued by the General Authority for Veterinary Services and the Certificate of Origin issued by the General Authority for Fish Resources Development (GAFRD). The health certificate is issued for batches of seed approved free of contagious disease and pathogens or parasite or its infectious stages. The procedure involves a series of detailed inspections and laboratory examinations. The certificate of origin indicates the source of the seed, brood, establishment and date of production. Both certificates are issued if requested by the buyer especially for export purposes; neither deals with the issue of genetic quality.

Uganda is more advanced in the seed certification process. All fish seed producing, supplying and fingerling-raising farms and companies have to be certified by law. This follows the making of the statutory instrument regulating aquaculture activities under the Fish Act 1964 known as the Fish (Aquaculture) Rules 2003 instrument number 31. The operator has to apply using a formatted application form, submit the application to the Chief Fisheries Officer or to a person designated by the Chief Fisheries Officer to work on his or her behalf. Inspectors are then dispatched to the aquaculture establishment to inspect and ensure that all requirements and plans are in place to ensure responsible production of quality fish seed. Upon receiving the report of the Inspectors, the Chief Fisheries Officer then issues a Fish Seed Production Certificate. This process ensures that farmers get quality fish seed and to prevent ecosystem alteration and ecological and genetic disruption from either escape of farmed fish or entry of unwanted fish into the production system. In essence, one is not allowed to produce or pass on fish seed without certification.

LEGAL AND POLICY FRAMEWORKS

Legal and policy frameworks under which aquaculture are regulated are non-existent, vague and/or unenforced. When they exist at all, there are two general types of aquaculture laws: 1) those that are more about control and taxation (Egypt, Nigeria, Zimbabwe) and 2) those designed to encourage development (Cameroon, Ghana, Uganda). Most African countries have expressed a strong interest in aquaculture development, even when financial and human resources are being diverted to more pressing issues such as education and health care.

Cameroon

In Cameroon, the Ministry of Animal Industries and Fisheries (MINEPIA) is charged with the promotion of aquaculture for food security and rural economic development (RDC, 2003). However, current regulations in Cameroon barely mention aquaculture and make no specific reference to fingerling supply or quality. Nevertheless, the government is actively advocating the expansion of aquaculture and there is a long-standing policy of providing some basic support through the operation of government stations (RDC, 1997). Although there are no specifics provided and no funding mechanism identified, the Rural Development Strategy Paper (RDC, 2002) noted several prospective roles for government in the promotion of aquaculture, such as:

- extension of appropriate techniques for aquaculture
- training of extension agents and farmers
- development of a functional technical and economic framework
- advising banks on the viability of aquaculture and opening lines of credit for investors
- promoting private sector fingerling production
- involving women and youth in aquaculture
- organization of restocking programs

Although not part of the legal code, the newest policy document that deals with aquaculture is the Poverty Reduction Strategy Paper (RDC, 2003). This document emphasizes “the lifting of constraints to the production of fingerlings and transferring technical solutions to peasant farmers” as main areas of government engagement. Although MINEPIA extension staff are more or less committed to lifting constraints to aquaculture, there currently exists no structure formally charged with the assurance of fingerling or broodstock quality, or any quantitative criteria against which such assurance could be given.

Egypt

In Egypt, aquaculture legislation is more advanced than in the other case studies. However, compliance and enforcement remain low, with over 90 percent of farms and hatcheries operating without licenses. In addition, there are no stipulations concerning seed quality or any policies designed specifically to support sectoral growth. The GAFRD is the licensing agency for all aquaculture in Egypt. Presidential decrees define land and waterbodies under GAFRD's jurisdiction and give it the right to implement fisheries and fish farming laws. The GAFRD has the authority to lease out wetland and all lands that are within 200 meters of the sea and lakeshores. The Fisheries and Fish Farming Law outlines codes for the construction of fish farms.

Article 48 of the law forbids the construction of a fish farm except on wasteland, which is not suitable for agriculture and agriculture drainage or lake waters are the only source of water for these farms; use of irrigation water is strictly forbidden. Exempted from this rule are government hatcheries. Article 48 of the Law 124/83 stipulates that fish farm or hatchery construction requires the approval of the Ministry of Irrigation delimiting the amount of water volume allowed for use, the source, size of inflow sluice and the method of draining.

In the second chapter of the Fisheries and Fish Farming Law, Article 17 states that it is not allowed to use or introduce alien fish, eggs or larvae into Egypt for any reason except after having a written permit of the GAFRD and after consulting the National Institute of Oceanographic and Fisheries.

Ghana

In Ghana, aquaculture has been regarded as a type of fishery and hence is included in other fishery legislation, lowering its value to the aquaculture sector. On the other hand, Ghana has a pro-user attitude reflected in the following guidelines for government when dealing with fishery-related enterprises:

- contract private companies to produce seed for the industry
- improve Ghana's access to international markets within the domain of the international fish trade
- obtain optimum benefits for Ghanaians as owners of fish-related enterprises, as employers of the fishing industry, as consumers of fish products and as beneficiaries of foreign exchange earnings from fish trade
- enhance investment in a private sector-driven industry.

It is noteworthy to observe that the current Fisheries Act (2000) of Ghana conforms to FAO's CCRF.

Nigeria

As in Ghana, the Nigerian seed industry only benefits from generalized fisheries policy and a legal framework that emphasizes capture fishery and mostly deals with licensing. The umbrella national fisheries legislation is the Inland Fisheries Decree 108 of 1992 and the Marine Fisheries Decree of 1991. However, export or import of live fish (including seed) is to be carried out with the permission of the Minister of Agriculture. States also provide for the registration of premises where any commercial activity (including seed production) is carried out. The Environmental Impact Assessment (EIA) Decree of 1988 also recommended the carrying out of EIAs for activities that may impact negatively on the environment (e.g. intensive water recirculation seed production systems which generate a lot of ammonium liquid and gaseous waste discharges) on any land area up to 50 ha.

Uganda

As with their seed certification legislation, Uganda is advanced in its concern for suitable legislation regarding the importance of the sector (Fish Act 1964), the delineation of the public sector's role in aquaculture (Fisheries Sector Strategic Plan 2002) and the regulations under which producers must operate (Fishery and Aquaculture Rules 2003). These policy instruments are still evolving to take into consideration the changing face of Ugandan aquaculture, but they are generally focussed on supporting the growth of aquaculture by ensuring that best management practices are respected.

Zimbabwe

As part of the Parks and Wildlife Authority and considering the relative unimportance of aquaculture to the national economy, the only specific regulation relating to aquaculture are restrictions imposed on the dissemination of alien species, particularly the Nile tilapia, which cannot legally be grown other than in the Zambezi valley.

KEY STAKEHOLDERS

Main stakeholders for each case study country are listed in Table 6.1.5. To ameliorate the weak policy environment within which aquaculture functions and to strengthen the working relationships among the various stakeholders, a new African initiative on the part of the FAO and the WorldFish Center to develop Strategic Frameworks for Aquaculture Development was elucidated in 2003. In this document, the roles of the key groups of stakeholders in resolving the general shortage of quality fingerlings are addressed:

Government should:

- provide regular information on sources and prices of good quality seed to private farmers;
- provide guidelines in producing/ensuring good quality seed through such measures as seed certification;
- maintain broodstock of selected culture organisms corresponding to the identified production systems;
- encourage commercial farmers and hatcheries to facilitate access to quality seed for the entire sub-sector.

Direct investors (seed producers) should:

- produce and distribute quality seed;
- sell products at a fair price;
- find mechanisms to facilitate access to high quality seed throughout the sub-sector;
- as appropriate, assist outreach program in promoting good management practices favouring improved yields;
- monitor results.

Producer organizations should:

- serve as a forum for information sharing among stakeholders;
- lobby for collective bargaining and appropriate public sector intervention;
- link with research organizations.

TABLE 6.1.5

Fingerling survival, final average weight, number harvested and profitability data per m² for *Clarias gariepinus* nursing systems (over 35 days) in periurban Yaoundé, Cameroon. Price of fingerlings is dependant upon size of fingerlings: >5 g = $0.20, 2-5 g = $0.15, < 2 g = CFA $0.10 (Yong Sulem and Brummett, 2006)

System	Survival (%)	Final Average Weight (g)	Number Harvested per m²	Gross Revenue per m²	Net Profit per m²
1	48.5 ± 26.31	5.9 ± 2.23	3.6 ± 1.97	0.64 ± 0.33	0.03 ± 0.37 a
2	46.8 ± 43.35	5.5 ± 3.23	7.0 ± 6.50	1.05 ± 0.97	0.01 ± 0.97 a
3	28.4 ± 6.12	4.2 + 0.31	8.5 ± 1.84	1.45 ± 0.54	-0.25 ± 0.55 a

TABLE 6.1.6
Summary of key stakeholders in aquaculture development in six case study African countries

	Cameroon	Egypt	Ghana	Nigeria	Uganda	Zimbabwe
Lead Government Agency	Ministry of Animal Production and Fisheries	General Authority for Fish Resources Development (GAFRD)	Ministry of Fisheries	Federal Department of Fisheries, State Fisheries Divisions	Dept. of Fisheries Resources (DFR)	Parks and Wildlife Authority
Extension Services	National Agriculture Extension Program (PNVRA)	GAFRD extension and training directorates	Directorate of Fisheries	Aquaculture and Inland Fisheries Project, State Agriculture Development Programmes, Private Consultants	Aquaculture Unit (DFR), National Agricultural Advisory Services (private)	Department of Agriculture and Rural Extension
Research & Training Institutes	University of Dschang, Institute for Agriculture Development Research	Universities of Cairo, Ein Shams, Alexandria, Suez Canal, El Azhar, El Mansura, Tanta, Asuit, Zagazig, El Fayum, Aswan. Aquaculture Research Center	Water Research Institute (WRI), Kwame Nkrumah University of Science and Technology	National Institute of Freshwater Fisheries Research (NIFFR), National Institute of Oceanographic and Marine Rsch (NIOMAR), State Universities (especially Pt. Harcourt, Ibadan)	Fisheries Resources Research Institute, Kajjansi Aquaculture Research and Development Centre, Makarere University	University of Zimbabwe
Dominant Producers	None	Not specified	Crystal Lake Fish, Ltd; Pacific Farms, Ltd; Tropo Farms, Ltd.	Durante Fish Industries; Felimar Aquaculture Centre; Chi Farms	200 small commercial farmers	Lake Harvest Aquaculture, Ltd.
Other Notable Producers	3 000 small-scale investments	Not known	Afife and Libga stations (government); Aquafarms Ltd; Newco, Ltd;	Zartech; Oris Aquatics; Idomor Fish Hatchery; Gasedado Farms	11 000 smallholders	The Bream Farm, Mazvikadei Fish Farm, Clairmont Trout Farm, The Trout Farm, Inn on Ruparara
Producer Organizations	Evolving as fingerling/feed and marketing service providers	Egyptian Aquaculture Society	A number of small producer organizations	Fisheries Society of Nigeria, Association of Fish Farmers and Aquaculturists, Catfish Farmers Association, United Fisheries Association, Association of Fingerling Producers, Union of Fishermen and Seafood Dealers, Association of Ornamental Fish Exporters	20 district and five national fish farmers' associations	None
Other Stakeholders	NGOs, WorldFish Center, FAO, CIRAD	WorldFish Center	Bilateral Donors, FAO, WorldFish Center.	Nigeria Agriculture and Rural Development Bank, FAO, WorldBank, Bilateral Donors, Oil Companies	4 large-scale fish processing plants	Department of Livestock and Veterinary Services; FAO dam stocking program

FUTURE PROSPECTS AND RECOMMENDATIONS

Aquaculture has an important role to play in African economies and food security. There have been a number of reviews of African aquaculture conducted over the last 20 years and all of these have come to more or less the same conclusions: aquaculture is a viable economic and livelihood alternative at a range of levels and intensities, but African governments and international donors have failed as primary motivators in its sustainable development. The reviewers, engaged in the six case studies outlined in this document, agree that governments should relegate itself to a facilitating role and that, to remedy the critically important problem of fingerling supply and thus help aquaculture grow to the point where it can serve as an engine for rural economic growth - governments, donors and development agencies should strive to:

1. Support the development and implementation of Strategic Frameworks for Aquaculture Development to target extension efforts, clarify the expected roles for various stakeholders and establish the foundation for realistic and practicable legislation.
2. Target extension and research at the growth of a horizontally-integrated aquaculture sub-sector (emphasizing the critical role of private sector hatcheries) that can maximize economies of scale and the number of secondary economic opportunities created by aquaculture.
3. Work with NGOs and banks to make credit available to small- and medium-scale hatcheries, e.g. through loan guarantees.
4. Encourage the development of NGOs and farmers' organizations as partners in the delivery of key services such as marketing, feed and fingerling supply.
5. Engage large-scale farms to undertake adaptive research in partnership with government scientists. This will refocus research to become more relevant to immediate development problems as well as releasing pressure on weak government infrastructure and research budgets.
6. Create tax and/or credit incentives for vertically-integrated private farms to improve the global availability of fingerlings. Excess capacity engendered through use of improved technology can create surpluses that can be sold at fair prices to small-scale operators.
7. Create, through selective breeding, realistic options (to the importation of alien species/strains) for improving the quality of fish currently cultured.

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6.2 Freshwater fish seed resources and supply: Asia regional synthesis

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ABSTRACT

The freshwater sector holds a major share in Asian aquaculture production and the lack of quality fish seed and reliable supply are often documented as a bottleneck to meet the great demand for seed. This regional synthesis includes the results of 10 country case studies carried out in Asia to assess the status of fish seed resources, supply, breeding and nursing technologies adapted to meet the demand as well as measures adopted to overcome the constrains.

Issues related to available seed resources and technologies, nursery and hatchery management and interventions in genetic improvements of broodstocks are discussed. Despite the fact that seed of major cultivated species are produced in sufficient quantities in hatcheries, poor quality is perceived as a major constraint to the expansion of freshwater aquaculture. Several approaches have been adapted by countries and farmers to assure fish seed quality. These approaches range from institutional to farmer-managed decision-making tools. Although provisions are available under existing laws and regulations for registration and certification, a proper fish seed certification process does not exist in many countries in the region.

Building support services at the local level is crucial in expanding fish seed supply. Extension support ranges from decentralized government extension to total dependence on NGOs. Micro credit, which is undeveloped and difficult to access in many countries, is crucial to ensure the participation of small-holders and resource-limited farmers in fish seed supply.

The main actors involved in the fish seed marketing are hatchery and nursery operators, middlemen or seed traders and fish farmers. The break-up of production cycle is inevitable in many occasions due to land pressure and the costs involved in accommodating nursery facilities in the hatchery premises. Sales promotion, distribution mechanisms and types of distribution networks for fish seed marketing are not formally organized in many countries of the region. The regional focus has shifted to decentralized seed production, which offers opportunities for poor farmers to enter into fish seed production. In general, fish seed production is regarded as a profitable venture.

Knowledge gaps exist in the use of chemicals and chemotherapeutants, culture environment dynamics, quarantine and biosecurity measures in hatchery operations and bio-economics on the use of wild caught fish as feeds for predatory fish and developing suitable feeds. Future prospects and recommendations on hatchery and nursery management, capacity building, research and development and policy directions and regional issues to be addressed are included.

INTRODUCTION

Fish and fisheries play an important role in the economies of Asian countries, contributing to animal protein intake, household income, employment generation and foreign income earnings. As a food producing sector, aquaculture's most immediately apparent contribution to the achievement of the Millennium Development Goals (MGD) is as contributor to the eradication of poverty and hunger. Reducing hunger through increased production and availability of fish either to producers or to non-producers for purchase at local markets may, as outlined in the World Nutrition Report 2004, contribute indirectly to all of the MDG goals. Aquaculture also makes an important contribution to national Gross Domestic Product (GDP), accounting more than 1 percent of GDP in six countries studied (Table 6.2.1).

Freshwater aquaculture contributes more than 50 percent to the total aquaculture production in majority of the leading aquaculture producing countries in Asia (Table 6.2.1). A most notable feature of the aquaculture sector in South Asia is that majority of fish comes from inland waters and hence growth of the sector has been mostly due to increasing freshwater aquaculture. The top seven culture species in South Asia in 2003 were freshwater carps (bighead carp, grass carp, silver carp, common carp, rohu, catla and mrigal) which accounted for 88 percent of the total freshwater aquaculture production. Reported production of freshwater finfish alone constituted 98.8 percent of total finfish aquaculture production. In Southeast Asia, aquaculture production in terms of quantity is diversified. Freshwater aquaculture production contributes 39 percent to the total aquaculture production. Nevertheless, the growth trend is particularly strong for freshwater finfish culture, which has increased from 564 000 tonnes in 1990 to 1 834 tonnes in 2003 (FAO, 2004). In China, freshwater aquaculture is dominated by carps (bighead carp, common carp, crucian carp, grass carps) and Nile tilapia, which constitute 79 percent of total freshwater aquaculture production. The reported production of freshwater finfish alone constituted 96.6 percent of total finfish aquaculture production in China in 2003. Thus, the freshwater sector holds a major share in Asian aquaculture production.

As food fish represents the most important source of animal protein for many Asian countries, including China, the ability of aquaculture to meet demand is most critical in countries where the population is dependent on fish. Meeting the demand also depends on the availability of resources such as water, land and fish seed and inputs such as feeds, fertilizers, etc. Lack of quality fish seed supply is often documented as a bottleneck for freshwater aquaculture development in rural areas of many countries in the region. Breeding and nursing technologies of certain commercially-cultured

TABLE 6.2.1
Contribution of aquaculture in selected countries in Asia

Country	Freshwater aquaculture[1] production (million tonnes)	Percentage Contribution to national aquaculture production	Fish consumption kg/person/yr	Percentage Contribution of fish to animal protein intake	Production value as percent of GDP[2]
Bangladesh	0.756	88.2	12	63	2.688
China	17.04	59	25.6		2.618
Cambodia	0.018	97.3	38-58 67	75	0.893
India	2.06	93	6.9	NA	0.540
Indonesia	0.478	48		NA	1.662
Pakistan	0.012	100		5	
Philippines	0.155	33.7	36	NA	2.633
Sri Lanka	0.0042	42.0	17.2	NA	0.468
Thailand	0.283	36.6		NA	2.071
Vietn Nam	0.548	55.6	15-29	35	3.497

[1]Source: FAO (2005); [2]Total aquaculture production as percent of GDP Source: Sugiyama *et al.*, 2004;
NA = not available

freshwater fish species in some countries are not available for others. This synthesis includes the results of ten country case studies carried out in Asia to assess the status of fish seed resources and supply, breeding and nursing technologies adapted to meet the demand as well as measures adopted to overcome the constrains.

SEED RESOURCES AND SUPPLY

Over 75 species are used in aquaculture production in Asia (FishstatPlus, 2005). China alone uses more than 50 species in freshwater aquaculture (Annex 6.2.1). There are more than 30 freshwater fish and prawn species cultured in the lower Mekong Basin, a diverse collection of both exotic and indigenous species (Phillips, 2002). Fish seed for stocking in aquaculture systems are either collected from wild resources, produced in hatcheries or imported from other countries or from any combination of the three sources. Among the species used in seed production (Table 6.2.2) silver carp, bighead carp, grass carp, silver barb, common/mirror carp, Indian major carps, Thai pangus, Thai koi, Nile tilapia and the Genetically Improved Farmed Tilapia or GIFT are predominant. Some fish are bred for conservation purposes, e.g. *Mahseer* and black carp in Bangladesh. Red tilapia is being used for seed production under very limited scale. Polyculture is the normal practice with stocking regimes and densities varying with feed availability, water quality and market price.

Before the technique of hypophysation of Chinese carps and Indian major carps were developed in 1960s, aquaculture was mainly a wild seed dependent activity. Until the late 1970s, riverine seed collection was the main source of seed of carps

TABLE 6.2.2

Fish species used in seed production for freshwater aquaculture in 10 countries in Asia

Country	Aquaculture species
Bangladesh	*Catla catla, Labeo rohita, Cirrhinus cirrhosus, Cirrhinus ariza, Labeo calbasu, Labeo bata, Labeo gonious, Puntius sarana, Hypophthalmicthys molitrix, Cyprinus carpio, Ctenopharyngodon idella, Aristichthys nobilis, Barbonymus gonionotus, Pangasius sutchi, Oreochromis niloticus, Anabas testudineus, Labeo bata, Labeo gonia, Clarias batrachus, Heteropneustes fossilis, Ompok pabda, Mystus cavasius, Mylopharyngodon piceus, Tor putitora, O mossambicus x O. niloticus*
Cambodia	*Barbonymus gonionotus, Hypophthalmichthys molitrix, Cyprinus carpio, Oreochromis niloticus, Cirrhinus cirrhosus, Pangasianodon hypophthalmus, Leptobarbus hoevenii, Barbonymus altus, Clarias macrocephalus, Trichogaster pectoralis, Aristichthys nobilis, Labeo rohita, Channa micropeltes and C. striata, Pangasius conchophilus, P. larnaudiei, P. bocourti, Hemibagrus wyckioides*
China	*Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristychthys nobilis, Cyprinus carpio, Oreochromis niloticus, Mylopharyngodon piceus, Barbodes goniotus, Cirrhinus molitorella, Labeo rohita, Catla catla, Cirrhinus mirigala, Clarias* sp., *Channa* sp.
India	*Cyprinus carpio, Ctenopharyngodon idellus, Hypophthalmichthys molitrix,, Aristychthys nobilis, Labeo rohita, Catla catla, Cirrhinus mrigala*
Indonesia	*Cyprinus carpio, Oreochromis niloticus, Osphronemus gouramy, Clarias batrachus, Clarias garipienus, Pangasius suchi, Pangasius jambal, Puntius gonionotus, Osteochillus hasselti, Collosoma* sp., *Macrones* sp., *Leptobarbus hoeveni, Rana catesbiana, Cherax* sp., *Oxyeleotris marmoratus, Notopterus chitala, Channa* sp., *Anabas testudeneus, Trionyx* sp.
Pakistan	*Salmo gairdneri, Salmo gairneri, Cirrhina mrigala, Labeo rohita, Catla catla, Tor putitora, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio, Aristichthys nobilis*
Philippines	*Oreochromis niloticus*
Sri Lanka	*Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristychthys nobilis, Labeo rohita, Catla catla, Cirrhinus mirigala, Chanos chanos*
Thailand	*Clarias macrocephalus x C. gariepinus¸ Oreochromis niloticus, Barbodes gonionotus, Trichogaster pectoralis, Macrobrachium rosenbergii, Pangasianodon hypophthalmus, Channa striata, Cyprinus carpio, Trionyx sinensis*
Viet Nam	*Cyprinus carpio, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Hypophthalmichthys harmandi, Aristychthys nobilis, Labeo rohita, Catla catla; Cirrhinus cirrhosus, Cirrhinus molitorella, Mylopharyngodon piceus, Spinibarbus denticulatus, Carassius auratus, Barbodes goniotus, Oreochromis niloticus, Pangasius hypopthalmus, Clarias macrocephalus x C. gariepinus¸ Notopterus notopterus, Anabas testudineus, Oxyeleotris marmoratus, Ophiocephalus micropeltes*

for aquaculture, contributing 91.67 percent and 97.5 percent to the total fish seed production during mid- 1960s in India and 1980s in Bangladesh, respectively. The vast stretches of low-lying lands bounded by embankments that are filled with run-off from extensive catchment areas during the monsoon have been traditionally used in India as ‘natural hatcheries’ to produced wild seed of carps. The sudden influx of rainwater into these systems provides a stimulus for the fish to spawn (Mondal *et al.*, 2005). This natural way of induction to spawn accounted for a major portion of fish seed during the 1960s to 1980s in India. In Bangladesh, carp spawns and fry were collected during the monsoon season from different river systems, while fertilized eggs collected were incubated in earthen pits in the river banks for hatching in Bangladesh. This method of hatching yielded low hatching and higher mortality rates.

Dependence on wild seed collections for fish aquaculture declined rapidly in many aquaculture producing countries in Asia with the success of fish seed production through artificial breeding techniques and establishment of the hatcheries in the public sector, which also acted as centers of technology transfer. For example, the dependence on wild collected carp fish seed in India and Bangladesh have been to negligible (5 percent and 0.45 percent, respectively). Nevertheless, fish seed of several species are still currently being collected from the wild (Table 6.2.3). Fish seed collected from the wild constitute a significant share in the seed supply industry in Cambodia (26 percent) and China (20 percent) illustrating the heavy dependence on wild fishery. This share constitutes fingerlings of snakehead (*Channa micropeltes* and *C. striata*), pangasiid catfishes (*Pangasianodon hypophthalmus*, *Pangasius conchophilus*, *P. larnaudiei* and *P. bocourti*), catfish (*Hemibagrus wyckioides*) and barbs (*Barbonymus gonionotus*, *B. altus*., Of the fish seed collected from wild for cage culture, carnivorous species accounts for 95 percent. Even though this trade is illegal, collections amounting to 20 million fingerlings continued in Cambodia. There is an environmental concern regarding culture of predatory fish species that require wild fish as feed to sustain culture (Phillips, 2002). This mainly concerns snakehead and pangasiid cage culture in Cambodia and Viet Nam.

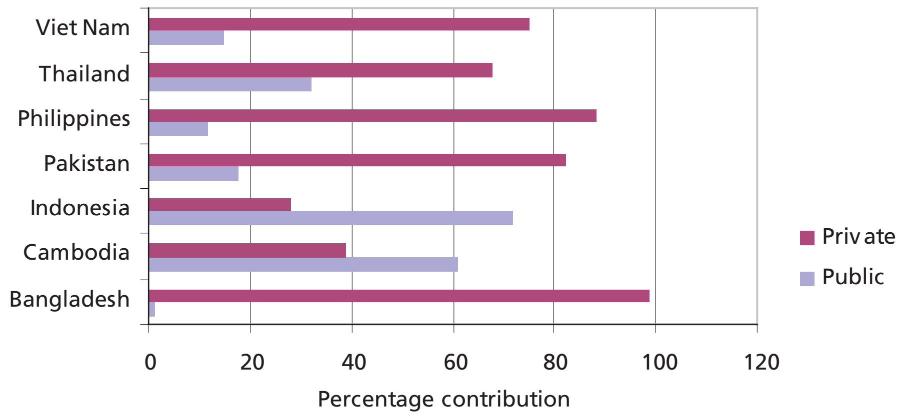
Wild fry collections of the euryhaline species *Chanos chanos* was practiced in Sri Lanka until the late 1980s for both freshwater and brackishwater aquaculture. Despite the estimated collection potential of 600 million fry/annum (Ramanathan, 1969), only 1.3 million have been collected between 1979 and 1983 (unpublished data, Thyaparan and Chakrabarty, 1984). The milkfish fry collection programme was abandoned in 1989 as a result of the withdrawal of state patronage to inland fisheries in 1990. Therefore no estimation could be made on the current status of this wild seed resource.

Fish seed are also imported due to the following: (i) inconsistent supply from local hatcheries of certain species in demand, (ii) lower price and (iii) depleting wild seed resources. During the 1980 and 1990s, Cambodia used to export billions of *P. hypophthalmus* fry and millions of *P. bocourti* fingerlings collected from the Mekong basin to neighboring countries. Now Cambodia imports fish seed of six exotic species and three indigenous species in the range of 60 million fingerling per annum,

TABLE 6.2.3
Seed of fish species collected from the wild

Country	Species	**Status**
Cambodia	Snakehead (*Channa micropeltes* and *C. striata*), pangasiid catfishes (*Pangasianodon hypophthalmus*, *Pangsius conchophilus, P. larnaudiei,* and *P. bocourti*), *Hemibagrus* catfish (*Hemibagrus wyckioides*) and barbs (*Barbonymus gonionotus Barbonymus altus*)	Currently practiced and constitutes the largest share
Indonesia	Marble goby (*Oxyeleotris marmoratus*), featherback (*Notopterus chitala*), snake head, climbing perch (*Anabas testudeneus*) and soft shell turtle (*Trionyx* sp.)	Currently practiced
Sri Lanka	Milkfish (*Chanos canos*) (for freshwater culture)	Not in practice
Viet Nam	Silver carp, mud carp, grass carp (in North Viet Nnam), Mekong catfish, silver barb, snakehead (in South Viet Nnam)	

FIGURE 6.2.1
Percentage contribution of fish seed supplied by private and public hatcheries



representing 56 percent of its fingerling requirements, from Viet Nam and Thailand. This indicates the rate at which natural populations of these species have declined.

It is believed that the imports of hybrid catfish will increase as a result of the recent ban on giant snakehead cage culture operation due to its dependence on small wild fish for dietary nutrient inputs (So Nam *et al.*, 2005). As a consequence, escapes of this hybrid catfish may bring negative side-effects in the aquatic environment. Ing Kimleang (2004) reported that many unlicensed traders imported an estimate of about 200 million fingerlings from Viet Nam (mostly) and Thailand to supply both cage and pond aquaculture farmers in Cambodia indicating that the transboundary movement of aquatic animals are largely unregulated. Implications are disease transmission and genetic pollution. The plausible reasons for importing fish seed from neighboring countries for supplying aquaculture in Cambodia are:

- local hatcheries are unable to meet the demand of fish seed for aquaculture;
- inconsistent supply;
- cheaper prices of imported fish seed than that of local hatchery produced fish seed;
- market potential of fish seed in Cambodia;
- depleted wild fishery resources.

With the advent of induced breeding technology of Indian and Chinese major carps, it became possible to obtain quality seed of the major carps for aquaculture. This resulted in an increased reliance on induced breeding for obtaining quality fish seed. At present, induced breeding accounts for most of the seed produced by many species throughout Asia. Although, artificial propagation is the main means of seed production, seed collected from the wild are mainly used for maintaining the quality of broodstocks. Broodstocks used for artificial propagation are usually raised in captivity using seed from the wild or from breeding centers where good natural stocks are maintained.

Private sector hatcheries and nurseries, particularly hatcheries and fry nurseries operated by farmers constitute a significant source of fish seed which far exceeds the public sector contribution (Figure 6.2.1).

SEED MANAGEMENT

Hatchery management

Hatchery management can be of single species or of multi-species. In multi-species hatcheries, broodstocks are kept separately by species or together as mixed species. Multi-species hatcheries often maintain Chinese and Indian major carp broodstocks. Broodstock is a prerequisite for all types of hatchery production and proper broodstock management will lead to better breeding responses and increased fecundity, fertilization, hatching and larval survival rates and more viable fish seed. Hence, the subject of broodfish management has assumed great importance in hatchery management.

The broodstock management process can be divided into two broad categories: (a) the pre-spawning process and (b) the post-spawning process. The pre-spawning process includes procedures for broodstock selection and procurement, maintenance, maturation, acclimatization, spawning and hatching. The post-spawning process includes facility maintenance, water quality management, broodstock handling; washing, selection, holding and transfer/transport of spawn, rearing of spawn, maintenance, health management, assessment of condition, selection and risk assessment for stocking, documentation and record keeping.

Since selective breeding and hybridization programmes of pedigreed fish are not carried out in fish seed farms, procurement of broodfish are done by collecting individuals from the wild, purchasing from cultured stocks in neighbouring farms or hatcheries, or developing new broodstocks through selection from previous fish populations. One of the most common problems in selecting fish from fingerling production ponds to develop broodstock is that only undersized and slow growing fingerlings are left for selection purposes since larger and fast growing fingerlings are sold. Therefore, positive mass selection procedure where the largest individuals with correct body shape, colour and free from external deformations cannot be practiced. Selection of female and male fish from two independent ponds to be raise as broodfish is advisable as it will reduce the possibility of pairing relatives that could lead to inbreeding problems. Nevertheless, this practice is largely ignored in small-scale hatcheries due to lack of pond space. The good practice of transferring spawners after spawning to a resting pond without mixing with ripe males and females is ignored too in many small-scale hatcheries for the same reason.

The domesticated broodstock may be either improved through a specific genetic improvement programme (GIFT, GET EXCEL, GST) to select for desirable traits or simply selected from stocks that show better traits (colour, growth) or are free from, or suspected to be resistant or tolerant to, specific conditions or pathogens. The development of GIFT tilapia has clearly demonstrated that rapid genetic improvement of farmed tilapia through selective breeding is possible. In Bangladesh, the Philippines, Thailand and Viet Nam, national breeding programmes and related tilapia genetic research are based mainly or exclusively on GIFT or GIFT-derived strains using approaches based on selective breeding. GIFT tilapia is now extensively used as a reference point for research on the development of tilapia farming in China and Indonesia. Methods used for GIFT tilapia have been used for genetic improvement of other species as silver barb in Bangladesh and Vietnam, rohu in Bangladesh and India, mrigal in Viet Nam and blunt snout bream (*Megalobrana amblycephala*) in China.

Several broodstock management issues are being experienced by the fish seed industry. The most reported genetic- related broodstock management issues include inbreeding, genetic drift, introgressive hybridization and unconscious selection. Ingthamjitr (1997) reported that hybrid *Clarias catfish* farmers in central Thailand, using fairly standard management practices had suffered a decline in production of good quality seed which was subsequently found out to be related to the quality of and management of the broodstock. Broodfish of fecund species for which relatively few fish are spawned may be particularly prone to mismanagement (Little, Satapornvanit and Edwards, 2002). Lack of regular introduction of fresh fish germplasm, with timed periodicities from natural sources or from distant hatcheries, was believed to be the main reason of inbreeding depression and reported to have occurred in some carp hatcheries in India (Eknath and Doyle, 1985). Oftentimes, over short timescales, it is unlikely that inbreeding is a major contributor (Mair, 2002). The common and wide belief of inbreeding as the cause of poor quality seed often overlooked the husbandry management and environmental factors that might be responsible for poor quality seed. Moreover, the current schemes to upgrade stocks with wild or improved fish (e.g. GIFT) may be unsustainable unless problems are better understood and improved management strategies developed (Little, 1998).

To avoid potential problems related to genetics, poor growth and survival due to inbreeding pressure, details of the different families/lines or origin of the domestic stocks (foreign or native) must be obtained. It is also useful to have performance and development data for the candidate families or lines under a range of environmental conditions. The selection protocol used is also important, i.e. whether the stocks were selected from ponds with better performance or survivors following a disease outbreak and the exact timing of the selection procedures. Large hatcheries as well as government hatcheries may have a system of record keeping. Most small-scale farmer- operated hatcheries, however, do not keep such important records. Small-scale hatchery operators should be made aware of the importance of record keeping and what information they should look for when purchasing broodfish from other sources. A system of certifying hatcheries for broodstocks will be advantageous for small-scale hatchery operators.

During reproduction, the nutritional requirement of broodfish are generally high. Mouth-brooding tilapia females undergo a non-feeding stage during buccal incubation which lasts for 10-13 days. Female tilapia need to be fed actively with quality feeds after this period to regain body condition lost during incubation and to obtain energy to support further reproductive activity. Most small-scale hatcheries may not meet this feed requirement due to high cost. Therefore, alternative feed sources should be made available for small-scale farmers or an appropriate formulation for farmer-made aqua-feeds.

One striking area that is lacking in broodstock management is the procedures for broodstock quarantine. Quarantine facilities are essentially a closed holding area where broodfish are kept in individual tanks until the results of screening for known diseases or disorders are known. Such facilities can be afforded by most large-scale and government hatcheries but not by small-scale or farmer-operated hatcheries. Quarantine holding facilities should ideally be kept some distance from the hatchery. In cases where this is not possible, measures should be taken to ensure that there will be no contamination from the holding facility to the other production areas.

Currently, harmonized technical standards for the hatchery production of freshwater fish seed for the region are lacking. It is important that such technical standards be developed, standardized, validated and agreed upon by thatchery producers both nationally and internationally, at least for the widely used species. However, hatchery standards should include options/levels to accommodate small-scale and farmer- operated hatcheries.

Nursery management

Success of fish seed nursing is critical as the fish seed production of a country is measured by the quality output from fry nurseries. Nursery operation can be carried out in two ways: (1) single-stage operation where hatchlings are raised until fingerling stage and (2) two-stage operation such as: (i) raising hatchlings to fry and (ii) raising fry to fingerlings. In a two-stage operation hatchlings are stocked at higher densities (e.g. 6 million carp hatchlings/ha in Bangladesh) than that in a single-stage operation (1-2 million hatchlings/ha) where fry are thinned out and stocked at lower stocking densities (0.2-0.3 million/ha) for rearing up to fingerling size. Sometimes further rearing stages are included by splitting fry rearing into early and late fry rearing.

Nursing operations tend to concentrate near centers of trading. Most nursery operators learned the nursing techniques from their neighbours. The types of species used vary within the country depending on the region. The main species used in nursery operations in the southeast region of Viet Nam are common carps and grass carp, while in the southwest region no single species dominates although silver barb and giant gourami are more common (AIT, 2000).

Nursery operators commonly purchase hatchlings from private hatcheries or use seed from produced from their own hatcheries. Experienced nursery operators purchase hatchlings from government hatcheries since they believe that hatchling quality is higher in government hatcheries (AIT, 2000).

Small-scale hatcheries and nurseries are usually located near the operators' homestead enabling close monitoring and employing family labour. This proximity to home allows greater participation of women in hatchery activities.

Nursery operations are based on stocking of a single species of hatchlings in fertilized earthen ponds at high stocking densities. Fish are raised as a batch for a few weeks or months before harvesting.

Government hatcheries which operate nurseries are expected to remain as important source of seed alongside with the growing number of private and corporate nursery operators. Government hatcheries will mostly remain as adjunct suppliers and to a certain extent, a competitor to private seed producers. The continued presence of the public sector in the seed market will benefit small farmers through the sector's promotion of hatchery and nursery management and other developments to various parts of the country. Although seed supply in most remote areas is still problematic, efforts by the public sector contributed to increased access and wider choice of seed resources for the benefit of small-scale farmers.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

During transformation from wild collection to hatchery production, hatcheries were used as a facility for hatching of fish eggs collected from the wild. Over the years, the development and refinement of the technique of induced breeding of carps has been improved. Hence more emphasis was given to the proper use of hatcheries for large-scale production of fry. Artificial fish breeding techniques and low cost hatchery designs have been successfully adapted during past three decades. Breeding techniques for Indian major carps (catla, rohu and mrigal) and Chinese carps were first developed mainly by public sector hatcheries from donor-assisted projects. These public sector hatcheries served as demonstration units. The technological progress in induced breeding of Indian and Chinese major carps was extended to a number of species such as silver carp, bighead carp, grass carp, silver barb, Indian major carps, common carp, Thai pangus and GIFT tilapia (Table 6.2.4). Other species such as *Mahseer* are being bred for conservation purposes in Bangladesh and India.

The evolution of carp hatchery systems in India was reviewed by Dwivedi and Zaidi (1983). These hatchery facilities range from simple earthen pits to pots, cement tanks to *hapas*, transparent glass and polyethylene jars to galvanized jars, tanks and Chinese-style circular tanks. Chinese-style circular spawning and incubation systems introduced from China or its modifications dominate in the region (Viet Nam, Sri Lanka, Bangladesh, Pakistan). The low-water head and large flow rates required by these systems are more suitable for areas not experiencing water limitations. However, these hatcheries work well for breeding of Chinese and Indian carps, *Spinibarbus* and silver barb. Hapas installed in a pond or water body are often used for tilapia as the spawning facility in farmer-operated seed production systems. Induced spawning and fertilization of stinging catfish (*Heteropneustes fossilis)* is also done in hapas.

Several hormone extracts as well as some synthetics are used in induced breeding technology (Table 6.2.5). The most commonly used hormones are pituitary extract/gland (PG) and luteinizing hormone-releasing hormone (LHRH). Oftentimes hatcheries spawn broodfish more than once in a season depending on species and demand for seed. It is common to spawn major carps 2-3 times in a season. Inappropriate use

TABLE 6.2.4
Freshwater fish species used in hatchery production

Species	Hatchery induced breeding	Hatchery natural breeding	Gene banking
Anabas testudineus	+		
Aristichthys nobilis	+	+	L
Barbonymus gonionotus	+	+	
Carassius carassius	+		
Catla catla	+		
Cirrhinus ariza	+		
Cirrhinus cirrhosus /*-mirigala*	+		
Clarias batrachus	+		
Clarias macrocephalus x C. gariepinus	+		
Ctenopharyngodon idella	+	+	L, C
Cyprinus carpio	+	+	C
Heteropnuestes fossilis	+		
Mystus cavacius	+		
Ompok pabda	+		
Anabas testudineus	+		
Labeo rohita	+		
Ompok pabda	+		
Oreochromis niloticus	+	+	
Hypophthalmichthys molitrix	+	+	C, L
Ictalurus punctatus	+		
Macrobrachium rosenbergii		+	
Mylopharyngodon piceus	+		
Mystus cavacius	+		
Pangasius hypopthalmus	+		C
Pangasius sutchi	+		
Puntius sarana	+		

C: Cryopreservation; L: Live gene bank

TABLE 6.2.5
Commonly used hormones in induced breeding

Species	Hormone extracts	Synthetic agents	Country
Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristychthys nobilis, Labeo rohita, Catla catla. Cirrhinus mrigala	Sufrefact, Human Chorionic Gonadotropin, Pituitary gland	Ovaprim, LHRH-Analogue, Surfrefact	Sri Lanka
Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristychthys nobilis, Labeo rohita, Catla catla, Cirrhinus cirrhosus, Labeo calbasu, Barbonymus gonionotus, Puntius sarana, Pangasius sutchi, Clarias batrachus, Heteropnuestes fossilis, Ompok pabda, Anabas testudineus,	Pituitary gland, Human chorionic gonadotropic hormone	Ovaprim, Profasi, Pregnyl, LRHA	Bangladesh
Hypophthalmichthys molitrix, Cyprinus carpio, Barbonymus gonionotus, Clarias macrocephalus x C. gariepinus, Labeo rohita, Catla catla	Pituitary gland, luteinizing hormone-releasing hormone, human chorionic gonadotropic		Viet Nam
Major carps	Pituitary gland, human chorionic gonadotropic	Ovaprim, Ovatide	India
Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristychthys nobilis, Labeo rohita, Catla catla,		Ovaparim, LHRH-Analogue	Pakistan

of hormones has been implicated to result to poor quality seed early in the season. The price of fish seed produced using only LH-RH is lower than that of using PG, reflecting the view of farmers who claim that LH-RH produced seed are of poor quality (AIT, 2000).

TABLE 6.2.6
Modes of fertilization of fish eggs

Species	Mode of fertilizsation			
	Natural	Induced natural	Induced artificial -	Artificial
Clarias batrachus			+	
Heteropneustes fossilis		+		
Ompok pabda		+		
Pangasius sutchi			+	
Oreochromis niloticus	+			+
Common carp	+		+	
Silver barb	+			
Clarias macrocephalus x C. gariepinus		+	+	
Pangasianodon gigas			+	
Clarias batrachus			+	
Heteropneustes fossilis		+	+	

Fertilization of eggs is carried in three ways: (i) natural fertilization, (ii) artificial fertilization by stripping and 'dry' fertilization or (iii) by both means (Table 6.2.6). In case of natural fertilization, induced males release sperms at the same time females release the eggs in the same tank for fertilization to take place. Fertilized eggs are collected and placed in the incubator for hatching. In the case of common carp or mirror carp breeding, sufficient quantity of aquatic grasses are placed in breeding tanks prior to spawning for use in the collection of the sticky fertilized eggs.

Artificial fertilization in fish is achieved by means of the following: (a) stripping sperms from the induced male and manually fertilizing eggs released by induced female (carps, pangas fish), (b) stripping both eggs and milt without using inducing agents (*O. niloticus*) and (c) fertilizing manually, or by stripping eggs from the induced female and milt from macerated testes of sacrificed males (catfishes). In the case of the mouth-brooding tilapia (*Oreochromis* spp.), sometimes the fertilized eggs are taken from the mouth of the mother for incubation. To enhance hatching success, the sticky eggs of certain species (e.g. common carp, mirror carp, catfish) are washed to remove stickiness or spread evenly in the incubation tray. Fresh milk or clay dissolved water are used to remove the stickiness.

Small-scale hatchery operators prefer to breed fast maturing fish with low-cost diets (e.g. common carp, silver carp, mrigal, tilapia). On-farm research on breeding of fast maturing fish requiring small broodstock such as Java barb (*Barbonymus gonionotus),* mad barb (*Leptobarbus hoevenii*), snakeskin gourami (*Trichogaster pectoralis)* and *Osteochilus melanopleura* are carried out in Cambodia. High fecundity and high fertilization, hatching and survival rates have been achieved for Java barb.

Gene banking

Interest in the development of gene banks to improve genetic quality of broodfish and thus the quality of seed is seen as important in the recent past. Large collection of crop varieties and carefully maintained livestock breeding nuclei and cryopreserved sperms and embryos, commonly called gene banks, are the basis of most of the world's plant and livestock breeding programmes and related research. By comparison, fish gene banks are rare and supported inadequately, especially in tropical developing countries (Brian *et al*., 1998). One of the most valuable fish gene banks in Asia is the Nile tilapia broodstock assembled for the development of GIFT, together with the GIFT synthetic base population and subsequent generations of selectively bred GIFT in the Philippines at the National Freshwater Fisheries Training Centre (NFFTC). The descendants of these fish remain available from this gene bank for national, regional and international breeding purposes.

Considerable progress is seen in Bangladesh with respect to gene banking. From 2002 to 2003, the Department of Fisheries of Bangladesh initiated the establishment of

12 fish broodstock banks in the Government Fish Seed Multiplication Farms with a target productions of 110 tonnes of genetically improved brood of Chinese carps, 1 800 kg spawn and 0.5 million fingerlings. The fry for the broodstock banks were collected from different rivers. To date, 85 tonnes of brood were produced and distributed to public and private hatcheries under the newly formulated fisheries policy. Another 20 brood banks have been established in 20 Fish Seed Multiplication Farms and one Fish Breeding and Training Centre under the Fourth Fisheries Project. Moreover, an NGO (BRAC) has established one carp brood bank in the hatchery and is planning to set up another. These broodbanks provide the necessary training for other government and private hatchery operators on broodstock management. Although cryogenic gene bank has not been established as yet, research is in progress in the cryopreservation of sperms of Indian major carps (*Catla catla, Labeo rohita, Cirrhinus cirrhosus*) and Chinese carps (*Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Aristichthys nobilis, Barbonymus gonionotus*).

Fish seed nursing

Fish seed nursing is either carried out in earthen shallow ponds (for carps), cemented tanks (for catfish) or hapas and net cages (for tilapia). Development of the hapa fry nursing has been recognized as a means of supporting the fingerling requirements in remote areas lacking good infrastructure. Both seasonal and perennial ponds are used as nurseries in Bangladesh to cater to the fingerling requirements in remote areas. Adherence to standard pond preparation procedures, similar to broodstock pond preparation, before stocking the ponds with post-larvae or fry is a common practice. Pond preparation is crucial as getting algae which is a prerequisite for stocking of carp spawn and fry. Prior to stocking of fingerlings, ponds are prepared by dewatering or by using toxins to remove unwanted fish. Aquatic weeds are manually removed. Liming and fertilization procedures are more or less the same as that of broodstock pond preparation.

Along with some supplemental feeding, farmers are mostly dependent on natural food produced in the ponds for fingerling rearing. To grow sufficient amount of planktonic food, urea, TSP and cow dung are applied with high doses. Preparation of compost at the corners of the ponds is common. As supplementary feed, mustard oil cake, rice bran, wheat bran and sometimes fish meal are used.

FISH SEED QUALITY

Fish seed quality assurance

Poor quality seed, perceived as a major constraint to expansion of fish culture, can have deleterious effect on fish production and broodstock development. Little, Satapornvanit and Edwards (2002) have emphasized the importance of freshwater fish seed quality in Asia and suggested criteria for selecting good quality seed for aquaculture. Some countries have adopted several approaches to ensure fish seed quality (Table 6.2.7).

China has established an institutional approach to ensure fish seed quality. As per "Aquatic Seed Management" definition of the Ministry of Agriculture, fish breeders should obtain the broodstock from one of the centres established under the National Aquatic Bred and Wild Seed System (NABWSS), which includes genetic breeding center (GBC), wild variety collection center (WVCC), wild/bred variety amplifier (WBVA), exotic species centers (ESC) and seed quality inspection centers (SQIC). A certification process has also been adopted but limited to the authorization of the release of genetically improved varieties. Under this certification process the National Certification Committee of Aquatic Wild and Bred Varieties (NCCA-WBV) has authorized the release of 32 strains, including 16 selective and 16 crossbreeding strains. Success of such public institutional approach suffers from inability to meet the demand for broodstock and more emphasis on licensing than quality assessment.

TABLE 6.2.7
Approaches in fish seed quality assurance

Approach	Measure	Country
Institutional approach	Supply of quality broodstock from government institutions	China
Fish seed certification	Certified genetically improved varieties	China
Quarantine		China
Quality criteria	Standards to measure quality based on age, size and colour	Indonesia, Thailand
	Body shape and behaviour	Sri Lanka
	Growth rate, survival, percentage deformity, behaviour	Viet Nam
	Body shape, abnormalities, body and scale damage, mortality soon after stocking	Bangladesh
Husbandry practices	Adoption of good husbandry practices	Pakistan, Sri Lanka, Banagladesh
Health management	Periodic checks on diseases and infections, prophylactic treatment	Sri Lanka, Thailand, Bangladesh, India
	Health certification	Thailand
Maintenance of genetic quality	Broodstock management, selective breeding	Thailand, Philippines, Cambodia, Bangladesh, Viet Nam
	Awareness on genetic issues among hatchery operators and farmer	Bangladesh, Philippines

Criteria and standards are available to assess seed and broodstock quality. Quality criteria are largely based on age and uniformity of size in terms of weight and length (Indonesia, Thailand), growth performance, survival and percentage of deformities (Viet Nam) and body shape and behaviour (Sri Lanka). Some farmers have experienced sudden spawn deaths and occurrence of deformed larvae/fry, more common for spawn produced during late breeding season, thus, farmers tend to avoid breeding during late spawning season. Further investigations are required to select and establish better criteria for quality assurance.

In Bangladesh and Indonesia, fish seed quality criteria have been adopted as national standards for eight species (common carp, Nile tilapia, Siamese catfish, walking catfish, gouramy, giant freshwater prawn and bullfrog). Quality of fish seed for sex reversed tilapia (SRT) and genetically male tilapia (GMT) are often assessed by the occurrence of any breeding in the production stock from unwanted females.

Fish seed quality assurance through health management is widely used as disease is considered as one of the important problematic factors in the seed industry. Parasitic diseases in nursery are one of the most important limiting factors for growth and survival of fry and fingerling. In many Asian countries, severe mortalities among carp fry have been reported and it was caused by different parasites such as *Ichthyopthirius* sp. (ich disease), *Trichodina* spp., *Ichthyobodo* spp., *Lernaea* spp., *Myxobolus* spp. and *Dactylogyrus* spp. *Myxobolus* and *Henneguya* affect the gills and have caused heavy mortalities in *Catla catla.* The most commonly adopted approach is periodic checks on the health status of fish seed and carrying out recommended treatment (Sri Lanka, Thailand, Bangladesh, India). During an outbreak of a disease in hatcheries and nurseries, farmers used different treatments such as chemicals and antibiotics, water exchange and manipulation of feeding and fertilization. Prophylactic treatment is a common practice. Health management practices are often considered as part of good husbandry (Sri Lanka, Pakistan). There are no specific/unique procedures or standards developed for maintaining hygienic condition in fish hatcheries but most hatcheries take precautionary measures before and during fry production. As a part of the precaution, disinfection of facilities and materials in use is commonly practiced.

The FAO Code of Conduct for Responsible Fisheries (CCRF) emphasizes that careful attention should be made when managing stocks to:

- avoid inbreeding;
- maintain stock integrity by not hybridizing different stocks, strains or species;
- minimize transfer of genetically different stocks;
- periodically assess their genetic diversity (i.e. by laboratory genetic analysis).

Inbreeding, inter-specific hybridization, negative selection of broods, improper broodstock management are reported as common phenomena in hatcheries, particularly in small-scale hatcheries. Hussain and Mazid (1997) reported reduced growth, physical deformities, diseases and high mortality in hatchery produced carp seed and they have identified improper management of broodstock, unconscious negative selection of broods, unplanned hybridization and inbreeding as probable reasons behind these reduced performances. Recent studies revealed high rates of inbreeding and inter-specific hybridization in both endemic and exotic carps (Simonsen *et al*., 2005, Simonsen *et al*., 2004; Alam *et al*., 2002). These factors result to low growth rate, high mortality, deformities of fish seed and less fecundity. The measures taken to ensure seed quality are selective breeding, ease of inbreeding pressure, genetic control and manipulation and gene banking. The deterioration of genetic quality in several cultured fish species in Viet Nam has been regarded as very striking since the late 1970s. Selective breeding programmes are available for freshwater fish such as common carp (Tien, 1993), Tilapia (Dan, Luan and Quy, 2001), Mekong tripped catfish (Hao, Sang and Khanh, 2004), grass carp and mrigal (Tuan *et al.*, 2005) and tilapia. Inbreeding pressure is high in carps; hatchery operators do not (i) maintain an effective population size and (ii) exchange broodfish between hatcheries. Poor performance of the resultant seed has been linked to inbreeding of carps in India (Eknath and Doyle, 1985). A communal or mixed spawning system for major carps in West Bengal is being practiced and is known to produce approximately 10 percent hybrids. This technique may lead to loss of genetic purity of important major carps.

Fish farmers often complain about poor growth of fish procured from certain hatcheries, particularly small-scale or farmer-operated hatcheries. They feel that such fish do not reach marketable size within the stipulated period. This is also attributed to inbreeding. It is believed that small-scale hatchery operations, particularly farmer-operated hatcheries, can rapidly give rise to deterioration of broodstock quality due to their limited capacity to maintain minimum effective population size of broodstock. Small-scale farmer hatcheries usually maintain multi-species broodstock in one or two ponds with excessive stocking densities. The broodstock ponds usually were either underfed or fed with low quality feed. Competition between fish species may also limit the potential of each stocked fish species in terms of maturation, fecundity, fertilization, hatching success and survival rates. It is reported that these hatcheries rarely recruit new broods from outside. If they do, the recruitment is from the subsequent generations of the same parent stock without any inflowing of new genetic material. In many hatcheries, the common practice of using the same brooders more than once in a breeding season causes deterioration of larval quality, mortality and larval deformity. Hatcheries are more concerned with quantity rather than the quality of fish seed; production does not follow any selection procedure, thus, high mortality rates, poor growth and high susceptibility to disease and other parasitic infection are common occurence. Several initiatives have been taken to preserve the genetic quality of broodstock to assure high quality seed.

Mass selection is the most ancient and simplest method to improve seed of species used in fish culture. Mass selection of common carp has been carried out in Viet Nam where 33 percent growth increase was achieved at the fifth generation (Tien, Dan and Tuan, 2001). This slow progress is due to low degree of inheritance in quantitative traits. To enhance the quality, mass selection was replaced by family selection. To improve seed quality. measures have been taken such as establishment of brood banks (Bangladesh) or gene banks (Philippines). Recently, emphasis has been placed on increasing awareness among farmers and hatchery operators concerning genetic issues in fish breeding to improve broodstock management practices.

Lack of records on breeding individuals, mass spawning of fish species and lack of knowledge or awareness on minimum effective population size have been identified as bottlenecks to improve genetic management in small-scale or farmer-operate hatcheries.

INSTITUTIONAL SUPPORT AND SEED CERTIFICATION

Policy and legislation

Fisheries and aquaculture are oftentimes both governed by fisheries policy. In recent past, there is progress in the recognizing aquaculture in government policies. For example, in Bangladesh, the Fisheries Policy adopted in 1998 included policy for freshwater aquaculture (Section 6.0 of the Fisheries Policy of 1998). The following provisions of the policy relate to the freshwater fish seed industry:

- leasing of government tanks, ponds and other similar water bodies to targeted poor or unemployed youth, both men and women, for fisheries as means of their livelihood;
- undertaking integrated aquaculture in inundated rice fields;
- providing support to the establishment of hatchery and nursery in both public and private sectors to produce the required fingerlings for stocking in open waters and for aquaculture as well as for the establishment of the fish seed industry;
- encouraging women in aquaculture;
- developing guidelines on the proper application of lime and fertilizer based on location-specific assessment of soil quality.

The new Fisheries Law (draft) of Cambodia describes aquaculture management comprehensively (DoF, 2004a as quoted by So Nam, 2005). The following inland aquaculture operations require permission from the Department of Fisheries:

- a pond or a combination of ponds with a total area larger than 5 000 m^2
- a pen or a combination of pens with a total area larger than 2 000 m^2
- a cage or a combination of cages with a total area larger than 15 m^2

However, it is not clear whether this regulation is aimed at minimizing negative impacts on the environment. In order to minimize negative environmental impact, the cumulative impact of total aquaculture establishments in an area should be taken into consideration rather than the total area of a single establishment. However, most of the small-scale fry nursing in both pond and hapas and household aquatic production systems will not come under scrutiny under the new law due to small area in extent.

In China, the amended Fisheries Law 2000 has more focus on fish seed production by including aquatic seed management. Under this law, any new aquaculture species can be propagated subject to certification by the NCCA and approved by the Ministry of Agriculture.

Indonesia has several ministerial decrees issued by the Ministry of Agriculture concerning the fish seed industry. These regulations are concerned with: (i) managing the supply and distribution of fish seed, (ii) prioritizing the production of quality domestic seed in required quantities and (iii) implementing technical standards of breeding to guarantee quality of seed produced.

Governments have also recognized aquaculture within the context of rural development and poverty alleviation policies (e.g. Viet Nam). Government policy in all Mekong riparian countries has been supportive of aquaculture and some governments have production and earning targets for future development. These pro-aquaculture policies have supported investments in research, infrastructure, education and extension that have contributed significantly to the growth of aquaculture in the past 10 years (e.g. Thailand, Viet Nam) and as a result there has probably been less attention paid to issues of inland fisheries (Phillips, 2002)

The most commonly observed aquaculture sector management approach by countries in the region is to apply a country's fisheries act or fisheries law which have significant implications concerning the establishment and operation of aquaculture practices. In addition to the above Fisheries Laws/Acts, the implications of certain protection and conservation laws should also be noted in the sector governing process. In recent years, there has been growing interest on the role of law and legal institutions in aquaculture development. Several countries have enacted specific rules relating to aquaculture under an aquaculture-specific legislative text. These include, for example the following:

Sri Lanka:

- Aquaculture Management (Health) Regulations 1999
- Aquaculture Monitoring (Residues) Regulations 2000), under a basic fisheries law (The Fisheries and Aquatic Resources Act 1996, National Aquaculture Development Authority Act 1998

China: The Fisheries Law of the People's Republic of China 1986

India: Indian Fisheries Act 1897, 1956

Thailand: Fisheries Act 2490; Animal Epidemic Act 2547/2499

Cambodia: Draft Fisheries Law) or under a protection and conservation legislation

Bangladesh: The Protection and Conservation of Fish (Amendment) Ordinance, 1982 and implemented by the Protection and Conservation of Fish Rules 1985)

In the latter cases, the existing legislation has a broad application, i.e. laws and similar regulations have been adopted to cover fisheries in general rather than aquaculture specifically. Although basic fisheries legislation does not have separate sections on aquaculture, some of its provisions are relevant to the subject. The Protection and Conservation of Fish Rules 1985 of Bangladesh, for instance, specifically deal with the protection of certain carp species, prohibit certain activities to facilitate their augmentation and production and stipulate that licenses for their catch shall only be issued for purposes of aquaculture. In Bangladesh, traditionally shrimp seed are collected from the wild and fish fry are trapped in ponds during tidal exchanges or seed may be collected from estuaries in the vicinity to stock in ponds. Recognizing that fry collection from nature may result in long-term ecological destruction, in 2000, the Bangladesh reportedly prohibited the collection of fry or post- larvae of fish, shrimp and prawns of any kind, in any form and in any way in estuary and coastal waters. It is common in fisheries acts or laws to incorporate protective and conservation measures. When implemented effectively, protection and conservation legislation can have indirect impacts on the well-being of the fish seed industry by ensuring the availability of wild resources for broodstock improvement. Examples exist in fisheries policies and acts of many countries as listed below:

- Prohibit indiscriminate fishing methods such as poisoning, dynamiting and use of nets with small mesh sizes, which may affect the recruitment.
- Establish fish sanctuary for natural propagation of fish and in this regard necessary water bodies need to be conserved by the Department of Fisheries.
- Identify and preserve breeding and nursery grounds of fish and shrimp and protect brood fish and fish fry.
- Prohibit complete drainage of water from small water bodies for fishing.
- Restore natural water bodies such as *beels, haors* and *baors* to be used for breeding and nursery grounds.
- Minimize negative effects of all development activities, for example, construction of flood control dams, irrigation, drainage, roads etc. - on safe migration of fishes to breeding and nursery grounds.

Presently, it appears that inadequacies exist in many legal instruments to enforce regulation concerning the fish seed industry in particular. An exception exists in the Assam State Government of India who have recently introduced certain policy parameters (Anon., 2004) to assist in regulating the fish seed industry. The notable parameters are:

- mandatory registration of all hatcheries with the Department of Fisheries;
- mixed spawning of carps is an illegal act;
- networking;
- growing of only pure strains of cultivable varieties of carps;
- fish seed markets;
- certification of seed by the competent authority;
- feed plants;
- leasing of non-functional hatcheries.

The principle deficiency in the legal framework with respect to aquaculture is the lack of a legal definition of aquaculture in many of the principle acts in almost all the countries in the region included in this synthesis. Including a legal definition of aquaculture in the principal governing acts will strengthen the national recognition of aquaculture as an economic sector. Even though "aquaculture" is not defined in the principal acts, the terms "fish", "aquatic animals", "aquaculture products" and "farm" have been defined in relevant regulations. It may be easier to handle aquaculture, from a legal point of view, as a fisheries-related activity or as an agricultural activity. When a legal definition for aquaculture is prepared, the collateral issues (e.g. relating to the aquaculture facility or the aquaculture product) also need to be taken into account and covered by the appropriate legislation (Van Houtte, 2001). A legal definition will facilitate the regulation fish seed industry, which is not in place in many countries.

The overall effectiveness of a legal system for the management of aquaculture depends largely on effective government administration of the aquaculture sector (Van Houtte, 2001). In attempting to identify current trends in institutional settings of different countries, it is important to note that, there are countries in the region which do not yet have a well-defined aquaculture policy. Even though there is no policy on aquaculure in these countries, recognizing aquaculture as a natural resource-based sector, it is expected that aquaculture will be an important component within future fisheries policies. This trend is already seen in the fisheries policy of Bangladesh which incorporated a policy for freshwater aquaculture to regulate, manage, control and develop freshwater fish farming in freshwater. The policy environment outside the fisheries sector has a major influence on the development of aquaculture (Phillips, 2002). For example, to alleviate poverty, conversion of rice fields to aquaculture including fry nursing ponds has been stimulated in Viet Nam and Lao PDR through changes in land use policy. However, conversion of rice fields for aquaculture for better economic returns needs careful consideration.

Potential barriers to the development of fish seed supply include the possibility of frequent adjustment of land tenure and water use issues. Fearing insecure use of land and water resources, farmers may opt to use these resources in an exploitative way. Investment in infrastructure and long-term productivity are thus hindered. For efficient use of land and water resources, a well-defined land tenure system would facilitate the transfer of land use rights and encourage farmers to enter into aquaculture. Water use rights and access to common property water resources will facilitate decentralization of fish seed supply by allowing poor farmers to enter into hapa nursing and the nursing networks which are essential to support aquaculture in rural areas lacking infrastructure.

In most countries, aquaculture administration is centralized and policies related to aquaculture were developed either by ministries in-charge of agriculture, fisheries/livestock and environment or a combination thereof. In some countries, fisheries is a devolved subject and responsibility is given at the level of state, provincial or regional level (India, the Philippines, Sri Lanka, Viet Nam). In some cases, even though the subject of fisheries is devolved, the discipline of aquaculture is not devolved (Sri Lanka). Nevertheless, delegation of authority from the central government to the provincial authorities is possible. Debates are still on-going on issues concerning form, function and sizing of units of central and local government for devolution. There are some countries where the responsibility for aquaculture is given to local governments (Cambodia, China, India, the Philippines Thailand). Nonetheless, centralized regulations to ensure equitable allocation and sustainable management of resources might be desirable, in order to establish the "level playing field" that is required within a free-trade scenario (Varadi *et al.*, 2001).

Institutional support

There are complex institutional arrangements for regulation and management of aquaculture. Apart from line agencies in fisheries, many other agencies, such as coastal conservation, environment, wildlife, urban development, agriculture, forestry and irrigation institutions, are often involved in regulation and management. Institutional arrangement for the development of aquaculture varies across the region.

Since basic technologies for small-scale fish breeding and fry nursing are in place, future support should emphasize on extension of knowledge and building of institutional support for rural households where there is potential for fish breeding and fry nursing. To involve rural poor will require a shift away from technology towards a more flexible people-centered and participatory approach in both extension and research (Phillips, 2002). Policies, institutions and processes should all support poor people's involvement in aquaculture (Haylor and Bland, 2001).

Building of support services at the local level is crucial in expanding fish seed supply. There are several organizations and institutions directly and indirectly involved in fisheries extension and aquaculture development. Bangladesh has a decentralized extension network. The Department of Fisheries under the Ministry of Fisheries and Livestock (MoFL) is the principal organization responsible for fisheries development and extension (Table 6.2.8). Besides fisheries and Upazila (sub-divisions of a district) fisheries offices, Aquaculture Extension Officers (AEO) and Extension Officers (EO) under different development projects are responsible for aquaculture extension. The district and Upazilla fisheries offices provide training on broodstock management, fry production through artificial breeding, nursery management, fish culture, integrated fish culture, prawn breeding, nursing and culture, feed management, disease control and others to government and private hatchery/farm operators, fish farmers, relevant NGO workers. The Government Fish Seed Multiplication Farms are also involved in training. Formal short aquaculture training courses for aquaculture officers, hatchery/farm operators and NGO personnel are provided by the six Fish/Shrimp Training Centres and the Fish Training Academy (FRSS, 2003-2004). Youth Training Centers under the Ministry of Sports and Youth Development provide two to three months residential training on aquaculture and other branches of agriculture to unemployed young men and women.

India has similar arrangement with more than 460 Fish Farmers Development Agenccies (FFDAs) spread over almost all states of the country. FFDA's mandate is to meet the basic needs of fish farmers with respect to technical, extension and financial support. The Government of India has been encouraging education, training, research and extension activities to enhance fish seed production in the country. Similarly, at state level, various programmes are being undertaken to boost fish seed production. In Haryana, an allocation of RS1.41 million was earmarked for the year 1999-2000 for education, training and extension to provide the needed training, refresher courses and to disseminate information on fish seed production and fish culture technology to fish farmers.

TABLE 6.2.8
Institutional arrangement with relevance to the seed industry

Country	Ministry	Institution/Agency	Mandate/Activities related to
Bangladesh	Ministry of Fisheries and Livestock: Department of Fisheries	64 District Fisheries Offices 460 Upazila Fisheries Offices 112 fish seed multiplication centres	- Aquaculture development - Fish seed and broodstock supply
		Fish Training Academy	- Training and extension of aquaculturists, hatchery & nursery operators, NGOs
		Fisheries Research Institute	- Aquaculture research and training
	Ministry of Sports and& Youth Development	Youth Training Centres	- Residential training on aquaculture for unemployed youth
	Ministry of Education	Agricultural University	- Aquaculture research, training for government and private hatchery/ nursery operators
	NGOs and& Donor organisations		- Aquaculture extension, micro-credit supply, hatchery and& farm establishment
Cambodia	Department of Fisheries Aquaculture Division	Inland Fisheries Research & Development Institute-	- Technology transfer and farmer feedback for further research
		Provincial Fisheries Division of Provincial Department of Agriculture, Forestry and& Fisheries	- Support extension
	NGOs		- Training and& extension for hatchery/ nursery operators & government personel, support establishment of provincial fish seed centres, promotion of small-scale village private hatcheries, supporting on-farm/on-station research
India	Ministry of Agriculture -	FFDAs (>450 covering most of the States in India)	- Meets the basic needs of the fish farmers in respect of technical, extension, and financial support.
China	Ministry of Agriculture	National Aquatic Bred & Wild Seed System (NABWSS) - Wild Variety Collection Centre (WVCC – 36 national level and& 100 Provincial level) - Wild Bred/Variety Amplifier (WBVA - 36 national level and& 100 Provincial level) - Exotic Species Centre (ESPC) - Seed Quality Inspection Centre	- Collection, conservation and supply of wild stock - Selective breeding of wild varieties, exotic species, approval for bred varieties - Introduction, risk evaluation, quarantine, production and extension of exotic species - Ensure the production of quality seedsseed
		National Certification Committee on Aquatic Wild and Bred Varieties (NCCA-WBA)	- Certifies the use of economic, genetically improved, exotic and& hybrid varieties for use
		Government hatcheries	- Demonstration of hatchery techniques and& seed supply for farmers
		The northern and cold water fish breeding center at Heilongjiang Fisheries Research Institute (Harbin)	- Development of breeding techniques
		Chinese Academy of Fishery Sciences, Yangtze River Fisheries Research Institute (Hubei Jingzhou),The Chinese Academy of Fishery Sciences, Yellow Sea Fisheries Research Institute (Qingdao),The Chinese Academy of Fishery Sciences, Pearl River Fisheries Research Institute (Guangzhou) and The Chinese Academy of Fishery Sciences, Heilongjiang Fisheries Research Institute (Harbin).	- Research and education

TABLE 6.2.8 (CONTINUED)
Institutional arrangement with relevance to the seed industry

Country	Ministry	Institution/Agency	Mandate/Activities related to
Indonesia		Research Institute for Freshwater Fish Species	- Technology development and transfer to hatcheries and farmers
		Technical Implementation Units (TIUs) of DGA	- Ensure application of developed technologies
		Local/District fisheries authorities	- Extension and training
Sri Lanka	Ministry of Fisheries and Aquatic Resources	Department of Fisheries and& Aquatic Resources (DFAR)	- Regulates the industry - Requires an Aquaculture Management License to operate an aquaculture practice - Aquaculture practices should abide by the Aquaculture Management (Health) Regulations of 1999.
		National Aquatic Resources Research and Development Agency (NARA)	- Research, development & technical inputs
		National Aquaculture Development Authority (NAQDA)	- The powers of Director General/ DFAR have been delegated to the Director General NAQDA in issuing of aquaculture Management License - Aquaculture extension
		CBOs	- Engage in fish fry rearing
Philippines	Department of Agriculture	Bureau of Fisheries & Aquatic Resources (BFAR) Freshwater Fish Hatchery and Extension Training Center Laguna Lake Development Authority (LLDA)	- Improvement, management and conservation of the country's fisheries and aquatic resources - Extension through its 12 regional, provincial and municipal Fisheries Offices
		San Miguel Corporation (SMC)	- Assist in farm designing and construction
		Government & private laboratories	- Testing and& monitoring

Cambodia does not have an extension arm for the development of aquaculture. It depends solely on NGOs and international organizations for aquaculture extension. It is not advisable to depend totally on either government machinery or NGOs for extension. Government extension workers in the region lack resources and recognition to fulfill the extension needs for the industry. NGOs may have different agendas. Therefore, it may be useful the government sector to develop partnerships with the private sector and appropriate NGOs for extension and training. For example, in Lao PDR, partnerships between local government, farmer groups, fry traders and nursing networks and in both Lao PDR and the Viet Nam Women's Unions were effectively used for extension (Phillips, 2002).

Micro-credit is crucial to ensure the participation of small-holders and resource-limited farmers. Credit systems in rural areas are undeveloped and difficult to access. Nevertheless, relatively well developed microfinance systems exist in Thailand and Viet Nam. The Viet Nam Bank for Agriculture and Rural Development, for example, provides loans for freshwater fish culture activities provided farmers have a 'red book' demonstrating 'ownership' of the land as collateral. Such micro-credit systems will not benefit resource poor farmers lacking collateral.

FISH SEED CERTIFICATION

A proper fish seed certification process does not exist in many countries in the region. Table 6.2.9 shows the kind of certification existing in six countries. In Bangladesh, the Ministry of Fisheries and Livestock has drafted the Law for Fish and Shrimp Hatchery 2005 known as "Matsha and Chingri Hatchery Ayen, 2005", which includes requirements for registration of hatcheries and the rules for fish and shrimp hatchery operation with elaboration on aspects of hatchery operation such as physical

TABLE 6.2.9
Modes of fish seed certification

Country	Authority	Purpose
Bangaladesh	National Committee	Preparing a policy for seed certification
India	NBFGR, at Lucknow, Uttar Pradesh	Recognized nodal agency for formulating legislation on aquatic animal health certification and quarantine
Cambodia	-	-
China	National Certification Committee on Aquatic Wild and Bred Varieties (NCCA-WBV)	Certification of genetically improved varieties
Indonesia	Director General of Aquaculture	Certifies the hatchery management & production process, food safety and traceability
Pakistan	-	-
Philippines	BFAR	Certifies and& distributes improved tilapia strains
Thailand	Department of Fisheries	Guidelines and codes developed on aquaculture farm standardization
Sri Lanka	-	-

infrastructure/facilities of hatchery, ponds, selection of brood fish for breeding, source of selected brood fish, environment etc. Similar certification process on hatchery management and operation exists in Indonesia. These initiatives will help improved the quality of fish seed produced.

The focus of certification process of NCCA-WBA in China and BFAR in the Philippines is on the genetically improved varieties. NCCA-WBA, which is operational at national and some province in China, certifies genetically improved varieties. BFAR has a certification process for tilapia seed to ensure good quality seed of tilapia will be disseminated to fishpond operators. BFAR distributes its certified seed of GET EXCEL strain and broodstock to BFAR multiplier stations in order to disseminate among private hatcheries encouraged them to breed their own fish and obtain feedback and superior breeding material. Certified Genomar Supreme Tilapia (GST) is propagated and disseminated through its eight-member Partner Hatchery Network to preclude unauthorized breeding. Nevertheless, this type of certification can not preclude propagation of strains at private hatchery operators' choice. Raising awareness among farmers to use the suitable strains and their identification will help the farmers to select the suitable strains. In practice, most Nile tilapia strains are difficult to determine at field level and are only distinguishable through DNA and other biochemical markers.

While the framed Fisheries Acts and Laws exist, it is a known fact that many countries in the region are faced with difficulties in regulating aquaculture activities. These difficulties are attributed to the numerous interests involved, the diversity of the natural resources, the variety of institutions involved, the tangled web of laws and regulations and related difficulties in enforcement as well as the forces driving global and regional markets towards environmentally and socially sustainable practices (Van Houtte, 2000). Difficulties in regulating aquaculture activities, urged a self-regulation approach in the forms of codes of conduct and good or best management practices. A few countries in the region have the interest in codes of conducts and good/best management practices, but largely on shrimp aquaculture. Alternative to fish seed certification, voluntary codes and guideline are implemented in Thailand from hatchery management and operation to out-grower and processor. The Department of Fisheries certifies Code of Conduct products from hatcheries to the processor to enhance customer/consumer confidence on quality, safety and environmental friendliness. The guidelines on Good Aquaculture Practices help the hatcheries and the farms focus on siting of farms/hatcheries, farm/hatchery management, feed, chemical input, animal health, farm/hatchery sanitation, post harvest and data collection. The Department of Fisheries has a monitoring mechanism to carryout regular monitoring for hygiene and good aquaculture practices of hatcheries/farms and targeted 30,000 hatcheries and farms to be certified for Code of Conduct and Good Aquaculture Practices by the year 2004. This monitoring is, however, emphasized on the use of feed and therapeutants.

In a situation where large quantities of fish seed are imported and distributed throughout the country needs, a fish seed certification and quarantine process to preclude transboundary movement of aquatic animal diseases is necessary. This concern is growing in Cambodia where there is no certification or quarantine process, but included in the draft new Law on Fisheries. To start with, fish seed quality certification process may be initiated for the fish seed importers to observe.

FISH SEED MARKETING

The main actors involved in the fish seed marketing are hatchery and nursery operators, middlemen or seed traders and fish farmers. The market channels for fish seed need to be relatively short and simple because of the high risk involved in selling the product due to its perishable nature. The number of actors involved in fish seed marketing and thereby the length of the market chain is often related to the type of the end product (spawn, fry or fingerling) of the hatchery and the accessibility between the hatchery and the farmer. The simplest form is a hatchery operator selling directly to grow-out farmers, either through delivery or pick-up. This type of direct marketing from the hatchery to out-grower is often seen when hatcheries produce fingerlings in their own nurseries and have established access to farmers. Some hatchery and nursery operators use agents to increase sales, especially in remote areas. Others sell directly and employ agents at the same time (e.g. Philippines), who resort to intermediaries to buy fry from other areas, which they nurse to fingerlings. Generally, agents obtain their incomes by a mark-up of price per fingerling or through pre-agreed commissions.

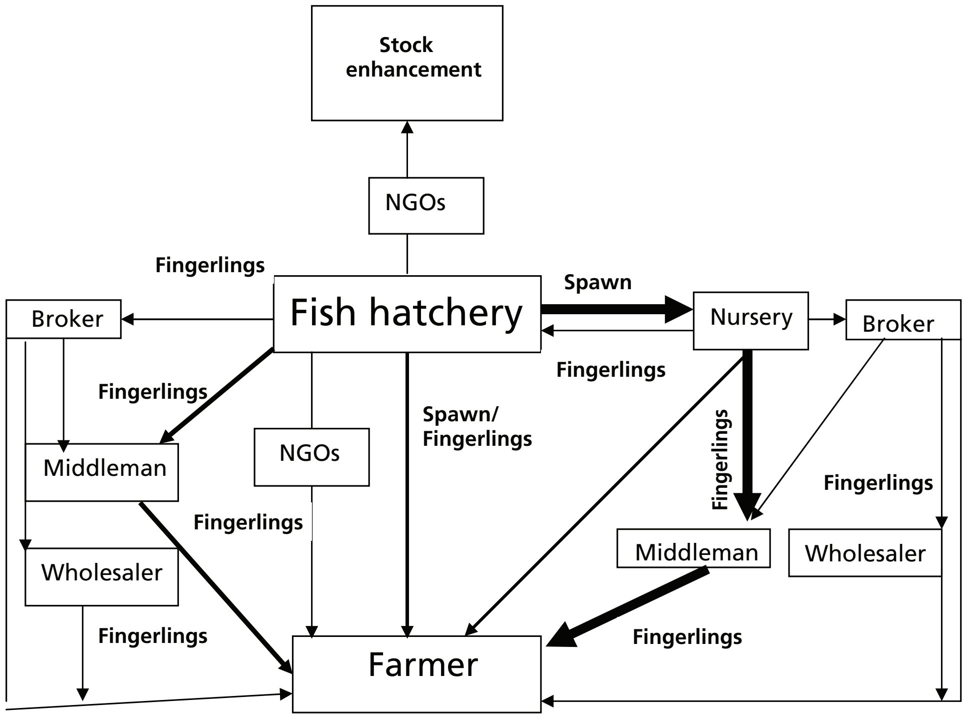
However, break-up of production cycle is inevitable in many occasions due to land pressure and the involved cost of accommodating nursery facilities in the hatchery premises. Break-up of production cycle into breeding and nursing offer opportunities for poor farmers to enter into fish seed production. As seen in Bangladesh fingerling marketing, it is generally through middlemen since very few fish farmers buy it directly from nursery farms. About 80 percent of fingerlings are supplied to the farmers through middlemen and some 20 percent of fingerlings are directly collected by the farmer from the nursery operator. In addition to this, when spawn are reared to fingerling at the hatchery cum nursery, fingerlings are also reached to farmers through the same channel. Buy-back arrangements are made between the hatchery and nursery, hatchery to provide spawn or fry on credit at given price to the nursery buy back fry or fingerlings from them at prefixed prices allowing adequate margin to the nursery operator (India). Sometimes NGOs and GOs are also seen in the market chain as buyers. NGOs buy fingerlings for the farmers who are in their development programmes, while GOs buy indigenous varieties for the purpose of stock enhancement (e.g. Cambodia).

Governments and public lending organizations are encouraged to generate income. As a result some government hatcheries focus on selling fingerlings directly to farmers creating a competitive environment between public hatcheries and private hatcheries and nurseries. A competitive environment can make producers of quality conscious of their product.

Sales promotion, distribution mechanisms and types of distribution networks for fish seed marketing are not formally organized in many countries in the region. Nevertheless, the competitive environment between public and private hatchery/ nursery operators in Cambodia has led to marketing promotions of their product. An NGO supported hatchery in Cambodia advertises its products through print and electronic media, which attracted buyers from various parts of the country.

Network arrangements to market fish seed have evolved. Such activities are noticeable in Chachra (Jessor), Poradoha (Khustia), Parbatipur railway station (in northwest of Bangladesh), BFRI corner (Mymensingh) in Bangladesh. Seed market

FIGURE 6.2.2
Actors involved in fish seed marketing



at the Parbatipur railway station, which receives fish seed from several regions in the country transported on train (Jessore, Bogra and Rajshahi), has a turnover sales of 100 to 125 million fingerlings every year (NEFP, 1993-1994). The fish seed distribution companies are active in northeast and northwest regions of China, where large small-scale farmers are concentrated, to facilitate distributions of fish seed received from the southern region of China. Such network arrangements involve fish seed collectors at local/village level who supply fish seed to regional collectors/distributers (Indonesia). The regional collectors/distributors provide funds for local collectors to make upfront payments or to provide loan payments for farmers at village level to commit them to supply. Therefore network arrangements are often induced by the distance of delivery. The exotic fish seed are distributed by companies/agents who import fish seed from abroad, and distributed through their sales network or outlets (eels in China, Cambodia).

Fish seed traders are the most critical actors in a complex network linking hatcheries and seed nurseries to fish farmers as they not only facilitate the seed supply, but also provide advice and disseminate knowledge on fish farming to farmers. Seed trading is mostly a seasonal occupation that, in most places confined to a particular fish seed rearing season. They use several modes and facilities to transport fish seed ranging from foot to motor vehicles and clay or aluminum pots to aerated containers or sealed polythene bags. While seed traders are useful in disseminating knowledge, they can also account to significant losses of seed during long journeys and reduce quality. Therefore, improvements to the modes of fish seed transportation are equally important to maintain fish seed quality. This important role of fish seed traders has urged training them on improved handling fish seed during transportation and basic fish culture to help dissemination of knowledge to the farmers (Northwest Fisheries Extension Project in Bangladesh).

The regional focus has shifted from centralized to decentralized seed production. Fast growing and more easily bred fish species such as common carp, silver barb and tilapia can be bred easily by farmers without the need for hatchery facilities, using only hapas submerged in a water body or in flooded rice fields. The small investment enables the poor farmers to adopt the technology. Local production and seed trading networks can reduce the need for long journeys to transport fish, and thereby reduce transport cost and improve seed quality. However, potential constraints exist when fish seed supply dependent on small, isolated fish broodstock populations. Unless decentralized fish seed production includes appropriate breeding strategies to maintain the genetic quality of broodstock, the performance of the production stocks will decline. Appropriate interventions to improve management practices and regular replenishment of high quality seed for broodstcok require concerted efforts through participatory approaches with farmers, government agencies and NGO stakeholders to develop institutionalize improved rural seed supply.

ECONOMICS OF SEED PRODUCTION

The major inputs of nursery operations are organic and inorganic fertilizers. Supplementary feeds may also be provided partly as a form of organic fertilization.

Market price of fish seed depends on species, strain, size, supply and demand deficit, quality, breeding season, farmer preference, source and mode of transportation (proximity to supply).

Carp fry produced from early breeding season fetch a higher price than fry produced from late season breeding. The normal practice is to purchase fry from the late season breeding at low price and then use these fry for over-wintering. The price of over-wintered fry is quite high as they grow faster than early breeding season fry (Table 6.2.10). Among Indian major carps, catla is more expensive than rohu and mrigal. Wild-caught fry are also more preferred than hatchery-produced fry. Fingerlings produced by farmers are often 20-30 percent more expensive than those from government hatcheries due to their higher quality. In Cambodia, this quality is measured in terms distance involved in the transportation of fingerlings to the farmer; short distance is preferred. In the Philippines, seed prices from government hatcheries have remained relatively stable; any price change is based on cost recovery. Genetically improved varieties such as SRT, GET, GST are naturally more expensive than mix tilapia fry/fingerlings. Nevertheless, higher price does not always mean higher demand or preference. In Viet Nam, even though improved common carp strain which has a 50 percent increased growth rate, higher survival rate and attractive appearance over the local strain, upland mountainous ethnic Thai farmers prefer the local strain (Tien, 1993). This preference is drive by other factors beneficial to poor farming households such as (1) ability to breed at the household level, (2) cheaper seed price with ready availability in close proximity, (3) better adaptability to shallow fields and terraced ricefields with flow-through water and (4) disease resistance. The local strain in upland mountain areas appears to be the better strain and this is also reflected in the 10 percent higher market price (Edwards et al., 2000). In Cambodia, the price of strictly carnivorous fish fingerlings such as hybrid catfish and snakehead is 30 percent more expensive during off-season.

In Bangladesh, traders who purchase wild collected freshwater prawn larvae earn a margin of around Tk500 to 700 per 1 000 post-larvae (Dr. Nesar Ahmed, pers. com.). The price of the hatchery bred freshwater prawn post larvae ranges from Tk1 200 to Tk2 500 per 1000 PL and early seasoned PL receives higher price than the full breeding seasoned PL.

It is hard to generalize the demand and supply status of fish seed in the region. Seed may not be currently a constraint at the national level in many countries in the region, but there may be problems of supply locally and at particular times of the year. Demand and supply status depends on species, season, country and sometimes a region within a country. Often carp spawn supply exceeds the demand and forces small hatchery operators to change species. Small hatchery operators change species from carp to indigenous catfishes, Thai pangas, Thai koi in Bangladesh to avoid economic losses, while large hatchery operators scale down their production or dispose the production early to keep the operating costs down. Selling of fry/fingerlings early will lead to low quality and poor productivity. Presently, there is a wide deficit between supply and demand of fish seed particularly in Sindh, NWFP and Balochistan provinces of Pakistan. Seasonality in demand is not observed in cases where hatchery and fry nursery operators cater to the needs of stock enhancement programmes (Sri Lanka).

Freshwater farming including hatchery and nursery operators provides opportunities for self-employment for operators and their families. Backyard/small scale operators rely mainly on family labour. Large hatcheries and nurseries employ regular full-time workers and seasonal or casual labor for the purpose of pond preparation, stocking and harvesting. There are times that there is an exchange labor from members of the community and neighbours and the owner is expected to reciprocate the initiative by helping fellow farmers when needed. These situations arise in rural areas where there is an abundant supply of labor and limited employment opportunities, wherein men, women and children participated and assisted hatchery and nursery operators.

Fish breeding and fry nursing are the sole income sources for some households. Fish fry nursing at small-scale farmer hatcheries significantly contributed to the total family income A survey conducted by Hasan and Ahmed (2002) revealed that fry nursing contributes 79.3 percent of the household income, while hatchery operation contributes 95.1 percent. Apart from aquaculture the hatchery and nursery operators earn money from other economic activities such as paddy cultivation, livestock-raising, vegetable and fruit production.

Costs and returns of freshwater fish farming vary substantially by production environments, type of technology and species cultured and across countries. Same applies for fish seed production. The tabulated data in Table 6.2.11 are clearly related to specific countries, sites and projects, and have a degree of variation which makes it difficult to derive generalized descriptions/conclusions. Nonetheless, there are fundamental relationships, e.g., as described by size, productivity and factor costs, which can be considered, and at culture system level it is possible to develop some trends and predictions on factors affecting future growth.

In general, fish seed production is regarded as a profitable venture. Average profit margins of 290 percent to 300 percent have been reported (So Nam *et al*., 2000) on fingerling production in farmer operated and government hatcheries and 800 percent profit margin for small-scale fry nursing in Cambodia. In contrast, the profit margin (95 percent) for fry nursing of carnivorous fish (*Pangasianodon hypophthalmus*) is low

TABLE 6.2.10
Prices of fish seed in Bangladesh

Species	Price of spawn per kg (TK)	Price of fingerlings per 1 000 (TK)
Rohu, Mrigal	500-2500	200-300 (average 5-8 cm size); Over-wintered 100-1 500
Catla	1000-3500	300-500
Calbaush	1000-2500	500-1000
Silver carp	500-2500	100-200
Grass carp	1000-3000	250-400
Bighead carp	2000-4000	500-1000
Silver barb	300-1000	100-500
Ghania	1000-2000	200-500
Common carp	1000-3000	300-1 000
Monosex male tilapia	0.30-0.40/individual	

US$1 = Tk69.03

due to high cost involved in feeding. However, these calculations of profit margins have not included the costs of broodstock maintenance and breeding and involved labour. An estimated US$600/year is expended on feed to maintain a stock of 50 slow maturing broodstock (i.e. *P. hypophthalmus*). This is a significant cost for a hatchery even with sufficient ponds needed to maintain such fish. Since most of the small-scale hatcheries

TABLE 6.2.11
Some indicative cost profiles of fish seed production systems

Capital costs

Aquaculture system	Culture practice	Capital cost (US$)	Notes: Country refers to case study in this publication
Hatchery of 18 million hatchling production	Carp	100 000 Indian Rs	India/Ramachandra (1996)
Hatchery of 10 million hatchling production	Carp		
Pond nursery (500m^2)	Carp (CBO managed)	707 US$/500m^2	Sri Lanka
Pond nursery (3500m^2)	Carp (CBO managed)	4950 US4/ 3500m^2	Sri Lanka
Pond nursery (500m^2)	Carp (privately owned)	752 US$/500m^2	Sri Lanka
Hapa	*Macrobrachium* fry rearing	8.25/4-5 m^3	Bangladesh

Total operating costs

Aquaculture system	Culture practice	Capital cost (US$)	Notes: Country refers to case study in this publication
Hatchery of 18 million hatchling production	Carp	103125 Indian Rs	India/Ramachandra (1996)
Hatchery of 10 million hatchling production	Carp	42100 Rs	India/Das and-Sinha, 1985
Pond nursery (0.1 ha)	Carp	2000 per crop	India/Das and Sinha, 1985
Pond nursery (0.2 ha)	Carp	7100 per crop	India/Das and Sinha, 1985
Pond nursery (500m^2)	Carp (CBO managed)	598 US$/annum	Sri Lanka
Pond nursery (3500 m^2)	Carp (CBO managed)	4184 US$/annum	Sri Lanka
Pond nursery (500m^2)	Carp (privately owned)	827 US$/annum	Sri Lanka
Hapa	Macrobrachium fry rearing	76.4/4-5 m^3/4-6 weeks	Bangladesh

Financial/economic performance

Culture system	Species	Production cost US$/kg	Net revenue US$	Profit margin	Return on operating investment	Notes
Hatchery of 18 million hatchling production	Carp	5729 Rs /1million hatchlings	50875		49.33%	India/ Ramachandra (1996)
Hatchery of 10 million hatchling production	Carp	4210/1 million hatchlings	20400		48.4%	India/Das and Sinha, 1985
Pond nursery (0.1 ha)	Carp		3400 per crop		170%	India/Das and Sinha, 1985
Pond nursery (0.2)	Carp		1900 per crop		26.8%	India/Das and Sinha, 1985
Pond nursery (500^2)	Carp (CBO managed)		558 US$/annum	48%	93%	Sri Lanka
Pond nursery (3500m^2)	Carp (CBO managed)		3906	48%	93%	Sri Lanka
Pond nursery (500m^2)	Carp (privately owned)		1311 US$/ annum	61%	158%	Sri Lanka
Hapa	Freshwater prawn fry rearing	0.05/juvenile	39.1	32%	51%	Bangaladesh

do not have sufficient pond space, broodstock maintenance of slow maturing species are meant for government hatcheries. Maintenance of medium (*Leptobarbus hoevenii, Osteochilus melanopleura*) and fast maturing (*Barbonymus gonionotus and B. altus*) broodstck may be within the reach of small-scale hatcheries as the estimated average maintenance cost is around 12 and 15 times less (US$50 and 40/year), respectively.
The difference in returns reported for 500m^2 for pond nursery rearing of carps in Sri Lanka is attributed to the management experience acquired by the private nursery operators over longer period of involvement than that of CBOs. However, the calculations of reported returns do not include certain fixed costs (loan repayment, lease/rent, etc.) and variable costs (labour and energy) costs. When these fixed and variable costs are included in the total operating costs the returns may be less attractive. The effect of labour on the returns may be significant and can minimize by determining an optimal economic size. Labour is required for fertilisation and feeding, and for guarding where ponds are distant from homesteads. Total labour requirements are likely to be in the region of 1-2 FTE per ha, which is a fairly standard figure for pond culture throughout the region. In the case of small homestead nursery ponds or hapas installed in water bodies near homesteads, a significant part of this labour input can be provided by women and children, and opportunity costs may be low, implying higher rates of return and/or lower production costs.

There are four important risk factors for nursery rearing:

- Loss of stock due to flooding
- Loss of stock due to disease;
- Loss of stock due to poaching;
- Poor growth and survival due to poor water quality, especially toward the end of the dry season/production cycle
- In adequate monitoring due to lack of onsite management tools

Nursing of post-larvae of freshwater prawns in hapas systems, even though profitable and generate healthy returns than fish fry rearing in ponds due to short cycle length (4-6 weeks), they require higher levels of investment and access to brackish water. However, the short cycle length (4-6 weeks) means that turnover is rapid, and any loan interest will be minimal.

Indicative cost structures of alternative seed production systems needs to be further analysed to determine these activities fall out into three major groups: the labour intensive systems; the feed intensive systems and the fertilizer intensive systems. The first and third of these categories are of most interest from the perspective of poverty alleviation.

Key financial performance measures return on labour and profit margin needs to be further analyzed. Profit margin measures profitability in terms of the ratio between profit and gross revenue, and is an indicator of both susceptibility to falling price, and relative production costs. Return on labour is a measure of the total net income generated per unit of labour expended and represents the maximum average wage for people engaged in the enterprise. If hapa and small pond nursing score well against these financial parameters, the economic benefits are likely to be more widely spread.

INFORMATION AND KNOWLEDGE GAPS

As technologies for small-scale aquaculture are now largely in place, information sharing mechanism on hatchery breeding and fry/fingerling production on a commercial scale will help build capacities in countries where these technologies are not well developed. Information dissemination and training in milkfish breeding is needed in countries like Sri Lanka which has interest in freshwater pond culture of milkfish. Therefore, more information emphasis should be given to disseminating existing knowledge on techniques that are relevant to rural households. Examples of good management practices also need to be shared more widely.

Chemicals in the form of pesticides, disinfectants, drugs, antibiotics, hormones and anesthetics are used in hatcheries as well as in nursery operations. They are often essential components in such routine activities as tank and pond preparation, water quality management, fish seed and broodstock transportation, feed formulation, manipulation and enhancement of reproduction, growth promotion, disease treatment and general health management. Chemicals must be used in a responsible manner as they can pose a number of potential risks to human health, other aquatic and terrestrial production systems and the natural environment (FAO, 2003). These include:

- risks to the environment, such as the potential effects of chemicals on water and sediment quality, natural aquatic communities and effects on microorganisms;
- risks to human health, such as the dangers to aquaculture workers posed by handling of feed additives, chemotherapeutants, hormones, disinfectants, pesticides and vaccines and the risk of developing strains of pathogens that are resistant to antibiotics used in human medicine;
- risks to production systems for other domesticated species, such as through the development of drug-resistant bacteria that may cause disease in livestock.

Understanding the safe and effective use of such chemicals is lacking particularly among small-scale hatchery and nursery farmers, who often lack access to expert advice and technical information. This is a considerable knowledge gap which needs to addressed.

Even though poor seed quality is often attributed to inbreeding pressure of the broodstock used, over short timescales, it would actually be very unlikely that inbreeding is a major contributor (Mair, 2002). The commonly and wide belief of inbreeding factor causing poor quality seed, often overlooked the husbandry management and environmental factors that might be responsible for poor quality of seed indicating a knowledge gap on pond environment dynamics.

Quarantine procedures and practical farm level biosecurity measures are also lacking.

Research agendas should be developed jointly with farmers so that their needs are addressed appropriately. A number of researchable topics are listed below:

- tools for decision making concerning broodstock and seed quality, breeding and culture environment and risk-reduction measures against diseases;
- indigenous broodstock management, breeding, genetics and fry nursing practices;
- use of wild caught fish as feeds for predatory fish;
- suitable farm-made feeds;
- IPM and aquaculture in rice fields.

FUTURE PROSPECTS AND RECOMMENDATIONS

Hatchery and nursery management

i) Hatchery and nursery operators of different scales should be made aware of the options and opportunities available for them for controlling diseases and maintaining the quality of broodstock and fish seed. In order to provide practical and effective technical guidance for hatchery and nursery management, it is first necessary to review the basic requirements for an effective hatchery and nursery production.

ii) Develop good hatchery and nursery management practices and documenting them with adequate scientific evidence and field data are appropriate and timely. Currently, harmonized technical standards/guidelines for the hatchery production and fry nursing are lacking. It is important that such technical standards be developed, standardized, validated and agreed upon by the hatchery operators, both nationally and internationally and by large-scale and small-scale producers.

iii) Accreditation of hatcheries at different production scales will provide opportunity for the recognition of hatcheries and thereby influence the production of high quality seed.
iv) Develop strong management tools for hatchery and nursery operators to facilitate own decision-making on broodfish and fish seed quality, breeding and culture environment.
v) Develop breeding technologies of commonly culture species dependent on wild seed to ease pressure on wild fishery and transboundary movement of large amounts of fish seed.

Capacity building

i) Farmers have a wealth of local knowledge on fish breeding and nursery rearing. This local knowledge should be studied, assessed, documented and disseminated.
ii) The capacity building themes for farmers wishing to enter into fish breeding and fry nursing should include indigenous knowledge-based spawning and fry rearing techniques. Successful mini-hatchery operators and nursery farmers who have the indigenous knowledge should be used as resources persons for such capacity building programmes.
iii) Adopt an incentive scheme for hatchery and fry nursery operators and fry/fingerling traders who have developed good management practices, e.g. using their services for extension. Encourage the spread of such services on a voluntary or paid basis. Make use of them in government training and development programmes to utilize their capacities as trainers and facilitators on an incentive payment basis. This can reduce the cost of extension.
iv) Prepare a directory of hatchery/nursery operators practicing good management practices to make their services available at village/commune level and also for development programmes. Seed producers and fry traders can be effectively used as trainers since they usually have a good appreciation of what is possible under local conditions.
v) Extension should not only be limited to strengthening knowledge and skills and changing attitudes and behaviour to become primary producers but also developing entrepreneurship skills to become successful traders.

Research and Development

i) Research institutes should build an 'institute-industry research partnership' with hatchery and nursery operators to improve quality broodstock and produce quality fingerlings.
ii) Undertake research studies to determine the cause/s of poor quality seed.
iii) Investigate echnological innovations to use ricefields for fingerling production.
iv) Research support be channeled to researchable subjects based on farmer needs.
v) Research on the use of wild-caught fish as feed as basis for support to policy decisions for efficient resource use.

Policy directions

i) The principle deficiency in the legal framework with respect to aquaculture is that there is no legal definition of aquaculture provided in the sector governing principle acts in almost all the countries in the region. Aquaculture tends to be considered as part of national fisheries legislation. When a legal definition for aquaculture is prepared, the collateral issues relating to the aquaculture facility or the aquaculture product will be taken into account and covered by the appropriate legislation. Therefore, a legal definition will facilitate the regulation of the fish seed industry, which is not in place in many countries.

ii) It appears that there is no reliable statistics and available statistics certainly underestimate the contribution made by large numbers of small-scale household fish seed producers. Reliable statistics can influence policy directions to build effective support services for small-scale aquaculture producers.

iii) Translate technical documents and reports produced by development projects into local Languages and circulate to concerned institutions and interested parties such as planners and policy makers to help in planning follow up development actions.

iv) Codes of conducts have been adopted by ASEAN on shrimp aquaculture, e.g. the Manual of ASEAN Good Shrimp Farm Management Practices was adopted at the 20th Meeting of ASEAN Ministers of Agriculture and Forestry (AMAF) held in Hanoi, Vietnam, in 1998, The ASEAN has also published two other guidelines on fisheries, namely the Manual on Practical Guidelines for the Development of High Health Penaeus monodon Broodstock and the Harmonization of Hatchery Production of Penaeus monodon in ASEAN Countries. Considering the socio-economic importance of freshwater fish seed supply in aquaculture, similar initiatives may be adopted in the freshwater fish seed production.

v) Shift in government role as a fish seed supplier competing with private sector to genetic conservation would be more beneficial in the long term viability of the fish seed industry. The government hatcheries with some back-up by large-scale private hatcheries should focus on maintain genetic stocks and broodstock of species to support overcome the constraints related to genetic quality, such as inbreeding problems and difficulties in breeding some species, faced by small-scale hatcheries due to lack of pond space and broodstock management capacity.

vi) The bulk of existing production is from omnivorous and herbivorous species, both indigenous and exotic species. There is a preference in the region for indigenous species, and this should be supported by broodstock management strategies that preserve genetic diversity.

vii) The conversion of wetlands and rice fields for fish nurseries for better returns at the expenses of livelihoods loss due to wetland degradation and wild fisheries and loss of staple food should be discouraged. Staple food such as rice, once scarce can not be valued.

viii) Encourage and involved in decentralized seed production and networking for seed supply to reach remote areas through support from local government institutions. Farmers to have access to high quality fish seed available at the appropriate time for stocking will ensure the smooth flow of products and value along the entire aquaculture value chain. It is also important that local government line agencies place greater emphasis on providing services and focus on the poor isolated farmers or those who do not have access to private hatcheries to ensure that they are not marginalized and have access to quality broodfish.

Regional issues to be addressed

i) Introductions of fish seed, including genetically improved strains and exotic species, have a role in the supply of fish seed for aquaculture. Any movement of fish seed between natural ecological boundaries/watersheds may involve risk associated with disease spread, biodiversity and management of genetic resources. Therefore, the following are recommended:

- Increase cooperation in research, development and awareness with respect to transboundary issues related to introduction of fish seed, prevention of disease spread and management of genetic resources.

- Cooperation among countries in the region for refinement and wider application protocols, risk assessment methods and monitoring programmes for introductions of fish seed, including genetically improved and exotic species. States have important responsibilities in the development and implementation of such protocols and associated regulations, the establishment of clear roles and responsibilities and capacity building. Such efforts should be linked to obligations pursuant to FAO's CCRF, the Convention of Biological Diversity and other relevant international agreements.
- Information sharing and further communication should be strengthened on fish genetic diversity, environmental integrity in support of the development of quality fish seed supply.

ii) Develop standards for hatchery management and validated farmer decision making management tools, particularly in fish seed quality assurance and management of fingerling raising pond environment.

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6.3 Aquaculture seed resources in Latin America: a regional synthesis

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ABSTRACT

Latin America comprises all Spanish and Portuguese speaking countries of the American Continent. Aquaculture is present in 32 nations. Chile alone, produces 50 percent of the total estimated 1 294 954 tonnes of aquaculture products reported for the region in 2003, followed by Brazil and Mexico with 277 000 and 74 000 tonnes, respectively. Freshwater aquaculture is chiefly represented by tilapia, carps (common and Chinese), rainbow trout and, to a lesser extent, channel catfish as well as a number of native species, these latter especially in South America.

The overall growth of the freshwater aquaculture industry of the region demands an increasing supply of reliable and traceable seed to sustain regular production. Such a factor is critical to the sector's sustainability and has been approached firstly by governments and later by the farmers themselves. Even though governments produce large amounts of seed to sustain rural aquaculture programmes, as the aquaculture sector of the region grew and turned into an export-oriented industry, private investment has been channeled into seed production, either as an exclusive activity, or as part of vertically-integrated aquaculture ventures.

The highest number of hatcheries in the region is devoted to tilapia, given the increasing demand of this fish in international markets. Although reliable statistical information is scarce, an estimated annual production of almost 600 million fingerlings are produced at least in five of the top regional aquaculture producers: Brazil, Mexico, Ecuador, Cuba and Colombia. Cyprinids are second in terms of seed production, with an estimated 380 million fingerlings produced in the same group of countries.

Some 40 native species are under experimental breeding programmes with different levels of success. In some cases, commercial production of seed is already underway, such as in the case of pacú *Piaractus mesopotamicus* in Brazil and tambaquí *Colossoma macropomum* in Colombia, or the striped mojar *Cichlasoma urophthalmus* in Mexico.

Globalization has influenced both seed prices and quality. This is true especially for tilapia and rainbow trout, both traded internationally, within and in and out the region. In contrast, within some countries such as Cuba and Mexico, seed pricing is distorted by government intervention, given that official hatcheries produce and distribute tilapia, carp and trout fingerlings at subsidized prices.

Seed quality parameters (i.e. survival, growth rate, disease resistance, size homogeneity, etc.) within countries have historically been indirectly measured by the level of satisfaction

of seed buyers and are not regulated by governments. However, with increasing international seed trade, regional hatcheries are gradually introducing quality assurance measures, both in hatchery operation procedures and in terms of genetics of their broodstock. The only type of certification that is common to all countries of the region is an official zoosanitary certificate that is mandatory before movement of organisms domestically and regionally.

Since aquaculture is a well-developed, export-oriented industry in Latin America, support services are comprehensive and accessible. All countries of the region have institutes and universities that offer degrees related to aquaculture. Furthermore, there are several research institutes dealing with fish reproduction and genetics that could be an important partner to further develop the industry. However, links between producers and researchers are weak and skilled labour is concentrated in developed areas. Rural areas where many small hatcheries are present lack these opportunities.

The lack of a national aquaculture development plan in many countries, which defines lines of action based on a proper diagnosis of the sector, makes it difficult to carry out measures aimed at adequately developing the strategic seed production sector, especially in rural areas.

INTRODUCTION

The first attempt to culture aquatic organisms in Latin America dates back as early as the 1850s. A structured, strong and growing aquaculture sector is present in the region only since the early 1980s as a result of technological breakthroughs that made possible mass production of penaeid shrimp in Ecuador and Central America and the successful introduction and culture of the Atlantic salmon (*Salmo salar*) in Chile.

Given the ideal tropical conditions of a vast area of this sub-continent, aquaculture practices have successfully spread to 32 countries of the region; the bulk of regional aquaculture production is concentrated in only few of them. Chile alone, the top producer, contributes about 50 percent of the regional total and the top three (Chile, Brazil and Mexico), together contribute 79 percent of the total regional aquaculture production (Table 6.3.1).

The estimated total aquaculture production of Latin America was 1.34 million tons for the year 2004 (FAO, 2006) representing 2.3 percent of the global aquaculture production. This figure also means an overall average growth of 24.5 percent per year during the period 1970-2000 of which highly valued marine and diadromous species (i.e. penaeid shrimp and salmon) contributed with the largest share.

TABLE 6.3.1
Aquaculture volume and value of the top ten aquaculture producing countries of Latin America in 2004 (FAO, 2006)

Country	Total national aquaculture production (Tonnes)	Percentage (%) of the total regional aquaculture production	Value of national aquaculture production (X1 000us$)	Percentage (%) of the regional total value of aquaculture production
Chile	674 979	51.1	2 814 837	53.6
Brazil	269 699	20.4	965 628	18.4
Mexico	89 037	6.7	291 329	5.5
Ecuador	63 579	4.8	292 077	5.6
Colombia	60 072	4.5	277 036	5.3
Cuba	27 562	2.1	29 434	0.6
Costa Rica	24 708	1.9	80 218	1.5
Honduras	22 520	1.7	114 942	2.2
Venezuela	22 210	1.7	65 718	1.3
Peru	22 199	1.7	130 575	2.5

Freshwater aquaculture, on the other hand, was originally adopted by many Latin American countries as an alternative to increase animal protein availability in rural areas. Cyprinids, tilapia and to a lesser extent rainbow trout and channel catfish were introduced in rural communities in the early 1970s with mixed results.

Over the past five years the demand for tilapia in the United States of America alone, grew to an average of 25 percent per year, reaching 135 000 tonnes of imports in 2005, mostly from China, Central and South America (FAO, 2006). Such a demand has stimulated investors to create an increasing number of intensive tilapia farms in the region. An example of this is the Ecuadorian tilapia industry whose overall production grew 350 percent between 2000 and 2005 (De Wind, M. National Chamber of Aquaculturists of Ecuador, 2006, pers. comm.).

Recent regional efforts to diversify freshwater aquaculture have expanded the spectrum of fish species especially in South America, particularly, where a number of native species have been successfully domesticated and are mass produced for local markets. Colombia, Ecuador, Mexico and Venezuela are also culturing some native species and experimenting with others, both for restocking and for consumption in local markets.

In addition to finfish species, diversification of aquaculture in Latin America has included the successful introduction and culture of crustaceans (e.g. Australian red claw *Cherax quadricarinatus)* and amphibians (e.g. American bullfrog *Rana catesbeiana*).

The overall growth of the freshwater aquaculture industry in the region demands an increasing supply of reliable and traceable seed to sustain regular production. Such a factor is critical to the sector's sustainability and has been approached firstly by governments and later by the farmers themselves. The aim of this paper is to provide an overview of the state of freshwater fish seed resources in a representative number of countries of Latin America, based on country national reports prepared for Brazil, Colombia, Cuba, Ecuador and Mexico.

SEED RESOURCES/SUPPLY

Freshwater aquaculture species

Freshwater aquaculture production in Latin America is based upon a relatively small number of species out of the 210 reported world aquaculture species (Tacon, 2003). Of these, only a handful, all of which were introduced species, are cultured through a well-developed technology that allows mass production for the export market.

On the other hand, the overall increase in fish consumption in the region (e.g. 30 percent in Brazil, 18 percent in Mexico during the past ten years) together with the gradual involvement of an increasing number of academic groups involved in research and development of culture technologies have resulted to more than 40 native fish species already either being bred in captivity and mass produced for local markets or still under experimentation (Table 6.3.2).

Other freshwater aquaculture species introduced and cultured in the region include crustaceans (*Macrobrachium rosembergii)* and the Australian red claw (*Cherax quadricarinatus)*. The former is cultured and sold locally in Brazil, Ecuador, Mexico and some Central American countries such as Guatemala and Panama; the latter, introduced in the early 1990s is cultured in Cuba, Mexico, Guatemala and Ecuador.

The American bullfrog *Rana catesbeiana*, has also been introduced and successfully cultured in a number of countries in the region (Argentina, Brazil, Ecuador, El Salvador, Guatemala, Mexico, Panama and Uruguay).

Most of the species in the above list have reportedly been bred in captivity, either seasonally or throughout the year. Brazil has the largest number of native species cultured. Because of its size and population, the country has the largest volume of seed produced both through government and commercial hatcheries.

TABLE 6.3.2

Summary of freshwater fish species cultured experimentally or commercially in Latin American countries

Scientific name	Common name	Culture technology level	Market	Countries where it is cultured	Origin
Oreochromis spp	Tilapia	Highly developed	Export and local consumption	Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, Venezuela, Brazil, Cuba, Dominican Republic	Exotic
Cyprinus carpio	Common carp	Well developed	Local consumption	Mexico, Ecuador, Colombia, Venezuela, Brazil, Cuba	Exotic
Ctenopharyngodon idella	Grass carp	Well developed	Local consumption	Mexico, Brazil, Cuba	Exotic
Hypophthalmichthys molitrix	Silver carp	Well developed	Local consumption	Mexico, Brazil, Cuba	Exotic
Aristhichtys nobilis	Bighead carp	Well developed	Local consumption	Mexico, Brazil, Cuba	Exotic
Onchorhynchus mykiss	Rainbow trout	Highly developed	Export and local consumption	Mexico, Colombia, Venezuela, Brazil, Ecuador, Peru, Argentina, Chile, Uruguay	Exotic
Carassius auratus	Golden carp	Well developed	Export and local consumption	Mexico, Brazil	Exotic
Clarias gariepinus	Asian catfish	In process of technological adaptation	Local consumption	Cuba, Brazil	Exotic
Ictalurus punctatus	Channel catfish	Highly developed	Local consumption	Mexico, Cuba, Brazil, Venezuela	Exotic
Micropterus salmoides	Black bass	Well developed	Local consumption	Mexico	Exotic
Prochylodus magdalenae	Bocachico	Experimental	Local consumption	Colombia	Native
Piaractus brachypomus	Cachama blanca	Poorly developed	Local consumption	Brazil, Colombia	Native
Piaractus mesopotamicus	Pacú	Well developed	Local consumption	Colombia, Brazil	Native
Colossoma macropomum	Tambaquí, cachama	Well developed	Local consumption	Brazil, Colombia, Venezuela, Cuba	Native
Aequidens rivulatus	Vieja Azu	Poorly developed	Local consumption	Ecuador	Native
Brycon henni	Sabaleta	Poorly developed	Local consumption	Colombia	Native
Brycon siebenthalae	Yamú	Poorly developed	Local consumption	Colombia	Native
Brycon moorei	Dorado	Poorly developed	Local consumption	Colombia	Native
Pimelodus grosscopfi	Capaz	Poorly developed	Local consumption	Colombia	Native
Pimelodus blochii	Nicuro	Poorly developed	Local consumption	Colombia	Native
Pseudoplatistoma fasciatum	Bagre, cachara	Poorly developed	Local consumption	Colombia, Brazil	Native
Leporinus macrocephalus	Piavucú	Poorly developed	Local consumption	Brazil	Native
Prochilodus lineatus	Curimbatá, curimba	Poorly developed	Local consumption	Brazil	Native
Brycon amazonicus	Matrinxã	Poorly developed	Local consumption	Brazil	Native
Astyanax altiparanae	Lambari	Poorly developed	Local consumption	Brazil	Native
Rhambdia spp	Jundiá	Poorly developed	Local consumption	Brazil	Native
Leporinus friderici	Piau	Poorly developed	Local consumption	Brazil	Native
Brycon orbignyanus	Piracanjuba	Poorly developed	Local consumption	Brazil	Native
Salminus maxillosus	Dourado	Poorly developed	Local consumption	Brazil	Native
Leporinus obtusidens	Piava	Poorly developed	Local consumption	Brazil	Native
Leporinus elogantus	Piapara	Poorly developed	Local consumption	Brazil	Native
Hoplias lacerdae	Trairão	Poorly developed	Local consumption	Brazil	Native
Semaprochilodus sp.	Jaraqui	Poorly developed	Local consumption	Brazil	Native
Hoplias malabaricus	Traíra	Poorly developed	Local consumption	Brazil	Native
Leporinus amblyrhynchus	Chimboré	Poorly developed	Local consumption	Brazil	Native
Cichla ocellaris	Tucunaré	Poorly developed	Local consumption	Brazil	Native
Chirostoma estor	White fish	Poorly developed	Local consumption, restocking	Mexico	Native
Atractosteus spatula	catán	Poorly developed	Local consumption, restocking	Mexico	Native
Atractosteus tropicus	Pejelagarto	Poorly developed	Local consumption, restocking	Mexico	Native
Cichlasoma urophthalmus	Striped mojar	Well developed	Local consumption, restocking	Mexico	Native

SEED AVAILABILITY

Aquaculture in Latin America originally started as an alternative of government programmes to alleviate malnutrition in rural areas, driven by the so called "blue revolution" in the early 1970s. The first breeding stations and hatcheries were created and operated by government institutions. Species and culture methods were initially imported from Asia and the Middle East. As the aquaculture sector of the region grew and turned into an export-oriented industry, private investment was channeled into seed production, either as an exclusive activity or as a part of vertically-integrated aquaculture ventures.

The great majority of farmers in the region (> 95 percent) employ hatchery-reared juveniles. Only small-scale farms devoted to the cultivation of native species rely on the collection of wild seed, such is the case of the chame (*Dormitator latifrons*) in Ecuador.

Table 6.3.3 summarizes the reported installed capacity of seed production as well as the number of hatcheries reported for the countries included in this synthesis.

It is worth noting that systematic data collection on seed availability in Latin America is only carried out partially. This can be attributable to a number of factors including: (i) difficulty to access farms and hatcheries located in remote areas, hence they are neither officially registered nor providing information, (ii) some fish farming companies report only partial seed outputs from their farms in an attempt to reduce taxes and (iii) some farms or breeding stations that reproduce several species report only the species produced in large volumes.

Cuba seems to have the most reliable information system, since all fish breeding stations are managed by the government, thus directly reporting to the fisheries ministry where statistics are concentrated, structured and disseminated.

SEED MANAGEMENT

Breeding techniques for almost all introduced species (tilapia, common and Chinese carps, channel catfish and rainbow trout) are practically the same throughout the region. Two examples of these are presented in Tables 6.3.3 and 6.3.4, which summarize the main management parameters for seed production of tilapia and rainbow trout, respectively, employed in the countries included in the present report.

Native species are increasingly being the focus of attention of both researchers and commercial farmers of Latin American countries. Figure 6.3.1 presents a flow diagram of the artificial reproduction of a Central American species and a native Amazonian species. The former corresponds to the striped mojar, a cichlid distributed from southern Mexico through Nicaragua, bred in captivity both for restocking of natural habitats and for ongrowing to market size. The latter, the tambaquí *Colossoma macropomum*, is an abundant and increasingly demanded fish farmed in South America.

TABLE 6.3.3
Seed availability (millions/yr) and number of hatcheries in the countries included in this synthesis

Species	Colombia		Cuba		Brazil		Ecuador		Mexico	
	ASP	RNH	ASP	RNH	ASP	RNH	ASP	RNH	ASP	RNH
Tilapia	111.6	32*	36.7	26*	304.5	112	0.36	10	65	45
Cyprinids	2.76	9	192.5	26*	50	80	NR	1	120.7	22
Rainbow trout	27.5	26	none	none	4.2	14	0.1	43	7.2	75
Other exotic species	NR	6	6.6	3*	NR	1	NR	6	1.71	17
Native species	7.5	14*	none	none	246	106	NR	30	0.15	6
Estimated total annual seed production	149.3		235.8		604.7		NR		194.7	
Total No. of hatcheries		65	26	26		175		90		165

ASP = Annual Seed Production (millions of eggs/yr)
RNH = Reported Number of Hatcheries.
* = Hatcheries that produce multiple species

TABLE 6.3.4
Selected broodstock management parameters employed by tilapia farmers in Latin American countries

Parameter	Country				
	Colombia	Cuba	Brazil	Ecuador	Mexico
Sex ratio of breeders (M:F)	1:3-1:5	1:2-3	1-1.5:2-3	1.5-2:3	1-1.5:2-3
Breeding ponds	earthen	earthen/concrete	earthen	earthen	earthen/concrete
In-pond hatcheries	yes	yes	yes	yes	yes
Indoor controlled hatcheries	yes	no	yes	no	yes
Hormonal sex reversal	17α methyl testosterone 60mg/kg 30 days	17α methyl testosterone 60mg/kg 30 days	17α methyl testosterone 60mg/kg 30 days	17α methyl testosterone 60-120 mg/kg 30 days	17α methyl testosterone 60 mg/kg 28-30 days
First feeding	Most farms feed 40-45 % protein particles exclusively Few others combine with natural food (fertilization)	Breeding stations fertilize first feeding ponds Additionally, 35-40 % protein particles are only partially fed	Most farms feed 40-45 % protein particles exclusively Few others combine with natural food (fertilization)	Most farms feed 40-45 % protein particles exclusively. Few others combine with natural food (fertilization)	Most farms feed 40-45 % protein particles exclusively Few others combine with natural food (fertilization)
Sex reversal pond density (No./m²)	1 000-2 000/m² in ponds Up to 12/l in indoor tanks	500-1 500/m²	2 000/m²	NR	1 200-2 300/m² in ponds Up to 16/l in indoor tanks

TABLE 6.3.5
Selected rainbow trout broodstock management parameters employed in Latin America

Parameter	Country			
	Colombia	Brazil	Ecuador	Mexico
Broodstock maintenance	earthen or concrete ponds, at 20/m²	earthen or concrete ponds, at 10-20/m²	earthen ponds, at 5-10/m²	earthen or concrete ponds, at 10-20/m²
Manual stripping of breeders	yes	yes	yes	yes
Wet/dry fertilization method	dry	dry	dry	dry
Incubation	indoor troughs, flow-through	indoor troughs, flow-through	NR	indoor troughs, flow-through
First exogenous feeding of fry	42-48 % protein powder	42-48 % protein powder	42-48 % protein powder	42-48 % protein powder

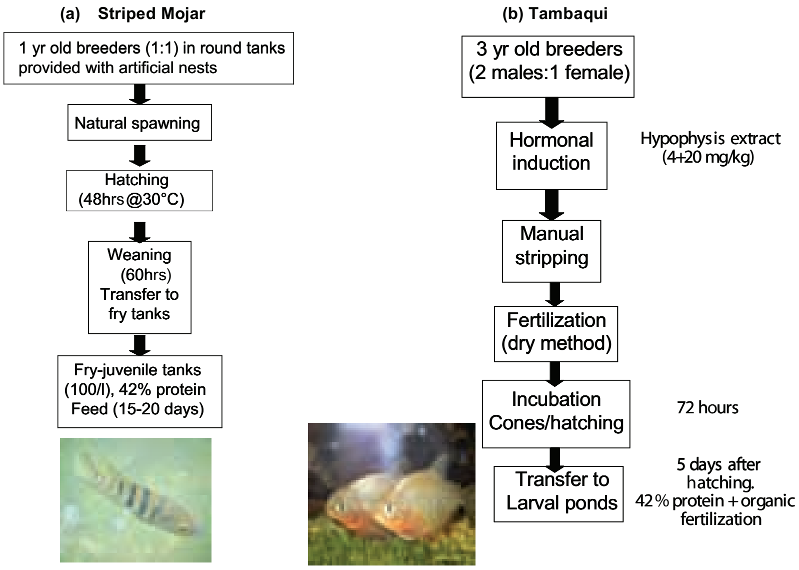
SEED QUALITY

In general terms, somehow the scale of the farm or hatchery keeps a positive relationship with the degree of technical skills and the level of record keeping by farmers. This includes breeding and larval performance. Small-scale hatcheries (< 200 000 fry/month) normally pay little attention to genetic improvement of their broodstock, while larger farmers (> 1 million fry/month) are more aware of the potential for genetic improvement, hence, they carry out a permanent on-farm selection of high performance breeders, or else, have a regular introduction of certified, good quality seed or breeders.

As far as government hatcheries are concerned, the quality of their broodstock has deteriorated in many instances, especially in the case of cyprinids and to a lesser extent, tilapia. This problem has been overcome by medium- to large-scale farmers, by avoiding seed from government sources either by buying from private hatcheries or importing seed. This is the case for tilapia farmers. On the other hand, small-scale farmers had to be subsidized and often donated fingerlings to stock their ponds with consequent lower performance.

FIGURE 6.3.1

Flow diagram of the reproduction protocol employed for (a) the striped mojar *Cichlasoma uropthalmus* (left photograph) and (b) the tambaqui *Colossoma macropomum*



There are a number of university and research centres that carry out fish genetics and genomics studies in the region. These can be found in Brazil and Mexico. Nonetheless, little communication between fish farmers and researchers makes research isolated from industry needs.

Seed quality levels in terms of survival and growth rates, as well as size homogeneity, is set by the market, i.e. individual buyers demand higher performance and if this is not up to their expectations, they change their supplier. Although quality parameters are not officially standardized, farmer associations of some countries like Brazil set their own standards and take advantage of economies of scale when they buy from the same supplier, especially if the source is international.

SEED CERTIFICATION AND LEGAL FRAMEWORK

As far as a legal framework to ensure seed safety and quality through a certification process in the countries included in the present synthesis, two types of controls can be found, namely: (i) a HACCP-type programme which is gradually being adopted by larger farmers on their own initiative in an attempt to improve quality and reduce the need for inspection when they export and (ii) seed movement permits granted by the national health authority both for national movement, or for import/export of seed and/or breeders. They vary slightly from country to country (Table 6.3.6).

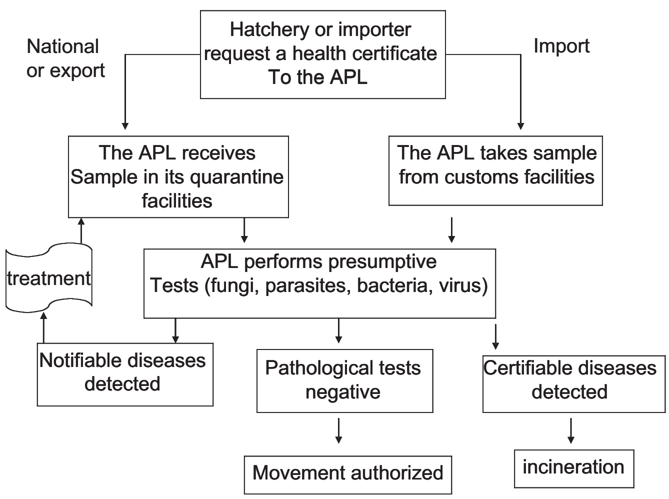
It is worth noting that the increasing demand for seed by the fast-growing Latin American aquaculture sector (17 percent average growth rate over the past five years for the top three regional producers) has created opportunity niches for importers, middlemen and new seed producers, thus increasing the number of both licensed and unlicensed hatcheries throughout the region. Such a rapid evolution has surpassed the capacity of governments to adequately regulate the sector.

Globalization has imposed the need to introduce quality control and certification processes, hence a growing number of medium- to large-sized seed producers are introducing, on their own initiative, quality improvement programmes in hatcheries. Also, governments are starting to professionalize their services, including health and inspection, which will gradually result in stricter regulation.

TABLE 6.3.6
Seed health and quality regulation for production and movement in Latin American countries

	Country				
	Colombia	**Cuba**	**Brazil**	**Ecuador**	**Mexico**
Government sanitary authority responsible for seed health/ quality	Colombian Institute of Agriculture and Animal Farming (ICA)	Ministry of Fisheries (MIP), Ministry of Health, Ministry of the Environment and Ministry of Science and Technology	Ministry of Agriculture and Animal Farming (MAPA), National Council for Environmental Affairs (CONAMA)	National Fisheries Institute (INP), National Aquaculture Research Centre (CENIAC)	National Commission of Fisheries and Aquaculture (CONAPESCA), National Service of Animal Health and Food Safety (SENASICA)
On farm/ hatchery quality/health control programme	none	Disease diagnostic and fish farm pollutants programme	none	none	none
Seed movement control/ authorization	Health certificate required by ICA	Required by MIP only for import/ export	Health certificate required by CONAMA	Health certificate and official pathology presumptive analysis. Quarantine required	Health certificate and official pathology presumptive analysis. Quarantine required
Officially established seed quality parameters	none	none	none	none	none
Government facilities for quarantine and inspection	none	There are a number of quarantine areas in state fish farming stations	none	Use of CENIAC and University facilities	Quarantine and laboratory facilities of the National Programme of Aquaculture Pathology Laboratories
Mandatory farm/hatchery official certification	none	in progress	none	none	in progress
Farmers' own quality/ health/genetic programmes	In larger, export-oriented farms	No private hatcheries	In larger, export-oriented farms	In larger, export-oriented farms	In larger, export-oriented farms

FIGURE 6.3.2
Flow diagram of the seed health inspection/certification process of Mexico (APL= Aquatic Pathology Laboratory)



Mexico's CONAPESCA has created a network of Aquaculture Pathology Laboratories distributed in strategic regions of the country. These are located either within university or research centres that are totally independent from the fisheries authority. They receive an annual grant and equipment in return for being the regional aquaculture health certification centre. The official pathological screening process carried out by these laboratories is represented in Figure 6.3.2.

Environmental risk analysis of the introduction of exotic species is currently absent from most regional legislation. This issue is only partially covered in the technical feasibility analysis required by aquaculture authorities as a condition to set up and operate a fish farm.

SEED MARKETING

Cuba is the only country of the region where aquaculture seed is not commercialized since all hatcheries and fish farming stations are owned by the government, thus, fingerlings and juveniles are either distributed at no charge throughout the country or stocked in reservoirs or dams for public access. There are also a number of fishermen and aquaculture farmers' cooperatives who also get seed from the government free of charge.

In Mexico, all of the federal and state fish farms and hatcheries mass-produce seed both for restocking of natural water bodies and for selling at a subsidized price to small-scale farmers. This has helped poor farmers to sustain small-scale operations aimed in most cases at producing fish food. On the other hand, such subsidies created a distortion of the seed market because of competition with private producers whose costs are much higher.

As the seed producing sector grows, market competition within the countries and between producing countries becomes the factor that sets the price. Table 6.3.7 summarizes the price ranges found for the most representative fish species of the region.

In the case of tilapia, the market price for sex reversed fingerlings is between 50 and 100 percent higher than that of non-reversed fingerlings.

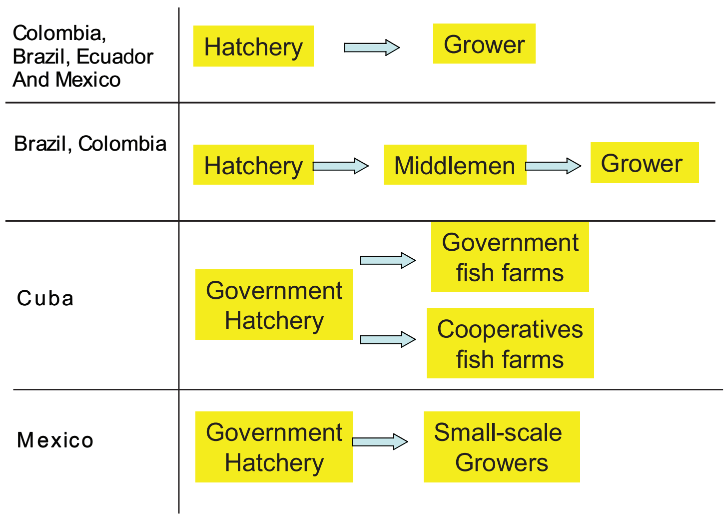
As far as distribution channels for seed are concerned, the most common is the direct selling of the hatchery to the farmer. However, as opportunity niches arise due to a growing demand, middlemen are becoming popular in many places. They buy directly from hatcheries or import seed from international sources and then sell them to small farmers. Figure 6.3.3 presents a flow diagram of the various distribution channels present in the region.

For long distance sales, once the corresponding paperwork has been completed, hatchery staff pack and transport the product to the airport. Short distance transportation can be carried out by the buyer, who collects the fry or fingerlings at the hatchery, or by the seller. Fingerlings are placed in containers with oxygen-supersaturated water and transported to the buying farms. Payment is usually done by depositing 30-50 percent of the total amount due and the balance paid upon receipt or delivery of the product. This allows for certain degree of risk evenness between buyer and seller.

TABLE 6.3.7
Price ranges of seed (fingerlings) of representative aquaculture species of Latin America (2006)

Species	Price interval (US$/individual)	Notes
Tilapia	0.03-0.07	Subsidized = 0.02 (3-5 cm)
Carp	0.02-0.03	Subsidized = 0.01 (4 cm fingerling)
Channel catfish	0.03-0.04	
Rainbow trout	0.15-0.17	Subsidized = 0.05 (5 cm fingerling)
Tambaqui	0.80-1.0	
Striped Mojar	0.06	

FIGURE 6.3.3
Seed distribution channels found in selected Latin American countries



SEED INDUSTRY: SCALE AND SUPPORT SERVICES

Overall the aquaculture sector is consolidated and well developed in the region. Two features can be identified regarding the scale of the sector. One is the fact that the current expansion of aquaculture in Latin America stimulates the opening of new farms and hatcheries, especially of tilapia. Secondly, in contrast, as the industry consolidates, market competition puts pressure on small-scale seed producers and larger companies has taken over them, thus thinning the list of seed suppliers.

Not all countries have a standard definition according to scale of production. In Mexico, three categories of producers can be identified: small farmers, whose production ranges between 10 000 and 30 000 fingerlings per month; medium-scale farmers whose production ranges between > 30 000 and 100 000 fingerlings per month and large farmers who produce more than this amount.

As far as support services are concerned, technical assistance is available through government extension services in most countries and through the academic sector. In many cases, training courses or even hydrological and biological tests are free of charge for poor farmers, while medium- and large-scale farmers have to pay for these services.

A reasonable number of academic degrees in aquaculture related subjects are offered throughout the region, hence, the availability of skilled manpower is not a limiting factor in developed areas. Nonetheless, rural areas where many small hatchery operations and farms are located lack these opportunities.

There are government programmes such as the “Product-system” recently created in Mexico whose objective is to link seed producers to fish growers and in turn are linked to processors and marketing services. The academic sector is also providing training and research to these clusters while the government provides financing not only for the system operation but also to individual projects which are part of it. It is expected that this system will increase productivity and improve quality, thus incorporating small farmers to the export chain. The network of Aquaculture Pathology Laboratories sponsored by the National Commission of Fisheries and Aquaculture also provides diagnostic and sanitary advice.

Brazilian farmers are usually organized in associations and take advantage of both economies of scale and collective political strength, thus, enabling authorities and the academic sector to get technical and even financial support.

The Ecuadorian government provides technical support through the National Institute of Fisheries, as well as the National Aquaculture Research Centre. Additionally, a number of universities have links with aquaculture producers.

CHALLENGES, OPPORTUNITIES AND RECOMMENDATIONS

There are a number of factors likely to determine the success and sustainability of the seed producing sector in the Americas at the short- to medium-term. These can be summarized in Table 6.3.8.

TABLE 6.3.8

Future challenges, opportunities and recommendations for the aquaculture seed production sector of Latin America

Challenges and opportunities	Recommendations
Environmental 1. Natural catastrophes have severely hit hatcheries and farms in the region. Highly vulnerable are Central American countries, Colombia and Ecuador. Erratic climate changes make it almost impossible to predict the level of flooding or hurricane risks. 2. Many hatcheries and vertically-integrated tilapia farms are located in areas of intensive agriculture, thus being under the risk of chronic exposure to chemical contaminants. 3. Many farms and hatcheries have been operating for a long time, hence their cumulative impact on the surrounding area might already be considerable. 4. Biosecurity measures are still not mandatory in many countries. The risk for unwanted escapes or egg dissemination by birds is high. Furthermore, some seed buyers that detect genetic malformations or below standard performance discard considerable amounts of fish in surrounding natural water bodies, thus posing a threat to wild stocks through non-specific pathogens or unwanted breeding. 5. Genetic deterioration of some strains through continuous inbreeding adds to low quality and malformation with consequent loss of competitiveness of farmers and ecological repercussions when discarded. 6. Native species represent an enormous area of opportunity, as internal demand for most of the already domesticated species is high in local markets and prices of seed are substantially higher than that of exotic species.	• Produce an atlas of vulnerability of regions suitable for aquaculture and seed production. • Gradual relocation of hatcheries with fiscal incentives and government aid. • Environmental monitoring programmes should be mandatory. • Biosecurity measures should be mandatory and a condition to release operation licenses to hatcheries. • Health certification of farms and hatcheries should be mandatory and a condition to operate. • Genetic banks and traceability should be promoted by governments and the academic sector. • Special grants should promote research of native species so that diversification of aquaculture lowers the possible ecological impacts of past dissemination of exotic species. • National aquaculture plans should include a diagnostic of the seed production sector of each country and projections should be made to ensure the provision of sufficient high quality seed to meet the projected expansion of the aquaculture sector.
Market 1. Some countries like Mexico have seed production programmes, through which seed of highly traded species such as tilapia and rainbow trout are sold at heavily subsidized prices (as much as 90 percent off the market price), or even distributed free of charge, thus distorting the market. In other cases, such as in Colombia, non-registered imports of tilapia seed sold below market prices produce the same effect. 2. Increased competition in local and regional seed markets induce price stabilization or even, in some cases, price reduction. This can be a positive factor for growers, but since the price of inputs for seed production keeps rising, the marginal profit of seed producers is reduced and so is their competitiveness.	• Limit subsidies to small-scale farmers that grow fish for food. • Implement tougher controls of imports, to prevent illegal introduction of seed, without intervening the market. • Farmer clusters should be promoted to take advantage of economies of scale, as well as collective technological improvements.
Technological 1. Limited access to farms and hatchery sites in some areas make regular supply difficult, which can result in seasonal production of seed and idle installed capacity. 2. Lack of brood management by the farmers, leading to genetic deterioration of farmed stocks. 3. Even though there is an increasing interest in native species, emphasis is still on exotic species. The number of applications for grants to carry out research on these exotic species by Latin American researchers still far outnumber those on native species. 4. The lack of a national genetic improvement programme and the lack of official genetic banks, adds to the risks of genetic deterioration and consequently reduction of seed quality.	• Include aquaculture in national development plans. Create basic infrastructure in suitable areas for aquaculture. • Stimulate through special grants research on native species. Promote native species in foreign markets. • Identify and disseminate indigenous knowledge. • Train extension service officers and hatchery operators on broodstock management. • Promotion of permanent links between universities and producers, as well as creation of a national gene bank and a national broodstock centre at least for priority species.

TABLE 6.3.8 (CONTINUED)
Future challenges, opportunities and recommendations for the aquaculture seed production sector of Latin America

Challenges and opportunities	Recommendations
Legal	
1. Even though all of the countries reviewed in this synthesis appear to have a legal framework for statistics data collection, no country, with the exception of Cuba, seems to have a reliable statistical data system. This makes systematic follow-up of the seed production sector a difficult task and as a consequence decision making is based on biased information. 2. There is an evident lack of coordination between the central (Federal government) and state or regional governments. This is in part due to the lack of a national plan for aquaculture development which is designed "from bottom to top". Synergy opportunities are lost and efforts are duplicated. 3. There is no well-structured quality assurance and sanitary programme for freshwater aquaculture farms or hatcheries in any of the countries included in the present synthesis. Such a legal gap allows for pathogenic and genetic dissemination with potentially harmful effects to the industry itself and to the environment. 4. Lack of an adequate legal framework that takes into account the current needs for regulating the sector and flexible enough to adapt to changing situations.	• It should be a priority to develop a reliable data collection system, which provides information in a timely manner for appropriate planning and decision making. • Create a national aquaculture development plan that integrates regional plans and coordinates and supports local efforts. • Legislate and/or revise the law. The new framework should include aspects to foster sustainability of the sector, in a social and environmentally responsible manner. • Health certificates for seed movement are a step forward, as long as the countries have the technical expertise to analyze and detect diseases.
Quality	
1. Lack of national quality standards for seed. No steps towards mandatory adoption of responsible hatchery practices.	• Set quality standards for seed, involving all stakeholders in the process. Develop national guidelines for responsible hatchery practices, with tax incentives for compliance and sanctions for failing to comply.

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7. Country case studies

7.1 Freshwater fish seed resources in Bangladesh

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ABSTRACT

Fisheries of Bangladesh play an important role in mitigating animal protein shortage as well as providing jobs to millions of people. The aquatic resources of the country are comprised of inland and marine waters in which inland waters are further segregated into closed and open water systems. Closed water culture system contributes about 43.52 percent to the total 78.34 percent inland fish production. Indian major carps, some exotic carps and catfishes are the main cultured species for the closed water system and production of these species completely depends on timely and adequate supply of quality seed. Until 1978, the country was completely dependent on natural sources for fish seed and spawns were collected during the monsoon season (May-August) from different rivers but in the course of time, production of fry in the rivers had been reduced and alternatively artificial breeding system through hypophysation evolved to compensate the production. So far, 878 hatcheries (112 public and 756 privately owned units) have been established and they provide almost entirely the required seed (99.55 percent) of both endemic and exotic carps of the country. Like carps, fry of freshwater prawn are produced in hatcheries and in the last 20 years, a good number of prawn hatcheries have been established both in private (Bangladesh Rural Advancement Committee and Proshika) and public sectors.

While Bangladesh is self-sufficient in meeting farmers' demands for seed, the quality of seed has deteriorated over the years mostly in private hatcheries for many reasons and among them, inbreeding, inter-specific hybridization, negative selection, improper broodstock management are most important. These factors result in low growth rate, high mortality, disease susceptibility, deformities, less fecundity of fish, etc. The high rate of inbreeding and inter-specific hybridization in both endemic and exotic carps results from the following: (i) keeping a very small number of broodstock in the hatcheries and rarely recruit new ones from outside, (ii) recruiting broodstocks from the subsequent generations of the same stock and (iii) breeding of the same brood twice, thrice in a season. To mitigate these genetic problems and to improve the quality of seed, the Department of Fisheries and the Bangladesh Fisheries Research Institute have taken some initiatives, such as establishment of brood banks, distribution of broods to government and private hatcheries from the brood banks and broodstock management trainings for hatchery and farm operators. In addition to brood bank, the Government

of Bangladesh in collaboration with donor agencies and non-governmental organizations established a number of fish sanctuaries in inflowing rivers, dead rivers, *haors* and *beels* (natural depression) to promote natural recruitment. The local fishing communities are the beneficiaries of the project but the success of the project is yet to be determined.

INTRODUCTION

Bangladesh is a South Asian country located in between latitude 20°34' and 26°39' north and longitude 80°01' and 92°41' east. It is a small country having an area of 143 000 sq. km but she accommodated about 140 million population, probably the highest density in the world within her boundary. Fisheries in Bangladesh play an important role in mitigating animal protein shortage as well as providing jobs to millions of people. Fish provides 63 percent of the total animal protein supply and the per capita annual fish intake is about 15.04 kg. The total fish production in Bangladesh is about 2.10 million tonnes in 2003-2004 with an annual growth rate of production of 5.20 percent (DOF, 2005). The fisheries sector contributes 4.92 percent to GDP, 23 percent to the agriculture sector and 5.10 percent to foreign exchange earnings through export.

Situated in the delta of the Bramaputtra, Meghna and Ganges river systems, Bangladesh is endowed with unique water resources comprised of both inland and marine waters. The inland waters are consisted of closed water bodies (ponds and ditches, oxbow lakes, shrimp farms) with an area of 513 548 ha. and open water bodies (river, estuary, beel, kaptai lake, flood plain, polder/encloser) with 4 920 316 ha. In addition to inland waters, Bangladesh has 166 000 sq km of marine water area including EEZ (200 nautical miles from the base line). According to the Fisheries Resources Information of Bangladesh (2003-2004), closed water culture system contributes about 43.52 percent to the total 78.34 percent inland fish production, while open water capture fisheries contribute 34.83 percent. The marine water contributes 21.66 percent to total production. Although Bangladesh is enriched with high biodiversity having 260 freshwater fish and 24 freshwater prawn species, not so many species are being commercially cultured. So far 12 exotic species have been introduced to Bangladesh. The main production in closed water inland fisheries comes from Indian major carps along with exotic carps, catfishes and tilapia. The following table presents the commonly cultured freshwater fish species in Bangladesh.

Both endemic and exotic carps have enormously contributed to the total aquaculture production since 1990s and from 1997 to 1998 it contributed 35 percent to the total fish production and 90 percent to aquaculture production (Hussain and Mazid, 2001).

TABLE 7.1.1
List of cultured fish species in Bangladesh

No.	Scientific name	Common name
1	*Catla catla*	catla
2	*Labeo rohita*	rui
3	*Cirrhinus cirrhosus*	mrigal
4	*Labeo calbasu*	kalbaush
5	*Hypophthalmicthys molitrix*	silver carp
6	*Cyprinus carpio*	common carp
7	*Ctenopharyngodon idella*	grass carp
8	*Aristicthys nobilis*	bighead carp
9	*Barbodes gonionotus*	silver barb
10	*Pangasius sutchi*	Thai pangas
11	*Anabas testudineus*	Thai koi
12	*Oreochromis niloticus*	Nile Tilapia
13	*Labeo bata*	Ilsha Bata
14	*Labeo gonia*	Kurio labeo
15	*Clarias batrachus*	Asian catfish
16	*Heteropnuestes fossilis*	Asian catfish

Indian, Chinese and common carp polycultures in small ponds produced 700 000 tonnes in 2002 which covered 80 percent of the total freshwater aquaculture production in Bangladesh (Collis, 2003). According to the statistics of the Department of Fisheries (DOF), silver carp contributed 23 percent of the total fishpond production in 2001 and has become an important food fish for the poor, together with silver barb and Nile tilapia. In recent times, culture of monosex male tilapia has got more popularity among fish farmers and it is becoming a big industry in Bangladesh. It is undoubtedly clear that in Bangladesh total fish production through aquaculture increased many folds in two decades. Such enormous increase of production has been possible due to many factors, among which production of fry of different species and the timely supply to the farmers are considered the most important. It is obvious that to uphold the existing increasing trend of aquaculture production and also to maintain its sustainability, quality seed production and its continuous supply need to be assured.

SEED RESOURCES SUPPLY

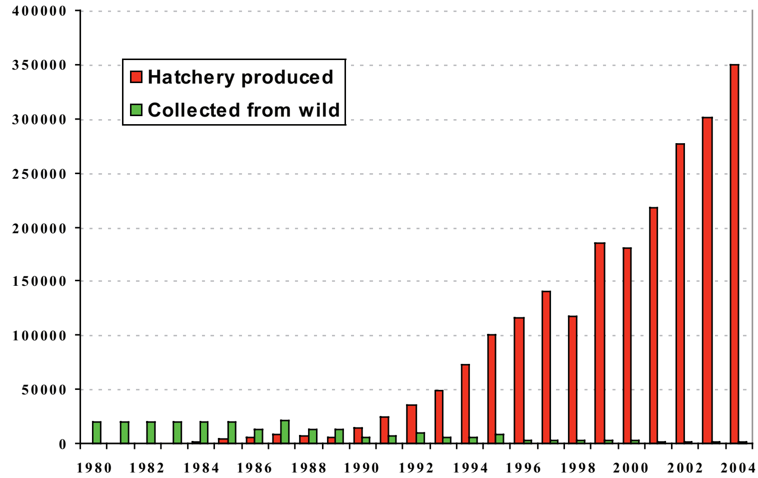
There are two major sources of seed of Indian major carps, i.e. hatcheries and natural sources such as rivers. Until the year 1978, the country was completely dependent on seed produced in rivers. Spawns are collected during the monsoon season (May-August) from different rivers of Halda, Padma, Jamuna, Brahmaputra and their tributaries. Carp fry are collected from Padma-Brahmaputra river systems while fertilized eggs are collected from the Halda River. Fishermen collect the eggs from the upstream of Halda River and incubate the eggs in earthen pits on the river bank for hatching. This unscientific hatching system is responsible for the low rate of hatching and high rate of fry mortality. With the course of time, the production of fry in the rivers has been reduced due to the destruction of many breeding grounds caused mainly by siltation. Production of fry is also hampered by the lack of broods as they are caught by extreme fishing pressure. Combining both reasons, the production of fry in rivers becomes critically low. For example, in 1984, the spawn production in the river systems in Bangladesh was estimated to be 24 551 kg and all hatcheries produced 652 kg; whereas in 2003-2004, the spawn production in hatcheries was estimated to be 345 227 kg and only 1 577 kg was reportedly collected from natural sources (FRSS, 2003-2004).

Along with the collection of spawn from rivers, induced breeding of carps through hypophysation was initiated in 1967. With the success of fish seed production through artificial breeding techniques, the Government of Bangladesh established a number of hatcheries in the public sector in different parts of the country. These hatcheries were not only used for seed production but also acted as centers of technology transfer providing training on seed production and broodstock management to a large number of entrepreneurs interested in establishing hatcheries on their own. In 1982, only three hatcheries were established in the private sector but due to easy and high returns, the number of hatcheries increased many times in the last two decades. Like indigenous carps, the fry of exotic carps are produced in the hatcheries by artificial propagation and only common carp and silver barb can reproduce in nature. Figure 7.1.1 shows the comparative fry production in hatcheries and rivers over two decades.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Aquaculture practices in Bangladesh started with seed collected from rivers, but now it is almost entirely (99.55 percent) replaced by hatchery-produced seed (FRSS/DOF, 2003-2004). Artificial fish breeding techniques and low cost hatchery designs have been successfully adapted to Bangladeshi conditions since 1975. Breeding techniques for the major carps (rohu, catla and mrigal) and Chinese carp were introduced by the DOF through donor-assisted projects such as the Chandpur Irrigation and Fisheries Project (1977-1982) and the Oxbow Lake Project I (1981-1986). Both projects were funded by the World Bank (WB) and a large number of public sector hatcheries were constructed and operated by the projects. During project implementation, induced breeding technologies were widely adopted by the private sector; they came forward and took the leadership to set up hatcheries all over the country. For example, from three hatcheries built by the private sector in 1982, the number of hatcheries rose to 40 in 1985 and 214 in 1987 (Aminul Islam, 1989). Presently, the number of fish hatcheries has reached to 878 consisting of 112 public and 756 privately-owned units. In 2004,

FIGURE 7.1.1
Production of Indian major carp fry in hatcheries and rivers from 1980-2004



both public and private sectors jointly produced 3 500 029 kg of 4–5-day old carp fry, while the quantity of fry collected from natural sources was only 1 577 kg (DOF, 2005). Production from hatcheries is sufficient to meet up internal demands and private hatchery sector accounts for over 98 percent of all hatchling production. Government hatcheries account for less than 1.5 percent of spawn production. The production of hatchlings in private and public hatchery sectors is presented in Table 7.1.2.

Alongside with the three Indian major carps, few other major and minor carps and catfishes have been successfully bred in hatcheries. So far, 14 endemic finfish species are used in hatcheries for seed production. Among them catla, rohu, mrigal, calbasu and Asian catfishes (Deshi magur and shing) are predominant. Other species are being used for seed production either under limited scale or for conservation purpose. Table 7.1.3 lists the species of endemic carp and other finfish used for artificial seed production in Bangladesh.

TABLE 7.1.2
Production of hatchlings in government and private sector hatcheries in 2004

Government			Private		
Hatchery	**Number of hatchery**	**Quantity of hatchling produced (kg)**	**Hatchery**	**Number of hatchery**	**Quantity of hatchling produced (kg)**
1. Fish seed/farms and hatcheries of					
a) Dhaka Division	28	1 069	Dhaka Division	155	75 600
b) Chittagong Division	17	343	Chittagong Division	176	61 643
c) Khulna Division	19	250	Khulna Division	165	82 976
d) Rajshahi Division	23	1 128	Rajshahi Division	217	112 369
e) Sylhet Division	8	184	Sylhet Division	13	3 465
f) Barisal Division	11	59	Barisal Division	30	9 174
2. Central Hatchery of Baor Development Project (Jhenaidah)	1	602			
3. Raipur Fish Hatchery and Training Centre	1	504			
4. Hatchery of Fisheries Research Institute, BFRI, Mymensingh	1	261			
5 Hatchery of Riverine Station, BFRI, Chandpur	1	34			
6. Parbatipur Hatchery, Dinajpur	1	337			
7. Faridpur Training and& Extension Centre	1	31			
Total	**112**	**4 802**		**756**	**345 227**

PLATE 7.1.1
Carp hatcheries in Bangladesh

About 13 exotic fin fish species used in hatcheries for seed production (Table 7.1.4). Among them silver carp, bighead carp, grass carp, silver barb, common/mirror carp, Thai pangus, Thai koi, Nile tilapia and other improved tilapia strains are predominant. Mahseer and black carp are being bred for conservation purpose. Red tilapia is being used for seed production under very limited scale.

For artificial induced breeding of endemic and exotic carps, fish pituitary gland (PG) extract and Human Chorionic Gonadotropic (HCG) hormone are usually used as inducing agent. Besides these, some synthetic agents such as Ovaprim, Profasi, Pregnyl, Luteinizing hormone releasing hormone (LH-RH) etc., are also used. Prior to hypophysation, the injectable dosages of the pituitary extract is calculated in terms of mg of PG/kg body weight of the recipient fish. The required amount of PG is weighed and thoroughly pulverized in a tissue homogenizer with 0.7 percent physiological saline/distilled water. The homogenate is centrifuged, the supernatant separated, and

TABLE 7.1.3
List of endemic carp and other finfish species used for artificial seed production in Bangladesh

Species	Common name
Labeo rohita	rohu
Catla catla	catla
Cirrhinus cirrhosus	mrigal
Labeo calbasu	calbasu
Cirrhinus ariza	Reba carp
Labeo bata	Bata
Labeo gonious	Kurio labeo
Puntius sarana	Olive barb
Clarias batrachus	Asian catfish
Heteropnuestes fossilis	Asian catfish
Ompok pabda	Butterfly catfish
Mystus cavasius	Gangetic mystus
Anabas testudineus	Climbing perch

TABLE 7.1.4
List of exotic carp and other finfish species used for artificial seed production in Bangladesh

Species	Common name
Hypophthalmichthys molitrix	silver carp
Aristicthys nobilis	bighead carp
Ctenopharyngodon idella	grass carp
Mylopharyngodon pices	black carp
Cyprinus carpio var. *communis*	common carp
Cyprinus carpio var. *specularis*	mirror carp
Barbodes gonionotus	silver barb
Tor putitora	Putitor mahseer
Pangasius sutchi	Thai pangus
Clarias gariepinus	African catfish
Oreochromis niloticus	Nile tilapia
O. niloticus	GIFT tilapia
0. mossambicus x O. niloticus	Red tilapia
Anabas testudineus	Climbing perch (Thai koi)

withdrawn into a hypodermic syringe for injection. The HCG solution is prepared by adding the required amount of physiological saline/distilled water to it as it is imported in powder form. The PG extract/HCG injection of female fish is always administered with one or two doses; in case of two doses six hr interval is maintained between two injections (Table 7.1.5). Males are injected with a single dose of PG or HCG at the time of the first injection of the females and kept with female partners in circular spawning tanks or suitable concrete tanks provided with a continuous flow of fresh water. The dosage varies with the temperature, potency of the pituitary gland, gonadal maturity of the recipient and the prevailing climatic conditions (Jhingran and Pullin, 1988).

Fertilization of eggs can be done by two ways: i) natural fertilization and ii) artificial fertilization by stripping. In case of natural fertilization, the induced males are kept in the circular tank and take part in the spawning just after the start of ovulation of the females; females release the eggs and at the same time the males eject the milt and

PLATE 7.1.2
Freshwater fish breeding and nursery facilities in Bangladesh

TABLE 7.1.5
Optimum female and male hormone doses for the artificial propagation of different carps and catfishes

Species		Preliminary dose (for each kg)	Interval between two doses (hrs)	Final dose (for each kg)	Ovulation (hrs after final dose)
Labeo rohita	Female	PG 2 mg	6.0	PG 6 mg	4-6
	Male	-	-	PG 2 mg	
Catla catla	Female	PG 1-2 mg	6.0	PG 5-6 mg	5-6
	Male	-	-	PG 1-2 mg	
Cirrhinus cirrhosus	Female	PG 1-1.5 mg	6.0	PG 5-6 mg	4-6
	Male	-	-	PG 1-1.5 mg	
Labeo calbasu	Female	PG 1-1.5 mg	6.0	PG 4-5 mg	5-6
	Male	-	-	Pg 1.5-2 mg	
Hypophthalmicthys molitrix/Aristicthys nobilis	Female	a) PG 2 mg b)HCG 200-250 IU	6-9 9-12	a) PG 6 mg b) HCG 500 IU+PG 3 mg	6-8
	Male	-	-	PG 2 mg/kg	
Ctenopharyngodon idella	Female	PG 1.5-2 mg	6-8	PG 4-6 mg	5-7
	Male	-	-	PG 2 mg	
Cyprinus carpio var. *communis* *Cyprinus carpio* var. *specularis*	Female	PG 1 mg	6	PG 4 mg	6
	Male	-	-	PG 2 mg	
Barbodes gonionotus/ Puntius sarana	Female	-	-	PG 4-5 mg/kg	6.0
	Male	-	-	PG 2 mg	
Pangasius sutchi	Female	PG 2 mg	9	PG 6 mg	8-9
	Male	-	-	PG 2 mg	
Clarias batrachus	Female	PG 50 mg	6-8	PG 100 mg	9-12
	Male	-	-	-	
Heteropnuestes fossilis	Female	PG 70 mg	6-8	PG 70 mg	8-10
	Male	-	-	-	
Ompok pabda	Female	PG 3 mg	6	PG 15-17 mg	7-8
	Male	-	-	PG 7-8 mg	
Anabas testudineus	Female	PG 3-4 mg	-	-	9-12
	Male	PG 2 mg	-	-	

fertilization takes place. Fertilized eggs are collected through the outlet of the circular tank and placed into the incubator for hatching. Prior to spawning, a sufficient quantity of aquatic grasses should be placed in the breeding tanks of common carp or mirror carp to collect the sticky fertilized eggs.

For artificial fertilization of eggs, six hrs after the second injection, eggs and sperms are collected from the ovulated females and males by stripping the abdomen of the fishes with a gentle hand. Eggs are collected first into a plastic bowl. Then males are stripped over the same container. The eggs and sperms in the bowl are mixed together with a soft feather for 1 min or by shaking the bowl for five min and then washed with fresh water. The fertilized eggs are washed three to four times by changing the water, broken eggs and any other unwanted particles are removed. The swollen eggs are transferred into a Chinese type circular incubating pool or a series of funnel type incubating jars that are connected with a flow of clean water to keep the eggs moving. Usually hatching of carp eggs takes place within 20 to 30 hrs if the water temperature of the incubating system remains 24 °C to 27°C.

Just after the hatching of eggs much care should be taken as high rate of mortality of the fry may occur due to inadequate aeration or any other poor condition of the incubating system. The inflowing water should be free from plankton especially from *Cyclops* (a zooplankton belonging to Copepod group) that may kill larvae during early development. Fries of four to five day old when they begin swimming are transferred to nursery ponds or suitable cement cisterns for selling to nurseries.

For induced breeding of catfishes, Magur (*Clarias batrachus*) females are injected with PG extract and checked for ovulation on an hourly beginning from six hrs post-injection and continued up to 12 hrs of injection. As soon as the females are ovulated, eggs are collected by stripping and then fertilized with sperm. For collecting milt, males are sacrificed as milt could not be collected by stripping but by macerating the dissected testes in 0.85 percent sodium chloride solution. As eggs of catfishes are sticky, fertilized eggs should be spread as quickly and as homogenously as possible in incubation trays which receive continuous gentle shower through porous pipes for aeration. Similar to magur, shing (*Heteropneustes fossilis)* are bred using artificial breeding technique. In some cases, both female and male shing fishes are induced with hormone injection but males receive one injection during female's second injection with the first dose of female. The induced female and male are kept in a hapa where the female release the eggs and males release sperm and where fertilization takes place. The fertilized eggs are collected from the hapa and kept in cisterns for hatching. For Pabda breeding, the techniques described for shing are used. For Thai Pangas breeding, females are given two and males are given one injection (same dose of female's second dose and second injection time) and kept in circular breeding tank for ovulation. When females start to release eggs, females are caught and stripped for collection of eggs. Milt is collected by stripping the males and fertilized the eggs. As the eggs are sticky, fertilized eggs are washed with fresh milk or clay water to remove the stickiness of the eggs and kept in incubation jars for hatching.

A number of catfishes such as magur, shing, pabda are successfully bred and reared in the Faculty of Fisheries, Bangladesh Agricultural University (Mollah, Sarder and Begum, 2003). Thai Pangas was extensively bred in Jessore, Bogra and Mymensingh regions in mid-1990s and onwards where millions of spawn and fingerlings were produced. According to the farmers at Jessore and Adam Dhigi, Bogra, Thai Pangas production exceeded 50 million juveniles in 1997 (FFP, 1997). As Thai Pangas is a very fast growing cash-crop fish species, its culture received highest popularity during the period of 1995-2002, but due to the falling of market price resulting from bad muscle flavour and high feeding cost, farmers lost their interest to culture pangas.

For tilapia breeding, no inducing agent was applied but the fertilized eggs are collected from the mouth of the brood mother. The captive brood parents are normally kept in hapa (fine mesh net cage) where females release eggs and males release sperm and fertilization takes place. Immediately after fertilization, females take the eggs into the mouth and incubate them there until the eggs hatch out. During the mouth-incubation process, fertilized eggs are collected from the female and placed in incubating trays or plastic jars for hatching that takes around 6 days. In some parts of Bangladesh especially in the north, brood tilapia are released in paddy fields where breeding takes place and fries are collected from the field for culture in ponds. Poor people in northwest Bangladesh also developed techniques to breed the easily-bred and fast-growing species (e.g. common carp, silver barb, and tilapia) by using a small hapa suspended in a water body, or in a flooded rice field (Little, Golder and Barman, 1999).

Freshwater prawn (golda) fry production

Prawn juveniles are traditionally collected from rivers, canals and natural depressions by netting followed by stocking in ponds. Sometimes prawn fry are collected by entrapping them in the low lying coastal areas by constructing embankments (locally called ghers) and allowing tidal water to enter into the ghers. In southwest Bangladesh, freshwater prawn culture still depends on wild post-larvae (PL). Farmers prefer to stock wild PL rather than hatchery-produced PL, since fry production in hatchery is limited. The quality and survival rate of hatchery-produced PL is inferior to the wild PL (Ahmed, 2004). Thousands of rural poor are involved in prawn PL collection on the Pasur River from Mongla to Heron Point on the south coast from April to June as part of their livelihood. Two types of nets are used for PL collection: the *behundi* net and the pull net. However, the catching and marketing systems are not well developed and high rate of PL mortality occurs due to poor handling (Ahmed, 2003).

Due to unavailability of juveniles in the natural waters and realizing the need of large number of prawn fry for commercial culture, work on prawn hatchery began in the 1980s but it was not expanded well. In 1988, the first commercial PL production was successfully done in Khulna region under the Prawn Culture Project. In 1993, the Riverine Station of the Bangladesh Fisheries Research Institute (BFRI) and the Department of Fisheries (DOF) in Chandpur jointly started work on the establishment of backyard prawn hatchery and provided training to NGOs, unemployed youth and interested farmers.

During last 20 years, a good number of prawn hatcheries have been established both in private and public sectors and millions of fry/PL are produced. In the private sector including NGOs, 18 prawn (golda) hatcheries are currently in operation and produced 50 million fry, while in the public sector, 12 prawn hatcheries produced 5 million fry (FRSS, DOF, 2003-2004). For breeding, berried prawns are collected from rivers, cultured ponds and ghers from March to July. The availability of berried prawn during breeding season is limited. It is very important that care should be taken during handling and transporting of berried prawn.

Nursery

Nursing of larvae/spawn is an important stage in fish culture. In Bangladesh, there are about 7 057 private carp nurseries, with an average area of 1 ha each. Besides these, most of the government Fish Seed Multiplication Farms (GFSMF) are used for nursing the fry. About 5 030 million fingerlings are produced from private sector nurseries compared to 18.4 million fingerlings produced from public sector nurseries (FRSS, 2003-2004).

Both seasonal and perennial ponds are used as nurseries in Bangladesh. Seasonal ponds are prepared without using pesticides. In case of perennial ponds, they are prepared by dewatering or by applying insecticides/piscicides such as Rotenone, Phostoxin, Cellophos, etc. After drying or poisoning the pond, lime is applied at 1-2 kg/decimal and cow dung at 5-7 kg/decimal, five to seven days before stocking. Inorganic fertilizer such as urea and TSP (triple super phosphate) are also used at 100-150 g and 50-75 g/decimal, respectively. Pesticides namely Dipterex or Sumithion are usually used at 0.15-0.25 ppm just one day before stocking for eradicating insects (water pleas) and large-sized planktons like cladocerans. TSP and urea are regularly used at 25 and 20 kg/ha/month, respectively, after stocking the spawn (Aminul Islam, 1989).

Two main types of nursing are practiced in Bangladesh: i) single-stage nursing and ii) two-stage nursing. In single-stage nursing, hatchlings are grown to fingerlings in one operation. The stocking density is maintained at 1.0 to 2.0 million spawn/ha and 2-3 inch-sized fingerlings are obtained within four to six weeks. In two-stage nursing, hatchlings are reared for 10-15 days in nursery ponds with a density of 6.0 million spawn/ha for obtaining 1 inch size fry. Then the fries are thinned out and stocked at a density of 0.2-0.3 million/ha and reared for another four to six weeks for growing up to fingerling size (2-3 inches). Some nursery operators specially in south Bangladesh carry out nursery rearing in three stages such as: i) early fry raising (spawn to early fry for 6-8 days); ii) fry raising (early fry to fry for 20-30 days) and iii) fingerling raising (fry to fingerling for 90-100 days) (Hasan and Ahmed, 2002).

For both types of nursery practice, newly hatched spawn are fed with boiled egg-yolk finely mixed with water. Then in the next four to five days, cooked wheat flour and boiled egg-yolk dissolved in water are provided. After that, fry are regularly fed with overnight-soaked mustard oil cake in water until reaching fingerling size.

Prawn fry nursing

Before stocking of larvae, the larvae rearing tank is filled up with de-chlorinated water. About 50 000 to 100 000 larvae can be stocked per tonne of conditioned water in the tank. Usually no feed is supplied to larvae for the first 24 hrs of stocking. After 24 hrs of stocking, two to three decapsulated *Artemia* is supplied to each larva with two hrs interval. It is continued up to seven to eight days. After that prepared custard is provided with a size of 100-150 µ and it is supplied at daytime while *Artemia* is supplied at night time. With this feeding regime, the larvae develops into post-larvae (PL) within 25-30 days. The PL is stocked in the nursery pond at the rate of 50 000-60 000/acre and 1.0-1.5 acre sized pond is better for PL nursery.

Gene bank

Gene banking of fish can be of two types: i) live gene banking and ii) cryogenic gene banking. Both types of gene banking are new in Bangladesh although the idea and the urge for establishment of such banks have been realized quite long ago. Production of fry from the hatcheries is sufficient to meet the domestic demand but the quality of fry has deteriorated over the years. Among many reasons, ignorance and lack of knowledge on scientific broodstock management techniques, inbreeding and intentional interspecific hybridization, negative selection, use of immature fish for breeding, etc. are held responsible for such quality degradation. Realizing the need to stop further quality deterioration as well as to improve the quality, the DOF has launched two big brood bank projects namely Brood Bank Establishment Project directly funded by DOF and Brood Bank Project under the Fourth Fisheries Project of DOF. BFRI also takes some programmes to improve broods' quality. The Northwest Fisheries Extension Project (NEFP) imported fry of silver carp, bighead carp and grass carp from the river of Yangtze, China with the help of Network for Aquaculture Centres in Asia (NACA) in 1994 and reared them to broods. In the year 1997, NEFP started to breed the Chinese carps and distributed the fry to eight government farms, BFRI, Bangladesh Agricultural University (BAU), NGOs such as Bangladesh Rural Advancement Committee (BRAC), CARITAS, Grammen Matsha Foundation (GMF), Rangpur Dinajpur Rural Services (RDRS) and private hatcheries for future broodstock development. In 2002-2003, the Brood Bank Establishment Project of DOF has started its work to set up 12 brood banks in the Government Fish Seed Multiplication Farms in six divisions with a target of 110 tonnes of genetically improved broods, 1 800 kg spawn and 0.5 million fingerlings production. Fry were collected from different rivers such as Halda, Jamuna and Padma and reared in the selected hatcheries following specific brood production techniques. In the mean time, 85 tonnes of broods were produced and from this the required number of broods are being sold and distributed to different public and private hatcheries following newly formulated policy of DOF for selling and distribution of broods, fry and fingerlings. In addition to the government initiatives, NGOs especially BRAC has already established one carp brood bank for their own hatchery purposes and they are going to set up another brood bank for tilapia soon.

Similarly 20 brood banks were established by collecting fry from natural sources and rearing in 20 Fish Seed Multiplication Farms and one Fish Breeding and Training Centre with the funding from the Fourth Fisheries Project. Brood fishes from the bank are being distributed to different government hatcheries. Necessary training for government and private hatchery operators and owners on broodstock management are being provided from both brood bank projects.

For the establishment of cryogenic gene bank (sperm cryopreservation) for fish, no initiative has been taken yet. However, project-based research work on cryopreservation of sperm of Indian major carps, *Catla catla, Labeo rohita, Cirrhinus cirrhosus*, exotic carps, *Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthyes molitrix, Aristhicthys nobilis, Barbodes gonionotus* were conducted with the collaboration of

BAU, DOF and BFRI. More research on Indian major carp sperm cryopreservation and cryogenic gene banking are presently going on in the Faculty of Fisheries of BAU.

SEED MANAGEMENT

Husbandry management of broodstock

Brood fish is considered as the heart of the hatchery and management of broodstock is the key of quality seed production. Success of induced breeding depends on availability of sufficient number of brood fish. Therefore broodstock should be maintained scientifically so that ripe broods could be obtained during the whole breeding season. Most of the government hatcheries have own broodstock and around 25 percent recruitments take place in every year. On the other hand, few private hatcheries have their own stock and maintain them more or less scientifically but there are many private hatcheries that do not have the required number of broods. During breeding season they instantly buy broods from others and produce fry from them to fulfill their target. Besides this, most of the private hatcheries make new brood recruitment from the subsequent generations of few pairs of original parents that result in inbreeding.

The management techniques adopted by different hatcheries are varied from each other. Brood fish are reared in ponds having the area of 0.5 to 1.0 acre and water depth between 1.5-1.8 meter. During preparation of brood fish ponds, the usual practice is to eradicate the predator and weed fishes by dewatering and drying. Sometimes toxins such rotenon, phostoxin, etc. are also applied to kill the unwanted fish species. Aquatic weeds and other submerged plants are manually cleaned. After cleaning the pond, lime is applied at the rate of 1-2 kg/decimal and five to seven days after liming cow dung is used at the rate of 5-7 kg/decimal or 3-4 kg/decimal of poultry droplets as organic fertilizer. Inorganic fertilizers such as urea, TSP are also used at the rate of 150 g, 75-100 g per decimal respectively. Even after stocking the broods, liming (250-300g/decimal) and fertilization (cow dung 1.5-2.0 kg, urea 40-50 g, TSP 20-25 g per decimal) are continued for whole season with fortnightly intervals to keep the water quality suitable and to make the planktonic food available to the broods.

Most of the government hatcheries maintain the stocking density of 2 500-4 000 kg/ha which is much higher (5 000-6 000 kg/ha) in private hatcheries. Usually seven carp species are stocked and reared together with the following ratios (Table 7.1.6):

TABLE 7.1.6
Species composition and ratio in a broodstock pond

Fish species	Stocking rate
Silver carp	30%
Catla	5%
Rohu	20%
Mrigal	25%
Grass carp	10%
Bighead carp	5%
Silver barb (Thai Sarputi)	5%

Apart from the availability of natural food, most of the fish farms feed their brood stock with supplementary feed by maintaining 25-30 percent protein level. The composition and ingredients of the supplementary feed are as follows (Table 7.1.7):

TABLE 7.1.7
Ingredients and doses of supplementary feeds for broods

Ingredients	Dose
Mustard oil cake	30%
Wheat bran	15%
Rice bran	30%
Fish meal	15%
Wheat flour	5%
Molasses	5%/2%

In addition, 200-300 g Embavit-L per 100 kg of feed is provided to enhance the gonadal development of fish. The supplementary feed is applied at 2-3 percent of standing crop. For grass carp and silver barb, a soft grass (*Topa pana*) cut into small pieces are supplied to the pond.

Besides regular liming, fertilizing and feeding, Horra is pulled along the bottom of the pond to remove any accumulated gas in the bottom. Water exchange is done with removing some old water and adding some new underground water. To check the health of the fish and to calculate the feeding ration, the fish is netted at least one or two times per month. Except for *Argulus* infection, no other diseases are encountered in brood fish ponds in Bangladesh. For *Argulus* treatment 0.25 ppm Sumithione or 0.5 ppm Dipterex is used twice a week with five to seven days interval.

Fingerling feed management

Prior stocking of fingerlings, ponds are prepared by dewatering or by using toxins to remove unwanted fish. Aquatic weeds are manually removed. Liming and fertilizing procedures are more or less same as brood stock pond preparation.

Along with some supplemental feeding farmers are mostly dependent on natural foods produced in the ponds for fingerling rearing. To grow enough planktonic food, urea, TSP and cow dung are applied with high doses. Preparation of composed at the corner of the ponds is common. As supplementary feed, mustard oil cake, rice bran, wheat bran and sometimes fish meal are used.

SEED QUALITY

Quality fish seed production is the prerequisite for sustainable aquaculture. In Bangladesh production of seed is not a problem but the crucial factor is to maintain its quality. Over the last two decades Bangladesh became self-sufficient to produce and distribute fry to the users but the quality of seed has been deteriorated. Inbreeding, interspecific hybridization, negative selection of broods, improper broodstock management are common phenomena in hatcheries especially in the private hatcheries. These factors result in low growth rate, high mortality, deformities, less fecundity of fry and so on. Many of the private hatcheries keep very small number of broods and rarely recruit new broods from outside; if they do, recruitment takes place from subsequent generations of the same stock. Some hatchery operators/owners collect broods from the farmers' grow-out ponds during breeding season and sell them out after breeding. Breeding of same broods more than one time in a season is another common practice in many hatcheries that presumably deteriorates the larval quality and increases the occurrence of deformed larvae and death. Hussain and Mazid (1997) and Sarder (1998) reported reduced growth, physical deformities, diseases and high mortality in hatchery produced carp seed and they have identified improper management of broodstock, unconscious negative selection of broods, unplanned hybridization and inbreeding as the probable reasons behind these reduced performances. Recent studies have revealed high rate of inbreeding and inter-specific hybridization in both endemic and exotic carps (Simonsen *et al.*, 2005, Simonsen *et al.*, 2004; Alam *et al.*, 2002). In order to stop the further genetic deterioration and at the same time to improve the quality of seed, DOF and BFRI have taken some initiatives, such as brood bank establishment project, brood bank project, distribution of broods to government and private hatcheries from the brood banks and brood management trainings for the hatchery and farm operators.

Disease is considered as one of the important problematic factors for the seed industry. There are few published reports on disease in both hatcheries and nurseries in Bangladesh. Parasitic diseases in nursery are one of the most important limiting factors for growth and survival of fry and fingerling. In many Asian countries severe mortalities among carp fry have been reported and it was caused by different diseases especially by ich disease, *Trichodina* spp., *Ichthyobodo* spp., *Lernaea* spp., *Myxobolus* spp. and *Dactylogyrus* spp. *Myxobolus* and *Hennegyua* have caused heavy mortalities in *Catla catla* with the disease called gill myxoboliasis. It was reported that 61 percent of carp fry were infected with ectoparasites in nurseries of Greater Mymensingh District and highest mortality of carp fingerling was occurred by *Trichodina, Myxobolus* and *Dactylogyrus*. Chandra *et al.* (1996) reported high prevalence of myxosporean ectoparasites in juvenile Indian major carps (*Labeo rohita* and *Cirrhinus cirrhosus*) in nursery ponds of Mymensingh. They also reported severe gill infection of these juvenile carps by five different myxosporean ectoparasites belonging to the genus *Myxobolus*.

Ahmed (1997) reported that hatchlings, PL and fry of carps are affected by gas bubble disease which is cause by supersaturated oxygen and nitrogen gases. The author also reported that in hatchery the most serious diseases of eggs are caused by the fungal infection with *Saprolegnia* and *Achlya* sp. Hasan and Ahmed (2002) conducted a survey on disease problems in 180 carp hatcheries and nurseries in southern and eastern regions of Bangladesh and reportedly found disease as a big problem for hatcheries and nurseries. They listed a number of diseases found in hatcheries and nurseries which were white spot, tail and fin rot, EUS (epizootic ulcerative syndrome), sudden spawn death, fish louse, gill rot, dropsy, malnutrition, air gulping and deformities. The reason for sudden spawn death was unknown but the operators assumed sudden sharp rise of water temperature in hatcheries and nurseries could be responsible for such massive death. In the survey study many farmers mentioned that the sudden spawn mortality and occurrence of deformed larvae are more common for spawn produced during late breeding season.

There are no specific/unique procedures for maintaining hygienic condition in hatcheries but most of the hatcheries take some precautionary measures before and during the fry production. As a part of the precaution all the components of the hatchery such as overhead tank, breeding tank, circular tank, bottle jar system, delivery pipe, shower, gate bulb etc are washed with detergent powder (wheel powder), bleaching powder and formalin. Salt water and potassium permanganate are also used to clean the hapa, bowls and beakers. If any disease appears during the fry production the hatchery operators immediately discard the diseased fry from the hatchery and the whole hatchery components are cleaned with the above mentioned cleaning agents before the start the next round of production. Hasan and Ahmed (2002) reported that during outbreak of disease in hatcheries and nurseries, farmers used different treatments such as applying chemicals and antibiotics, water exchange and manipulation of feeding and fertilization.

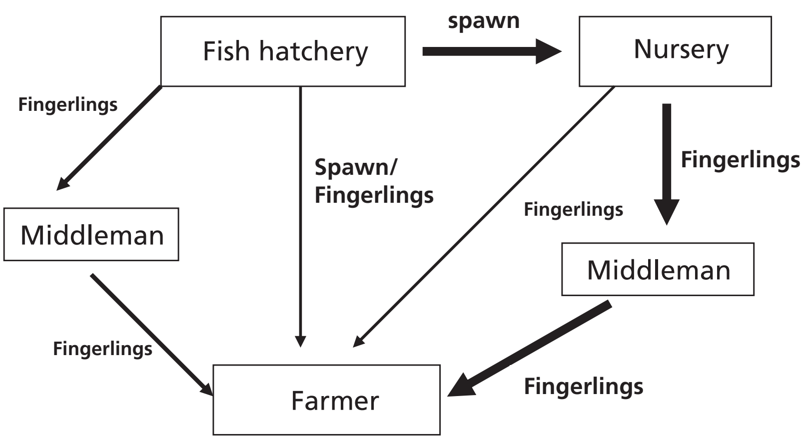
There is no available set criterion from both government or private sectors for maintaining or improving seed quality in Bangladesh. However, after discovery of inbreeding and hybridization in both private and public hatcheries, many farmers start to query on seed quality before buying the fry. Consequently many hatchery operators put their attention in keeping enough number of broods, its management, and maintaining seed quality for the sake of their business interest. The government has already taken some measurements such as establishment brood bank to improve the quality of seed.

SEED MARKETING

Next to seed production and nursing, timely supply of seed to the farmers is a very important task for aquaculture. There is a complex network of seed supply, not institutionally organized, involving hatchery operators, nursery operators, middlemen (seed trader) and fish farmers. The following flowchart shows the distribution channel of seed.

Although there are around 800 hatcheries and 7 057 private nurseries, these are not equally distributed all over the country but rather more or less clustered to few places. Among the hatcheries many of them have both breeding and nursery facilities. Many of the government fish seed multiplication farms are also used for both purposes. Fish seed traders play a vital role in providing a link between hatchery, nursery and fish farmers. They are the main actors that make seed available to the farmers' pond side. In the flow chart above, it is shown that fish spawn are directly collected by the nursery operators from the hatcheries and reared to fingerling stage.

FIGURE 7.1.2
Supply channels of fish seed from hatchery to farmers



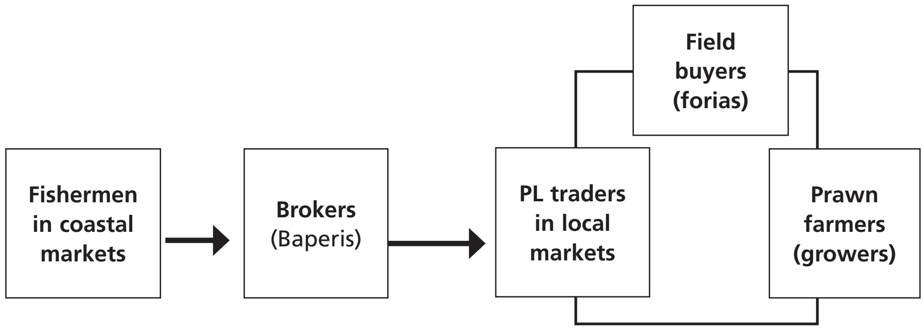
Fingerling marketing is generally done by middlemen since very few fish farmers buy directly from nursery farms. About 80 percent of fingerlings are supplied to farmers by middleman (fish seed traders) and some 20 percent of fingerlings are directly collected by farmers from the nursery operators. In addition to this, when spawn are reared to fingerling at the hatchery *cum* nursery, fingerlings also reach farmers through the same channel. At present there is no established and formal fish seed market for selling and buying seed but some spots for example, Parbatipur Railway Station (northwest part of Bangladesh) where seed are accumulated from Jessore, Bogra and Rajshahi regions by train, are used as seed market. Fish seed traders in the northwest often procure fingerlings from sources as far away as Jessore, Bogra and Rajshahi, and between 100 to 125 million fingerlings are usually traded at Parbatipur railway station every year (NEFP, M&E Annual Report, 1993-1994). It is noteworthy that fish traders are not only involved in seed supply, they also provide some advice on fish culture to farmers. Northwest Fisheries Extension Project had took a project on seed transportation and its management, and under this project a large number of fish seed traders received training on handling during transportation of seed and also some basic training on fish culture that are disseminated to the farmers during seed sale.

Transportation of seed

Fish spawn/hatchlings are transported in polythene bags filled with oxygen. Usually 10-12 l of clean pure water is taken into a 90 cm x 50 cm sized plastic bag and 250-500 g of four to five day old spawn are placed in the bag. The bag is then filled up with oxygen and the mouth of the bag tightly sealed with rope. For protection of the bag another polythene bag with the same size is taken and the bag with fry placed into the second bag. Finally the plastic bags are placed into jute made bag for more protection during transportation by bus, train, van, pick-up truck, etc.

Fish fingerlings are transported by using indigenous and modern techniques. Before transportation, the fingerlings are netted for two consecutive days to make them strong and accustomed. On the day of transportation, the fingerlings are caught by using soft, small mesh sized net and water is splashed for 15-20 min from outside the net so that the fish will be frightened and release faeces. This type of conditioning of fry helps to keep the water clean for longer time during transportation. Using indigenous method, earthen pots called *hundis* and other aluminum or metallic containers with hand agitation of water are generally used for transportation of fish seed. Usually 20-30 fingerlings/l of water in the container are carried either on foot

FIGURE 7.1.3
Freshwater prawn post-larvae supply chain from fishermen to prawn farming areas in Bagerhat District



or by bicycle, by rickshaw, by train, etc. A constant jolting or hand agitation of water is useful for replenishing of atmospheric oxygen in the water. During longer period of transportation, the water may get dirty and is periodically replaced with new fresh water. Dead and injured fry are also removed from the container at times preventing rotting and fouling of water. During transportation, the containers are often covered with moist cloth and gunny bags to keep the container cool.

Using modern techniques, fingerlings are transported in 90 cm x 50 cm sized polythene bags filled with oxygen. Usually 4-6 l of water are taken into the bag and 50-100 fry/l are carried. In case of large-scale seed transportation, fish hauling tank equipped with agitator and oxygen supply is used. Sometimes the body of the truck is temporary converted into a water pool using plastic pool filled with water. Plastic barrels (200 l) are also used to transport fry specially the pangas fry and the barrels are carried by pick-up van or truck. The barrels are filled with clean fresh water prior to transfer the fry from the hapa but manual water filling of barrels is time consuming and costly. Sometimes it is difficult to get available clean fresh water. To make the water available and to easily fill the barrels, recently in Mymensingh region, many water filling stations are established along the high way. It is a station where underground water is withdrawn from shallow or deep tube-well by using two to four H.P. pump and the water is delivered to the barrels using delivery pipe. In the absence of mechanized tube-well, clean pond water is delivered to the barrels by simple lift pumping.

Prawn fry marketing and transportation

The chain for transporting and marketing of prawn PL is complicated. A number of intermediaries exist: brokers (locally known as *baperis*), PL traders and field agents (*forias*) are involved in the PL marketing chain linking the fishermen to the prawn farmers (survey study conducted by Dr. Nesar Ahmed, personal communication). Usually PL collectors do not have any direct contact to the prawn farmers; they sell the PL to *baperis* who carry it to the PL traders. The PL traders sell the PL directly or via *forias* to the farmers. The *forias* play a dual role: first, to supply the PL to the farmers and second, to get the market-sized prawn from farmers to the prawn traders. *Forias* work with a little amount of capital and often take temporary loans from the PL traders.

Like carp fry, prawn PL are transported by both indigenous and modern methods. Transport of live PL to traders takes place at night or in the very early morning hrs, to take advantage of cooler temperatures. Usually aluminium containers of 10 to 20 l covered with wet cloths or nets are used to carry the PL with pick-up vans, buses, minibuses and taxis. During transportation, saline water with 10 to 15 ppt is used, normally at a ratio of two l per 1 000 PL for eight hrs transportation. PL mortality rate following the above conditions is very low, less than 10 percent (Dr. Nesar Ahmed, personal communication). Dayue (1988) mentioned that loading density, packing and transportation methods affected survival rate of prawn PL during transport. At a loading density of 5 000 PL/l of water at 18 to 23 ppt and 15 to 20 °C temperature, the survival rate can be above 95 percent over 20 hrs of transport. Prawn PL is also transported in polythene bags filled with oxygen. One-third of total space of the bag is filled up with water and two-third with oxygen and in this condition 1 000-2 000 PL/l of water can be transported for eight to ten hrs. Venkataswamy, John and Kaleemur Rahman(1992) noted that at 26 °C packing in oxygenated bags could help in increasing survival rate of PL.

Finance

To operate the government fish seed multiplication farms, government provide money to the farms by fixing a target with either production of certain kg of spawn or earning of certain amount of money from selling spawn or fingerling for each year. However, most of the private hatcheries and nurseries are self-financed. Many hatchery/nursery operators take loans/credits from different sources: government banks such as Sonali Bank, Janata Bank, Krishi Bank, Pubali Bank, Co-operatives; private banks such as Grameen Bank, Employment Bank (karmosagnsthan Bank); NGOs such as BRAC, Proshika, Caritas, ASA. They also take money from local rich people (Mahajan) as loan with interest rate.

Sales promotion

The main customer of the fry is the rural small fish farmers. However, since many big commercial fish farms have been established in the country over the last few years, a large portion of fry are being used by these farms. From mid-1980s, the government has taken programmes to release and stock fry in open waters every year and for this purpose a large number of fingerlings are bought from both public and private hatcheries and nurseries. In addition, to rehabilitate poor farmers who suffered from flood, cyclones, the government, donor agencies and NGOs such as World Vision and Caritas procure fingerlings from hatcheries and nurseries.

SEED INDUSTRY

On the basis of the production of spawn the hatcheries can be categorized into three groups which are shown in Table 7.1.8 below.

RISKS

Socio-economic condition

Many private hatchery owners are rich and some of them are educated. They have established their hatcheries using their own capital but sometimes they take financial assistance from commercial banks. Most of them have either received training from government hatcheries and institutes or learned the technology from other existing hatcheries and operate them with the help of some labourers. In some cases, technicians have been trained by hatchery owners for smoothly running the hatchery. Nevertheless, many hatchery owners and most of the labourers are illiterate or have little education and could not understand and adopt latest technologies easily. If any problem such as disease appears they feel very nervous and could not the take right and timely decision.

Persons who are involved in fingerlings production belong to poor lower-middle class. Some nursery operators have little

TABLE 7.1.8
Type of hatcheries based on fry production

Type of hatchery	% number of total hatchery	Production of spawn (kg)/year
Small	50	50-100
Medium	40	100-300
Large	10	300-2 500

education while most of them are uneducated. They raise the fry to fingerling either in own ponds or take ponds on lease. In many cases fry is reared to fingerling stage in small-scale and homestead ponds and thus many women along with men get involved into the fish rearing business. Some nursery operators have taken training on nursery practice from government and research institutes; however, many of them share working experiences with each other.

Environment

The environment of Bangladesh is highly favourable to fish culture. Until the 1970s fish was everywhere in Bangladesh and the main source of fish was inland open water capture fisheries. But fish production from inland water fisheries declined over few decades due to implementation of flood control, drainage and irrigation schemes which resulted in depletion of flood plains used for breeding and nursery grounds of fishes. Another reason, a large number of Bangladeshi rivers have originated from India and due to the downstream location, Bangladesh is becoming a flood prone country. Almost every year, Bangladesh is affected by the flash flood water at which time many parts of the country become inundated and a large number of fish farms are partially or fully damaged. Flood water not only cause damage to farms, it also has become responsible for outbreak of different diseases.

Transportation, market, recovery money

Trading of fish seed is a seasonal occupation and in most places it starts in April and ends in September. Seed traders typically carry a few thousands seed in aluminum containers and travel on foot, by bicycle or train to reach farm customers. They face significant risk of seed losses during long transport/journeys. Sometimes bad road communication increase the risk of seed loss. Another problem for the seed traders is to sell the fingerling with a variable price and also on credit to seed buyers. Sometimes it is difficult for the traders to recover the credit money from the buyers and make profit out of the business. The practice of selling fry and fingerlings on credit is involved in all sections of fry trading, i.e. from hatchery to nursery to fish farmers.

Others

Stealing, poisoning, electricity failure, high temperatures, low underground water level just after winter season are also considered important risk factors for maintaining broods, fish seed production, trading and culture. Extremely high temperature (e.g. 40-45°C) sometimes causes massive death of fry and broods. Similarly, low underground water level especially during the month of March to May, before the start of rainy season, bring difficulties for maintaining broods as required amount of underground water can not be withdrawn and supplied.

SUPPORT SERVICES

There are several organizations and institutions directly and indirectly involved in fisheries extension and aquaculture development in Bangladesh. However, the Department of Fisheries (DOF) under the Ministry of Fisheries and Livestock (MOFL) is the principal organization responsible for fisheries development and extension. DOF has a strong network throughout the country consisting of 6 Divisional head quarters, 64 District Fisheries Offices, 460 Upazilla Fisheries Offices and 112 fish seed multiplication farms with a staff of about 4 500 individuals. The main job of these office bearers is to develop aquaculture and extension of fisheries activities. The 460 Upazilla Fisheries Officers are directly involved in aquaculture extension. In addition, there are some other personnel such as Aquaculture Extension Officer (AEO), Extension Officer (EO) under different development projects are working for promoting extension of aquaculture. The District and Upazilla Fisheries Offices provide training on different aquaculture aspects such as broodstock management, fry production through artificial breeding, nursery management, fish culture, integrated fish culture, prawn breeding, nursing and culture, feed management, disease control, etc. to government and private hatchery/farm operators, fish farmers, relevant NGO workers. In addition to this, the Government Fish Seed Multiplication Farms are also involved in such training programmes. For formal training for aquculture officers, hatchery/farm operators and NGO personnels, the government has established six Fish/Shrimp Training Centres and one Fish Training Academy and from these institutes short aquaculture training courses are offered (FRSS, 2004). The Youth Training Centers under the Ministry of Sports and Youth Development are providing two to three months residential training on aquaculture and other branches of agriculture to unemployed youth (men and women). The Bangladesh Fisheries Research Institutes (BFRI), another national institute under the MOFL, has seven stations and sub-stations with a manpower of 376. Research on aquaculture and fisheries are the main task of the institute but very often it also provides aquaculture training, sometimes alone or with collaboration with DOF and donor agencies such as Worldfish Centre, Danida, DFID, FAO, UNICEF, to government and private hatchery and nursery operators, NGOs, unemployed young men and women. The Fisheries Faculty of the Bangladesh Agricultural University (BAU) sometimes arranges training, mainly research project-based training, for government and private hatchery/farm operators, NGO persons and farmers. The Fisheries and Marine Resource Technology (FMRT) Discipline of Khulna University also arranges similar training programmes.

Technology developed and disseminated

So far 36 technologies, many of them related to freshwater fish and prawn seed production, have evolved and disseminated to farmer level by the DOF, BFRI and universities. A number of manuals (e.g. fish culture manual, improved brood fish production and breeding techniques, fish genetic improvement and broodstock management, fry transportation and stocking management development course, nursery management course, fundamental extension course, environmental friendly shrimp culture management course); books (e.g. genetic improvement and conservation of carp species in Bangladesh, genetic management and improvement of exotic carp species in Bangladesh, tilapia culture); booklets (e.g. pituitary gland collection techniques, improved carp hatchery management techniques, improved carp nursery management, prawn fry production in backyard hatchery and pond culture, genetic problems and remedies for induced breeding of Bangladeshi fish, carp brood bank establishment and management technique, carp and prawn fry transportation, freshwater prawn hatchery operation, freshwater prawn fry nursery management etc are published and distributed to relevant persons by DOF, BFRI and universities.

SEED CERTIFICATION

There is no seed certification system for hatcheries in Bangladesh. However, realizing the need of seed certification for controlling seed quality in carp and prawn hatcheries, the MOFL formed a National Committee in 2001 by picking up personnel from different relevant institutions to formulate a policy for seed certification. The committee already drafted policies for seed certification and submitted it to MOFL for its final approval. The name of the drafted law is “Matsha and Chingri Hatchery Ain 2005” (Law for Fish and Shrimp Hatchery 2005). It includes the clauses for registration of hatcheries, and the rules for fish and shrimp hatchery operation. The latter elaborates few things which are necessary for hatchery operation such as physical infrastructure/facilities of hatchery, ponds, selection of brood fish for breeding, source of selected brood fish, environment, etc.

LEGAL AND POLICY FRAMEWORKS

Policy framework

The Fisheries Policy of Bangladesh was adopted in 1998 to provide appropriate regulatory and supportive rules for continuing growth and development of the different sub-sectors of fisheries. The policies are summarized by Mazid (2002). It has the following objectives:

i) fisheries resources development for increased fish production;
ii) poverty alleviation through creating opportunities for self-employment and improving socio-economic conditions of fishermen and fish farmers;
iii) meeting animal protein requirement of the country;
iv) increased foreign exchange earning and the rate of economic growth through export of fish and fisheries products;
v) environment protection, biodiversity conservation and public health improvement.

Legal jurisdiction of National Fisheries Policy (Section 3.0)

The jurisdiction of the national fisheries policy is:

i) All national and multinational agencies both government and private including individuals involved in fisheries development activities within the geographical boundaries of Bangladesh shall fall within the purview of the National Fisheries Policy (Section 3.1).
ii) The conservation, development and management of all potential fisheries water bodies shall come under the purview of the policy (Section 3.2).

Policy for Inland Open Water Fisheries Development (Section 5.0)

i) Minimizing negative effects of all development activities including construction for flood control, irrigation, drainage, roads, urbanization etc. on fish and fisheries habitats.
ii) Transferring identified or part of the potential water bodies to the Department of Fisheries to establish fish sanctuary for natural propagation of fish.
iii) Natural water bodies like *khal, beel*, ditches, canals and other open water bodies not to be allowed to dry up in full.
iv) *Beels, haors* and *baors* shall be re-excavated, restored, improved and declared as the sources of fish production and these water bodies shall not be allowed to reduce.
v) Ensuring fish production as the primary use of all identified water bodies.
vi) Development of appropriate management guidelines and rigorous implementation of all acts and rules for conservation of open water fisheries.
vii) Identifying and preserving breeding and nursery grounds of fish and shrimp and protecting egg bearing fish and fish fry.

Policy for Freshwater Aquaculture (Section 6.0)

i) Demonstration of aquaculture technologies in the farmers' field at the Upazila and Union level through government initiatives.
ii) Encouraging women in aquaculture.
iii) Involving poor fishermen in community-based capture fisheries development in *haor, baor* (natural depression, oxbow lakes) and in other potential water bodies.
iv) Leasing government tanks, ponds and other similar water bodies to targeted poor or unemployed youth, both men and women, for fisheries as means of their livelihood.
v) Developing guidelines for proper application of lime and fertilizer based on location specific need assessment of soil water quality.
vi) Undertaking integrated aquaculture in inundated rice field.

vii) Providing support to private sectors to establish hatchery and undertaking programme to promote establishment of nursery in the public and private sectors for production of required fingerlings for stocking in open waters and for aquaculture as well as to establish fish seed industry.

Legal framework

For carrying out fisheries activities legally, there is a law in Bangladesh (formulated during the period of East Pakistan, former name of Bangladesh) which is generally known as the Fish Conservation and Protection Act, 1950. However, some amendments of the law were made at different times are as follows:

i) The East Bengal Protection and Conservation of Fish Act, 1950 (EB Act. xviii of 1950)
ii) The East Bengal Protection and Conservation of Fish (Amendment) Act, 1963 (E.P. Act. No. 11 of 1964)
iii) The East Bengal Protection and Conservation of Fish (Amendment) Ordinance, 1970 (East Pakistan Ordinance No. xxvi of 1970)
iv) The Protection and Conservation of Fish (Amendment) Ordinance, 1982 (Ordinance No. 55 of 1982)
v) The Protection and Conservation of Fish Rules, 1985 (SRO 442-L/85 October 16, 1985 MOFL)
vi) The Protection and Conservation of Fish Rules, 1985 (Ordinance), 1986 (No. 5/Fish/Misc 263/84/97) March 4, 1986. MOFL
vii) The Protection and Conservation of Fish Rules, 1985 (Amendment) 1987 (SRO-269-law/87) November 4, 1987. MOFL
viii) The Protection and Conservation of Fish Rules, 1985 (Amendment) 1988 (SRO-24-law/88) January 25, 1988. MOFL
ix) The Protection and Conservation of Fish (Amendment) Act 1995 (Law/9)

ECONOMICS

The market price of carp fry is highly variable depending on several factors such as species, supply and demand of the fry, season and transportation. The quality of fry is also considered as the determinant of the price. In recent times, communication system of Bangladesh has improved much and fry can be supplied to anywhere in the country in a day. In case of catfish fry, the price is also variable but less fluctuant. The following tables below show the price fry and fingerlings.

Normally fry produced in the early breeding season received higher price as the nursery operators can sell the fingerlings with a good price. Many farmers get their farms ready with supply water and do not wait for rainwater. If they can stock the ponds earlier with the early seasoned fry, they can get return of their investment with only few months of fish culture. Nowadays, there are many hatchery owners and nursery operators who stock the nursery ponds with the late seasoned fry (at the time when the fry got lowest price), rear them over the winter season (called over-wintered fry). The price of over-wintered fry is quite high as they grow faster than new fry and reach marketable size within few months in the immediate growing season. The price of 10 cm sized over-wintered fry is about Tk1 000 per 1 000 piece.

The price of fry depends mostly on supply and demand. From 1995 to 1966, both

TABLE 7.1.9

Price of fry of indigenous and exotic carps and catfishes

Species	Price of spawn, TKk/kg
Rohu, Mrigal	500-2 500
Catla	1 000-3 000
Calbaush	1 000-2 000
Silver carp	500-3 000
Grass carp	1 000-3 000
Bighead carp	1 500-4 000
Silver barb	300-1 000
Gonia	1 000-2 000
Common carp	1 000-3 000

government and private hatcheries are producing carp spawn enough to meet farmers demand and sometimes with surplus production, the price of the spawn declined significantly. As a result many small hatchery operators are out of business or changing species such as indigenous catfishes, Thai pangas, Thai koi, etc. Big hatchery operators are producing fry less than their capacity. So hatchery operators are getting less return from their investment. Fry price also depends on species (e.g. catla receives higher price than rohu and mrigal), season (early seasoned fry receive higher price and the price get down with the commencement of full breeding and late breeding seasons), quality of seed, etc.

TABLE 7.1.10
Price of fingerlings of indigenous and exotic carps and catfishes

Species	Price of fingerling, Tk/1000 individual
Rohu, Mrigal	200-300
Catla	300-500
Calbaush	500-1 000
Silver carp	100-200
Grass carp	200-300
Bighead carp	500-1 000
Silver barb	200-500
Gonia	200-500
Common carp	200-500
Bata	400-500 (average 5 cm size)
Shing	2 000 (average 5 cm size)
Magur	2 000 (average 5 cm size)
Pabda	2 000 (average 5 cm size)
Thai koi	500-1 500 (average 2 cm)

Hatchery and nursery operation are the main and sometimes only job for most of the farmers. With the money earned from the hatchery and nursery business, they maintain their whole family activities. Hasan and Ahmed (2002) observed, in their survey study on hatchery and nursery, that the average contribution of aquaculture to household income is reasonably high, nursery contributes 79.3 percent while 95.1 percent comes from hatchery. Apart from aquaculture, the hatchery and nursery operators earn money from other economic activities such as paddy cultivation, livestock raising, vegetable and fruit production.

The average price of PL collected from rivers varies from Tk 700 to 800 per 1 000 PL, but these PLs are ultimately sold to the prawn farmers with a price of Tk 1 200 to 1 500 (Dr. Nesar Ahmed, pers. comm.). The poor PL collectors maintain their livelihood by selling the PL. According to the private prawn hatchery owner, the price of the prawn fry is ranging Tk. 1 200- Tk. 2 500/1 000 PL and early seasoned PL receives higher price than the full breeding seasoned PL.

FUTURE PROSPECTS AND RECOMMENDATIONS

Prospects

- More than 98 percent of seed are produced in both private and public hatcheries which remarkably reduced the hunting pressure for carps and freshwater shrimp fry from natural sources, a practice which is in contradiction to natural biodiversity conservation.
- Along with Indian major carps breeding, many hatchery operators are engaging their efforts on breeding of undomesticated and endangered fish species. Such activity will definitely help to save the endangered fish species from extinction.
- Establishment of brood bank will definitely help to improve the quality of seed.
- Establishment of fish sanctuary in open water bodies through community-based fisheries will increase the natural recruitment and at the same time the livelihood of the fishing community will be improved.
- Availability of fish seed and farming technology will encourage a considerable number of people including rich people to invest money into fisheries industries.

Recommendations

- Establishment of hatchery and nursery in the private sector should be encouraged in all areas of the country to ensure availability of adequate quantity of quality seed for farmers in the entire country. Since most of the hatcheries and nurseries are clusteredly located in a few places, new hatcheries and nurseries should be established in remote areas and at the same time establishment of new hatcheries in the dominated areas should be regulated.

- Fingerlings, the main input for sustainable aquaculture, receive very poor attention. Therefore, necessary steps should be taken to establish nurseries within the government and private sectors.
- Since the quality of seed has deteriorated over the years due to inbreeding, hybridization, negative selection and improper brood stock management, special attention should be paid to improve the quality of seed. In this regard, live brood and cryogenic gene banks need to be established.
- The government in collaboration with private entrepreneurs should take necessary steps to establish brood banks in different parts of the country. Quality broods from the brood banks should be distributed to the hatcheries as required and its maintenance monitored.
- Hatcheries other than brood banks should not create their broodstock from their own produced fry, otherwise the genetic diversity of stocks will be further reduced. Breeder candidates should be procured from brood banks, where appropriate genetic diversity and adequate size of parent stocks are being maintained.
- Necessary training on broodstock management, breeding technology, nursery technology, disease control, etc. should be provided to hatchery and nursery operators, farm managers, and fish farmers. Awareness building of private hatchery operators and fish farmers should be further extended.
- To ensure quality of fish and shrimp fry, registration and seed certification system for hatcheries and nurseries should be adopted and implemented immediately.
- Since millions of fry of different fish species are coming from other countries without any check, proper quarantine system should be set up to control possible disease introduction.
- Catching or killing of broods and fry during breeding season should be banned and in this regard alternate employment for fishermen during breeding season should be arranged.
- Fish sanctuaries should be established and monitored in open water bodies as much as possible in order to promote natural recruitment.
- Total harvesting of fish by complete drying of natural water bodies should be avoided.
- Loss and destruction of breeding and nursery grounds due to construction of flood control dams, roads and embankments and irrigation should be stopped. Inter-departmental co-ordination needs to be developed to minimize the damage to fish habitats.
- Loans with little interest should be made available from government and private financial institutions for hatchery and nursery operators. The loan sanction and distribution procedures must be simplified. Since the nurseries are more vulnerable, nursery operators should get priority for loan.
- Formal fry and fingerling trading networks should be developed locally and regionally by the government and other developing partners so that fry and fingerling producers and farmers can get their actual benefit.

STAKEHOLDERS

Producers/farmers. Hatchery and nursery operators are the main producers of fry and fingerling of fish. Many of them have good knowledge of fish farming and they often offer their advice to farmers.

Local institutions. Many NGOs are involved in fisheries activities in Bangladesh and among them BRAC and Proshika are the leading organizations. They are involved in fish breeding, nursery operation, culture and in some cases marketing. The BRAC has a good number of carp hatcheries and brood bank, and freshwater shrimp hatchery. The Proshika also has carp and shrimp hatcheries.

Small hatcheries. About 30 percent of total hatcheries are small hatchery and are involved in production of carps and other indigenous and exotic fish seed. They are only involved in fry production and sell the 2-3 day-old fry to nursery operators. Many of them do not have good facility for brood rearing. Recently some small and medium hatcheries taking initiatives for artificial reproduction of wildly-bred indigenous fish such as pubda, koi, shing, magur, chital in the captivity.

Large hatcheries. About 10 percent of total hatcheries are large-scale and its main job is to produce fry of different fish species and sell them to nursery operators. Many of them have nursery facilities and rear the fry up to fingerling size before marketing. Some of the hatcheries rear its late seasoned fry in their own nursery ponds during winter season and sell the fingerlings to farmers as over-wintered fry. Few large hatcheries are producing spawn of endangered fish species. Other than hybrid production, no hatcheries are involved in developing new strains or varieties of fish.

Associations. There are some localized hatchery associations in Bangladesh and are mostly involved in promoting fry and fingerling production and marketing. The associations play an important role in the National Fish Fortnight Programme each year.

Government institutions. The DOF and BFRI are the two government institutions directly involved in fisheries activities in Bangladesh. They provide legal and policy frameworks for the seed industry, provide necessary training to hatchery operators, farm managers and also fish farmers. Department of Fisheries has a nationwide strong extension network to promote aquaculture.

Researchers. Other than researchers from the BFRI, scientists from different universities and in some cases NGOs are involved in fisheries research activities. Among the universities, BAU is the oldest and pioneering institution for formal fisheries education and research in Bangladesh. Fisheries education is also offered by five other universities and one fisheries college. Scientists from universities are always engaged in different fundamental and applied research through MS and PhD programmes. They sometimes arrange training for hatchery operators, farm managers, NGOs and fish farmers.

Donors (funding agencies). GEF (Global Environmental Facility), DFID, DANIDA, World Bank, WorldFish Center, Caritas, CARE are providing funds to different fisheries activities in Bangladesh.

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7.2 Freshwater fish seed resources in Brazil

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ABSTRACT

With 13.7 percent of the freshwater available in the planet, Brazil has an enormous variety of fish in its river basins and this is reflected in the large number of fish species being farmed in the country. A telephone survey of 175 seed producers in 22 states was made to collect data for this report. Hatcheries vary from small installations producing few thousands of seed to bigger installations with a capacity to produce over 20 million seed per annum. The sum of the seed production of all freshwater fish species was 617 million seed in 2005. Tilapia is the main fish produced in Brazil with a production volume of 304.5 million in 2005, followed by tambaqui with a volume of 52 million seed in the same year. The remaining 261 million seed are spread among 35 other species, of which 26 are indigenous to Brazil. This document describes the seed production technology for the main freshwater fish species farmed in Brazil, with information about broodstock maturation, spawning, egg fertilization and larviculture. Some general aspects of Brazilian freshwater seed industry like seed management, quality, marketing and certification are described for the main cultured species. A brief analysis of the legal framework describes the main constraints that hinder aquaculture development, statistical data collection, law enforcement and sanitary programs for aquatic organisms. Finally, future prospects and recommendations on actions to realize the great potential of aquaculture development in Brazil are provided.

INTRODUCTION

With 13.7 percent of the freshwater available in the planet, Brazil has an enormous variety of fish in its river basins and this is reflected in the large number of fish species being farmed in the country. Besides the exotic species introduced for aquaculture purposes like tilapia (*Oreochromis sp.*), carps (*Cyprinus carpio, Hypopthalmichthys molitrix, Aristichthys nobilis* and *Ctenopharyngodon idella*), catfish (*Ictalurus punctatus*) and trout (*Oncorhynchus mykiss*), there are a number of Amazon and Pantanal fish that are farmed all over the country with seed producers installed in almost every state. The so-called "round" fishes like pacu (*Piaractus mesopotamicus*), tambaqui (*Colossoma macropomum*), pirapitinga (*Piaractus brachypomus*) and their hybrids tambacu (F[1] tambaqui x M[1] pacu), tambatinga (F[1] tambaqui x M[1] pirapitinga), paqui (F[1] pacu x M[1] tambaqui) and patinga (F[1] pacu x M[1] pirapitinga) are well accepted by the local markets and aquaculture of these species has contributed substantially to increase fish consumption in Brazil. Many native fish that were available only in big fish markets in the Amazon and Pantanal regions are now encountered in almost every supermarket in all parts of the country. It is estimated that national fish consumption has increased in the last two years based on the information given by the Brazilian Supermarket Association (ABRAS) who reported an increase of 30 percent in the supermarket commercialization of fish. Freshwater fish farming is responsible for 67 percent of the national aquaculture production in 2004, with an estimated volume of 180 730 tonnes (Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA, 2005).

SEED RESOURCES AND SUPPLY

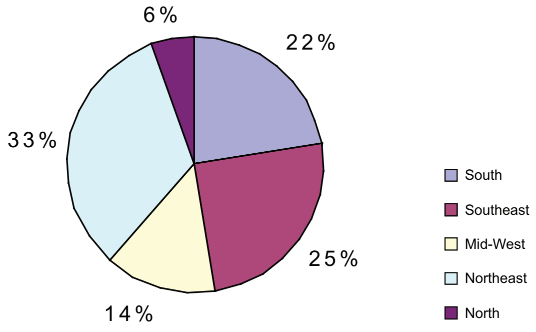
All fish seed comes from hatcheries. Pirarucu (*Araipama gigas*) is an exception as this species is collected from the wild as described in the section "Seed management". The great majority of hatcheries are privately-owned. Many government institutions and hatcheries were created in the 1970s to provide seed supply for stock enhancement in federal rivers and reservoirs. The two main government institutions are CODEVASF (Company for the Development of the São Franscisco Valley) and DNOCS (National Department of Engineering Against Droughts). These institutions are still very important in the northeast region where they supply seed for restocking and for small-scale aquaculture. The production of freshwater fish seed from government hatcheries was 75.1 million which represented 12.2 percent of the national seed production in 2005.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

The continental dimensions of Brazil and the informal situation of many aquaculturists that are not registered by local or federal authorities made it is very difficult to identify and contact all freshwater fish seed producers in the country. However, an exhaustive attempt to contact each seed producer either through reference from fish farmers or through advertisement in specialized magazines, allowed the identification of 175 hatcheries installed in 22 states.

Hatcheries vary from small installations producing few thousands of seed to bigger installations with capacity to produce over 20 million seed per annum. The sum of the seed production of all freshwater fish species was 617.5 million seed in 2005. Tilapia is the main fish produced in Brazil with a seed production of 304.5 million seed in 2005, followed by tambaqui (*Colossoma macropomum*) with a volume of 52 million seed in the same year. The remaining 261 million seed are spread among other 35 species, of which 26 are indigenous to Brazil.

FIGURE 7.2.1
Regional distribution of the freshwater fish seed production in Brazil in 2005



Source: Interview with 175 seed producers

Seed producers are present in all Brazilian regions and the northeast region leads the national production with 203.5 million seed in 2005 (Figure 7.2.1). This is due in part to the presence of 21 governmental hatcheries in the region that produce 57 million, not only for aquaculture purposes, but also for restocking programs in federal rivers and reservoirs.

Available technologies for production of freshwater fish seed include the following: (i) gonad maturation and spawning induction with hormones, (ii) hatching, (iii) breeding and (iv) rearing to fingerling and juvenile stages. A sperm bank of wild tambaqui was created in 2001 in the north region to avoid the increasing inbreeding among the progenies produced in other Brazilian regions. Broodstock improvement is not always easy considering that many seed producers are very distant from the natural banks of wild tambaqui. In this sperm bank, sterile test tubes are used to collect 6 to 12 ml of tambaqui semen per fish. The semen is then analyzed for its viscosity, motility and spermatozoid concentration before dilution in a cryopreservation solution for freezing and stocking in liquid nitrogen at -196 ^{O}C. Tests with frozen semen has obtained fertilization rates of 88 percent, followed by normal incubation and larviculture with survival rates of up to 70 percent (Panorama de Aqüicultura, 2003). Tilapia broodstock which originated from the Genetically Improved Farmed Tilapia (GIFT) population are available in Brazil through one of the biggest private tilapia seed producer, who supplies 20 million seed of "GenoMar Supreme Tilapia" annually.

TABLE 7.2.1
Scientific name, common name, regional distribution, volume and percentage of freshwater fish seeds in Brazil during 2005

	Species	Common name	Farmed in the Region[2]	Volume	%
1	*Oreochromis* sp.	Tilapia[3]	S, SE, CW, NE, N	304 481 275	49.31
2	*Colossoma macropomum*	Tambaqui	SE, NE, CW, N	51 981 654	8.42
3	*Piaractus mesopotamicus*	Pacu	S, SE, CW, NE, N	41 625 723	6.74
4	Hybrid (F[1] tambaqui x M[1] pacu)	Tambacu	SE, CW, NE, N	29 786 030	4.82
5	*Leporinus macrocephalus*	Piauvuçu, piauçu	S, SE, CW, NE, N	27 815 170	4.50
6	*Cyprinus carpio*	Common carp[3]	S, SE, CW, NE	18 878 848	3.06
7	*Ctenopharyngodon idella*	Grass carp[3]	S, SE, CW, NE	16 792 495	2.72
8	*Prochilodus lineatus*	Curimbatá, curimba	S, SE, CW, NE, N	13 552 110	2.19
9	*Brycon amazonicus*	Matrinxã	S, SE, CW, NE, N	13 405 230	2.17
10	*Astyanax altiparanae*	Lambari	S, SE, CW	10 935 450	1.77
11	*Prochilodus* sp.	Curimatã	S, SE, CW, NE, N	10 859 240	1.76
12	*Aristichthys nobilis*	Big head carp[3]	S, SE, CW, NE	10 036 125	1.63
13	*Ictalurus punctatus*	Channel catfish[3]	S, SE, CW	9 926 600	1.61
14	*Rhandia spp.*	Jundiá	S, SE, CW	9 803 610	1.59
15	Hybrid (F[1] tambaqui x M[1] pirapitinga)	Tambatinga	SE, CW, NE, N	5 782 000	0.94
16	*Piaractus brachypomus*	Pirapitinga	SE, CW, NE, N	5 362 450	0.87
17	*Brycon hilarii*	Piraputanga	S, SE, CW, N	5 254 400	0.85
18	*Leporinus friderici*	Piau	SE, CW, NE, N	5 241 360	0.85
19	*Hypopthalmichthys molitrix*	Silver carp[3]	S, SE, NE, CW	4 268 000	0.69
20	Hybrid (F[1] pacu x M[1] pirapitinga)	Patinga	SE, CW, N	4 244 600	0.69
21	*Oncorhynchus mykiss*	Rainbow trout[3]	S, SE	4 205 000	0.63
22	*Pseudoplatystoma* spp.	Pintado, surubim, cachara	S, SE, CW, NE, N	4 027 980	0.65
23	*Brycon orbignyanus*	Piracanjuba	S, SE, CW	2 048 735	0.33
24	*Clarias gariepinus*	African catfish[3]	S, SE	1 996 500	0.32
25	*Salminus maxillosus*	Dourado	S, SE, CW, NE	1 602 813	0.26
26	*Leporinus obtusidens*	Piava	S	565 000	0.09
27	*Leporinus elogantus*	Piapara	S, SE	563 925	0.09
28	*Hoplias lacerdae*	Trairão	SE	553 350	0.09
29	*Semaprochilodus* sp.	Jaraqui	N	500 000	0.08
30	*Hoplias malabaricus*	Traíra	S, SE	453 000	0.07
31	*Leporinus amblyrhynchus*	Chimboré	CW	400 000	0.06
32	*Cichla ocellaris*	Tucunaré	SE	183 705	0.03
33	*Hemisorubim platyrhynchos*	Juropoca	CW	120 000	0.02
34	*Micropterus salmoides*	Black bass[3]	SE	70 000	0.01
35	*Araipama gigas*	Pirarucu	SE, CW, NE, N	62 200	0.01
36	*Phractocephalus hemioliopterus*	Pirarara	SE, CW, NE, N	62 200	< 0.01
37	*Sorubim lima*	Jurupensen	CW	10 000	< 0.01

[1] F = Female and M = Male.
[2] N = North, NE = Northeast, CW = Center-West, SE = Southeast and S = South
[3] Exotic species

FIGURE 7.2.2
Freshwater fish seed hatcheries in Brazil (February 2006)

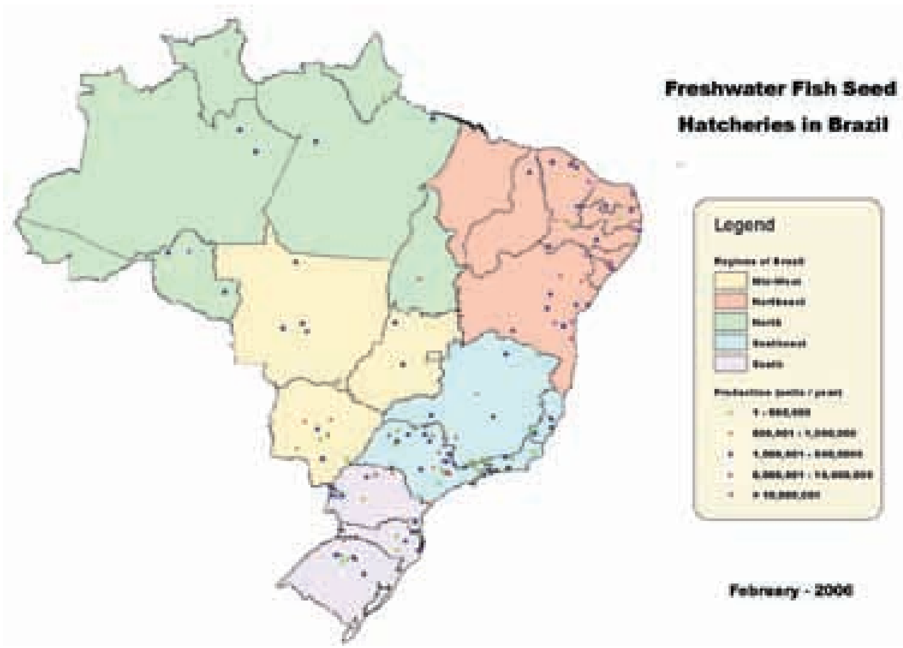


FIGURE 7.2.3
Freshwater fish seed hatcheries in Brazil (South Region, February 2006)

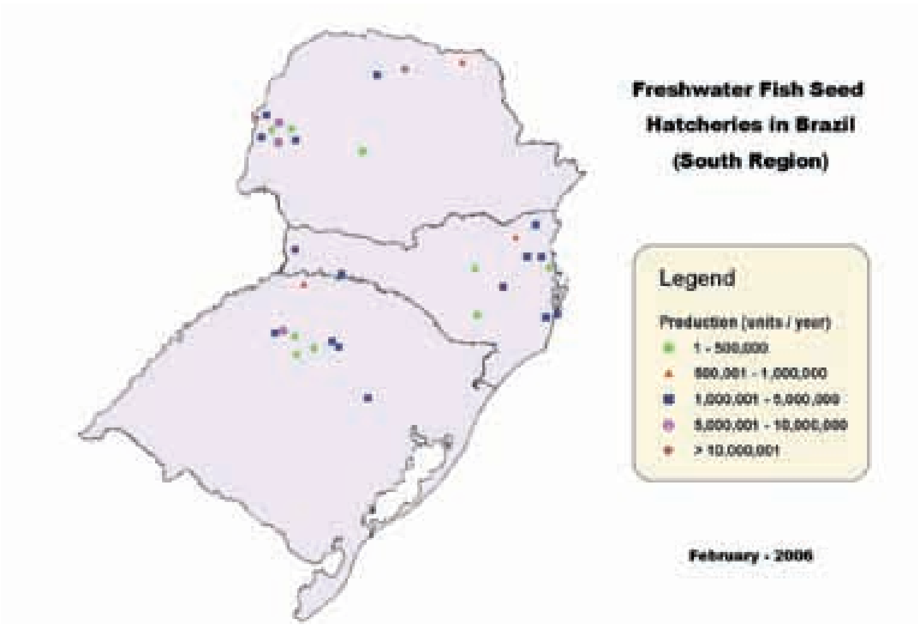


FIGURE 7.2.4
Freshwater fish seed hatcheries in Brazil (Southeast Region, February 2006)

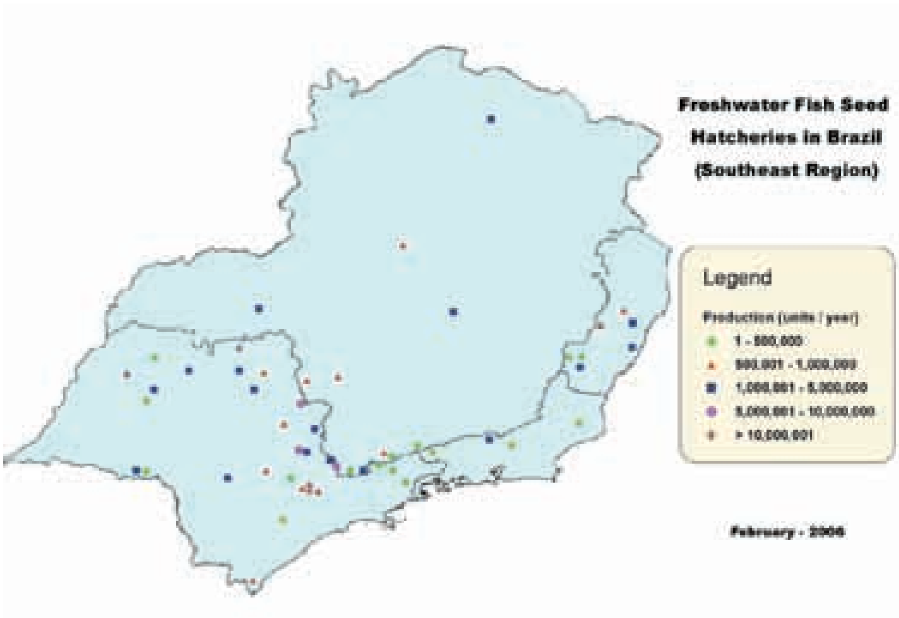


FIGURE 7.2.5
Freshwater fish seed hatcheries in Brazil (Mid-West Region, February 2006)

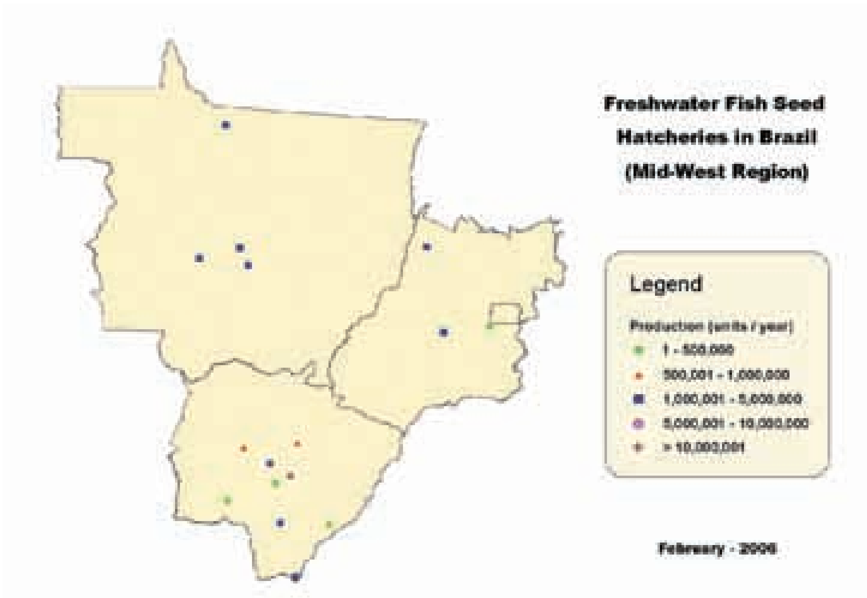


FIGURE 7.2.6

Freshwater fish seed hatcheries in Brazil (Northeast Region, February 2006)

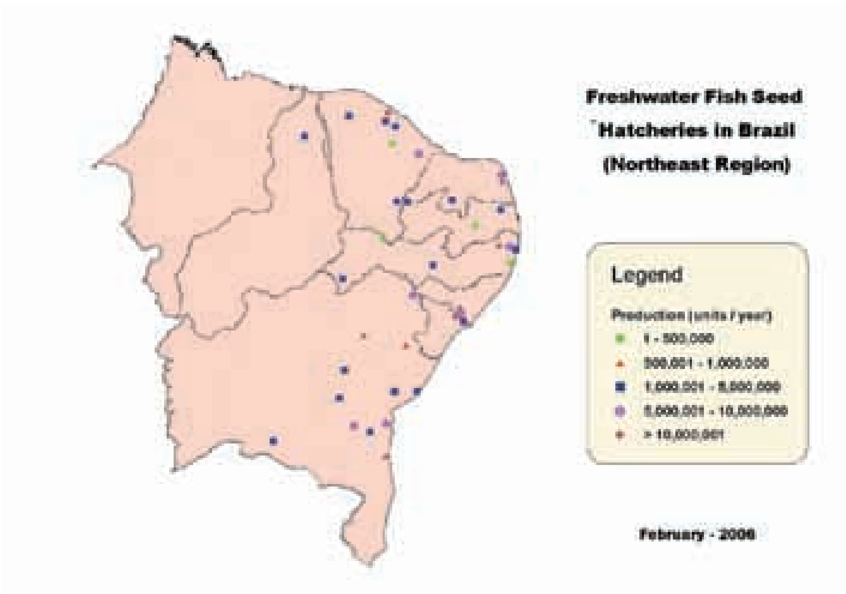
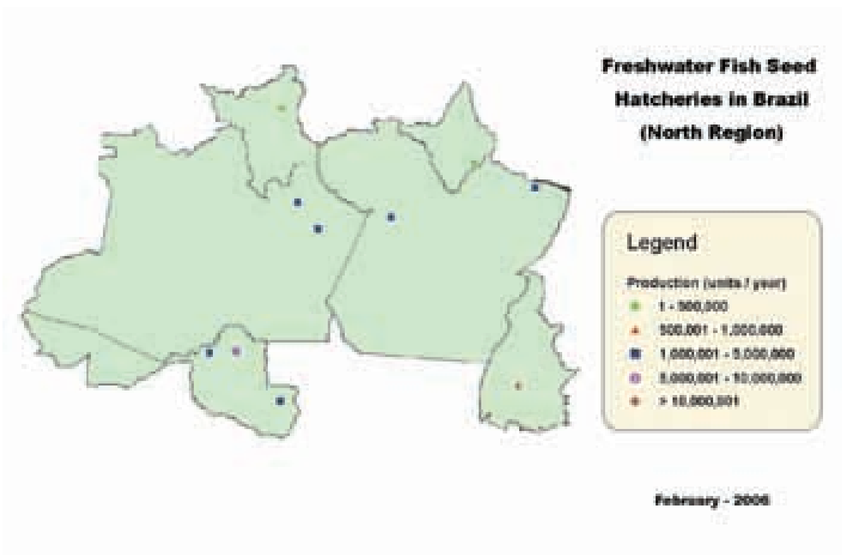


FIGURE 7.2.7

Freshwater fish seed hatcheries in Brazil (North Region, February 2006)



SEED MANAGEMENT

In pacu, tambaqui and pirapitinga, eggs and sperm are obtained through extrusion and fertilized in a container without water followed by incubation with continuous water movement. In some regions of Brazil, it is possible to obtain natural maturation of the broodstock with year-round spawns. Larvae start to feed five days after hatching when the water temperature is kept between 24 °C and 27 °C. First feed can be phytoplankton and zooplankton although these fish seems to prefer copepods (Zaniboni Filho, 2004).

Piau (*Leporinus friderici*), piapara (*L. elogantus*), piava (*L. obtusidens*) and chimboré (*L. amblyrhynchus*) show natural maturation in captivity and need hormonal induction for final maturation, ovulation and spawning. Spawn can occur in the tanks or through manual extrusion with dry fertilization. The latter is favoured by seed producers because it improves egg survival rate. Incubation is made in conventional incubators with continuous water movement. Larvae start feeding after five days and the main feed are *Cladocera* spp. and other zooplankton. Between ten and 20 days after first feeding, larvae accepts artificial feed (Zaniboni Filho, 2004).

Matrinxã (*Brycon lundii*), piracanjuba (*B. orbignyanus*), jatuarana (*B. cephalus*) and piraputanga (*B. cephalus*) reach their first maturation after one year for males and after two years for females. In captivity, final maturation and spawning can be obtained with hormones. For matrinxã, some producers utilize curimbatá hypophysis extract in doses of 4.4-5.5 mg/kg for females and 1.0-1.5 mg/kg for males (Gomes and Urbinati, 2005). Eggs are dry fertilized and kept in incubators with good water movement. Hatching occurs 16 hrs after fertilization when eggs are kept at 26 °C. First feed offered is zooplankton, mainly *Cladocera* spp., *Artemia* spp. and post-larvae of other fish. Great care with feeding is needed as these species show cannibalistic behavior when not fed to satiety. Best results with a survival rate of 72 percent are obtained during the 21 days larviculture from a density of 120 post-larvae/m^2. Post-larvae have to be fed three times per day using balanced feed with 35 percent of protein. Four days after hatching, the critical cannibal phase finishes and the larvae can be fed with pulverized commercial feed (Zaniboni Filho, 2004).

For the reproduction of the pintado (*Pseudoplatystoma corruscans*) and the cachara (*P. fasciatum*), seed producers use the same procedures as with gonad and hypophysis hormones. In captivity, males have their first maturation on the first year and females on the second year of life. The hormone treatment uses 5.5 mg of hypophysis extract per kg in females and 2 mg per kg in males. Production of eggs in the pintado and cachara is about 10 percent of the female weight and a 5-kg female can produce 1.1 million eggs. The hatched larvae measures about 3 mm and after three or four days, when they reach 4.5 mm, they start to feed on *Artemia spp*. The best density on the larviculture phase is 15 larvae/l and they need to be fed between 7 and 10 times per day with 500 nauplius/larvae. Survival rate in this phase is high, varying between 75 and 90 percent. Ten days after hatching, larvae can be fed with *Cladocera* spp. and copepods. In this phase, which normally takes 15-20 days, stocking density is reduced to 3-4 fish/l and survival rate varies between 50 and 80 percent. Balanced feed is offered after 60 days with 40 percent of crude protein. Juveniles are sold at 120-80 mm length and survival rate in the last phase is about 30 percent (Inoue *et al.*, 2003).

The dourado (*Salminus brasiliensis*), a fish greatly accepted by consumers especially by those practicing sports fishing, was first spawned under laboratory conditions in 2000. The fertilization rate that was initially at 10-20 percent is, nowadays, at 85 percent. This fish shows severe cannibalistic behavior, as soon as the yolk bag is absorbed, if not well fed. Excellent results have been obtained using curimbatá (*Prochilodus lineatus*) larvae as first live feed. Therefore it is common to schedule curimbatá spawns simultaneously with dourado spawns. Experiments have shown that 20 larvae of curimbatá for each dourado larvae is an appropriate feeding rate. The

PLATE 7.2.1
Illustration of some indigenous and exotic freshwater fish species (common names) of Brazilian aquaculture

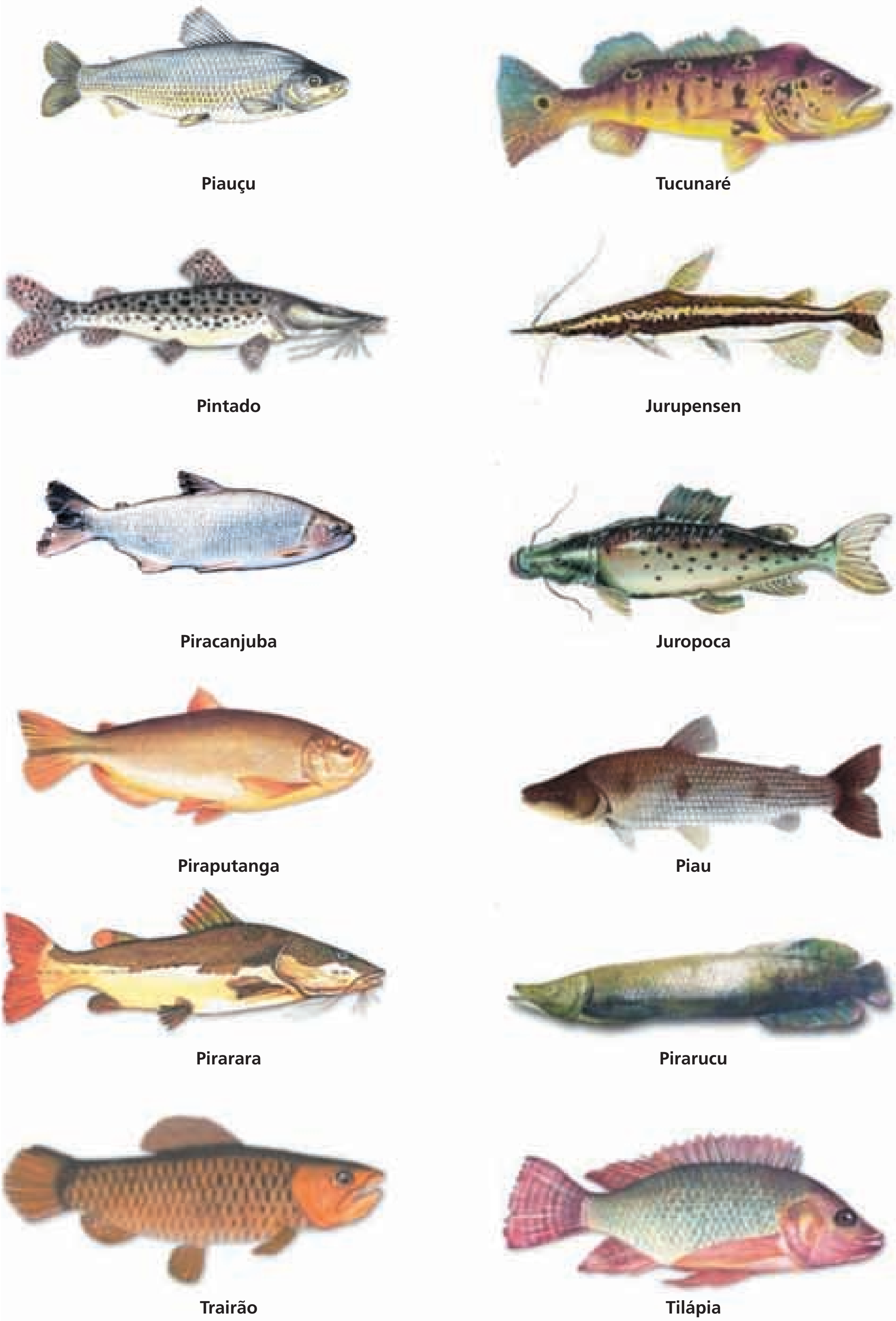
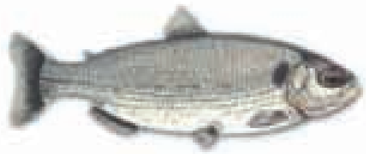


PLATE 7.2.1 (CONTINUED)

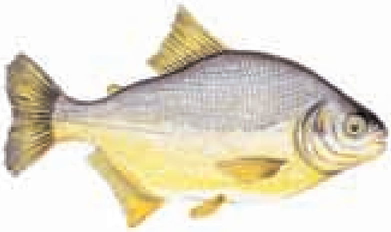
Illustration of some indigenous and exotic freshwater fish species (common names) of Brazilian aquaculture

Cachara

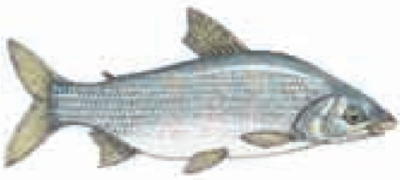


Matrinxã

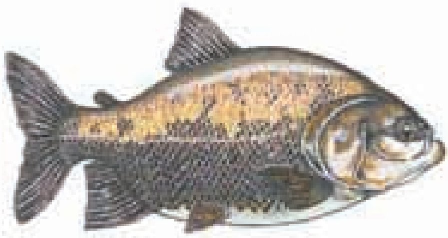
Cascudo



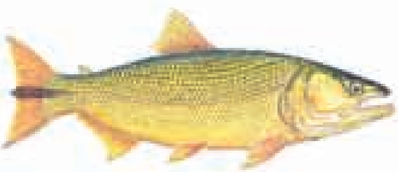
Pacú



Curimabata

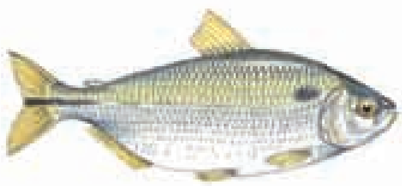


Tambaqui

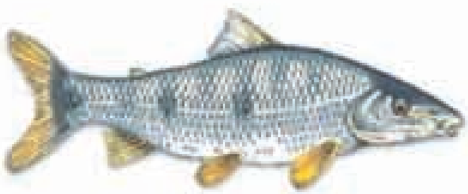


Dourado

Tabacú



Lambari



Piapara

larvae accept balanced feed five days after hatching. Best survival rate was observed with 24 hrs/day of light exposure while best growth rate was observed with 24 hrs/day of darkness. This fish grows fast until they reach 100 g and growth is reduced after this weight. More research are now underway to investigate the best timing for the feeding transition (from live feed to artificial feed), farming densities and practices, as well as nutritional demands for this species (Fracalossi, Zaniboni Filho and Meurer, 2002). The curimbatá, also known as curimatã, in some regions of Brazil, is easy to reproduce and handle. Their eggs are 2.9 mm in diameter and larvae hatch about 14 hr and 30 min after fertilization, with an average length of 3.5 mm when incubated at 28 °C (Fracalossi, Zaniboni Filho and Meurer, 2002).

The jundiá (*Rhamdia spp.*) is found in black, yellow, gray and albino colors. This fish matures and spawns naturally in captivity, but seed producers use hypophysis extract to induce maturation and spawning to enhance the efficiency of the process. A first dose of 0.5 mg/kg is applied in females kept at 25 °C and a second dose of 5.0 mg/kg is applied after 12-15 hrs. Males receive a single dose of 0.5 mg/kg simultaneously with the second dose applied in the females. Eggs are expelled 7-9 hrs after the application of the second dose, if the fish are maintained at 25 °C, or after 220-240 hrs at temperatures between 22 °C to 27 °C). Fertilization rate is around 70 percent and eggs hatch after 20 hrs at 25 °C. First feed offered is a balanced feed powder with 40-45 percent of crude protein together with *Artemia* spp. Fingerlings are kept at densities of 30 to 60 fingerlings/m^2 with good homogeneity until 30 days, but great heterogeneity (3.5-16 cm) is observed if these densities are maintained until 60 days (Carneiro *et al*., 2002).

Production of apaiari (*Astronotus ocellatus*) is based on natural maturation when couples are conditioned in reproduction tanks. Spawning is also natural and incubation is made by the fish in the same tank. Each couple makes an average of 3.5 spawns per year and they have a reproductive life between three and four years. Larvae start to feed on plankton four days after hatching; 20-day old fingerlings are fed with minced fish fillet, pure or mixed with balanced feed powder. After 50-60 days, when fingerlings reach 50 mm, they are separated from their parents, counted and stocked in 40 m^2 nursery tanks with a density of 50 fingerling/m^2. In general, it is common to obtain 600 fingerlings per spawn per couple, with a maximum of 2 100. In the nursery tanks, the apaiari are fed with minced fish fillet and/or minced shrimp twice a day with 5 percent of their biomass. The nursery phase takes about 40 days (Bezerra and Silva, 2005).

The major obstacle for the consolidation of pirarucu farming is the lack of methodology to develop controlled reproduction to satisfy the increasing demand for juveniles of this species. At this stage, all seed are obtained from fish collected in the wild that have spawned in captivity. Pirarucu has a complex mating behavior before spawning. The traditional techniques of hormone induction have not being observed with success and farmers do not have control on the mating behavior. Therefore, there are difficulties to produce fingerlings on a continuous and scheduled base. Research on pirarucu husbandry and reproduction is scarce, one of the reasons being the difficulty in handling the animal because of its size. Fish gonad maturation usually starts in between 40 to 60 kg body weight. Many pirarucu farms maintain a certain number of adult males and females (although the method to differentiate sexes are still under controversy) under captivity and their mating behaviors (e.g. nest construction, matting, egg deposition and fish hatch) are followed closely in order to collect the larvae as soon as possible. It is reported an average around 3000 fish per cycle, with 3 cycles/yr. Information about their need for space, water quality, nutritional demand and reproductive physiology is very limited and this limitation of knowledge hinders the control of reproduction of pirarucu. In captivity, the pirarucu can spawn thrice a year with an average of 2 000 juveniles/spawn (Cerri, 1995). Recent studies of induced reproduction of pirarucu have been faced with great difficulties particularly in handling the fish due to its size, reaching maturity at 40 to 60 kg and final weight of 120 kg. Moreover, the quantity and costs of hormone applications are enormous when compared to the quantity normally used for other commercial species. Pirarucu larvae absorbs its yolk sac eight to nine days after hatching and the fingerlings take between 3-4 months to reach the juvenile stage (5-7 cm), when they are collected and separated from their parents. Juveniles are fed at least six times a day with zooplankton until they are transferred to grow-out tanks (Pereira-Filho and Roubach, 2005).

SEED QUALITY

Only a small percentage of seed producers have appropriate means to evaluate the quality of their product. One aspect that is observed by most hatcheries is the mechanical classification of seed sizes in order to deliver seed batches that are homogeneous in this aspect. Tilapia seed producers have great care with sexual reversion efficiency and most of them reports that rates of 99 percent are attained. Some producers have reported that there are bad quality tilapia seed being offered at lower prices in the market, particularly in the aspect of lower rates of sexual reversion. Most producers also informed that their seed attain survival rates of 95 percent if well handled by fish farmers. Some large hatcheries maintain constant contact with their customers to get feedback on survival and feed conversion rates. Information about seed health management is very limited and there is no sanitary control to avoid the spread of diseases through the commercialization of seed within different regions of the country.

SEED MARKETING

Freshwater fish culture in Brazil is divided in two complementary sectors: seed production and fish farming. Only a minority of fish farmers produce their own seed. Therefore, the commerce between seed suppliers and fish farmers is a critical point in the productive chain, where there is a need to standardize seed size classes. The seed is currently sold as fingerling I or fingerling II or juvenile, accordingly to its size or weight. This variety in terms of sizes and prices leads to great confusion in the seed market and causes a big heterogeneity in the product. An analysis of the problem was made in 2003 and it was recommended that all seed should be called 'juveniles' and divided in four standard size classes to allow product and price comparisons by fish farmers (Gomes, Araujo-Lima and Roubach, 2003).

A number of seed distributors buy larvae from hatcheries and raise them until commercial size. The commercial size varies between species and the normal size range for the first sale to grow-out tanks is between 3-5 cm. Some distributors are specialized in producing juveniles of 6-8 cm or 8-10 cm that are used by those fish farmers who utilize cages for farming in lakes and reservoirs.

In general, each seed producer makes the commercialization of his own product and some of them may drive more than 500 km to deliver goods to distant customers. With some local exceptions, the fish farming sector is not organized in associations, thus, there is no systematic mechanism or networking for seed distribution and sharing of information concerning supply and demand for fish seed. Large- and medium-seed producers deliver to any location in the country where their products are requested, either by air or by road, charging the freight costs to the buyer. A high airfreight cost is one problem that hinders the efficient distribution by small producers. Some seed producers program their hatchery activities according to previous orders.

SEED INDUSTRY

The seed industry was strongly focused on the supply of seed for recreational fishing parks in the 1980s and commercial fish farming to supply restaurants, supermarkets and processing factories were only established in the 1990s. Nowadays, it is possible to find small-, medium- and large-scale seed production companies in almost every part of the country, although the exact number of producers is hard to determine due to poor statistical service by the government and non-registration of hatchery producers. Production scale varies from 5 000 to more than 50 million seed/yr and the distribution of hatcheries according to the production scales are shown in Figures 7.2.2-7.2.7.

Tilapia is by far the most produced species in Brazil and large companies are now increasing the participation of Brazilian tilapia in the international market. Tilapia seed production is also more technically developed than seed production of native or other introduced species. However, as this is the main species farmed in Brazil, prices are not very high, averaging US$29.50/thousand seed (price ranging from a minimum of US$13.6 to a maximum of US$59). Cyprinids and most native species are commercialized with an average price of US$30/thousand seed. Production of leading fish like pintado, cachara, surubim (*Pseuplatystoma* spp.) and jurupensem (*Sorubim lima)* are relatively difficult in comparison with the production of other native species which explains the lower production levels and very elevated prices which can be more than ten times, averaging at US$ 1/unit. Pirarucu is by far the most expensive fish; seed price is dependent on its length. The average price of a pirarucu juvenile with length of 15 cm is US$8.3/unit with maximum prices reaching US$13.6/unit. Non-payment among seed buyers was not identified as a problem based on interviews with seed suppliers.

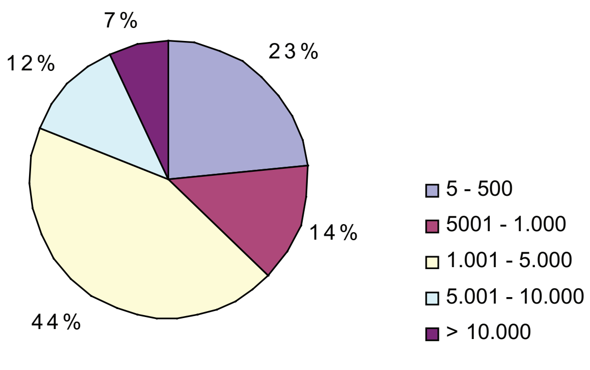
The number of employees in this industry sector was not determined, but some large hatcheries informed that up to 30 people are involved in seed production. If an average number of 15 employees per hatchery are assumed, it can be estimated that the sector generates 2 625 direct jobs. As many hatcheries are family-based business, women are therefore very much involved in this industry in Brazil. The number of indirect jobs is difficult to determine or estimate as there are numerous seed distributors and hatchery equipment suppliers in the country.

SUPPORT SERVICES

In general, the support services for seed producers are provided by universities and federal research institutions that are involved with aquaculture. Among the main institutions, it can be mentioned that the following are service providers, namely: (i) Aquaculture Research and Training Center – CEPTA in Pirassununga, São Paulo, (ii) Aquaculture Center of the São Paulo State University (CAUNESP - UNESP) in Jaboticabal, (iii) Freshwater Fish Aquaculture Laboratory from the Federal University of Santa Catarina (LAPAD – UFSC), the São Paulo Fisheries Institute, (iv) Superior School of Agriculture Luis de Queiroz from the University of São Paulo in Piracicaba (ESALQ – USP) and (v) Animal Reproduction Laboratory from the State University of Maringá in Paraná (UEM).

These institutions are responsible for the development of the fish reproduction technology of most indigenous species. The reproduction technology of some species like pintado *(Pseudoplatystoma* spp.) and patinga (hybrid of female *Piaractus mesopotamicus* with male *Piaractus brachypomus*) were developed by private hatcheries and are now available at the national level. A major deficiency in Brazilian aquaculture that also impacts on the seed production industry is the absence of efficient extension programs and services. Many seed producers have

FIGURE 7.2.8
Frequency of freshwater fish seed producers based on production volume in 2005 (x 1 000)



Source: Interview with 175 seed producers reported that they do not have access to the latest technology achievements made by the universities and aquaculture research institutions.

SEED CERTIFICATION

To date, there is no seed certification processes or organizations involved in certification in Brazil. There is only one organic tilapia producer in the Paraná State and he produces his own seed without sexual reversion. To avoid reproduction in the farm ponds, farmers separate females from males when they reach a bigger juvenile stage. The Brazilian Association for the Culture of Aquatic Organisms (ABRACOA) has recently launched a traceability program and they are now promoting training courses and making efforts to involve seed producers, fish farmers and fish processors/ distributors.

LEGAL AND POLICY FRAMEWORK

There are few legal regulations regarding aquaculture seed production in Brazil. According to the law, every hatchery and fish producer need to have an Aquaculturist Registration document issued by the Special Secretariat of Aquaculture and Fisheries from the Presidency of the Republic of Brazil (SEAP/PR). However, the Aquaculturist Registration is preceded by the emission of environmental license and, as the majority of aquaculture establishments are not licensed yet, the number of registered producers are also very low. This situation leads to a lack of good statistical information, which could contribute towards better governance and management of the national aquaculture sector.

Similarly, the lack of registration makes the implementation of sanitary control or health programs for aquatic animals difficult. The federal government structure to implement efficient sanitary control programs is very poor and the Ministry of Agriculture, Supply and Cattle (MAPA), who is responsible for this role, has only one technician to undertake this job.

At the moment, the National Council for Environmental Affairs (CONAMA) is discussing the elaboration of a federal regulation regarding the issuance of an environmental license for aquaculture establishments. Although some of the 24 States of the Federation have their own regulation to aquaculture environmental licensing, the majority does not have any legal framework in this aspect. It is expected that with the publication of the CONAMA regulation for the environmental licensing of aquaculture, this procedure will become less bureaucratic and more accessible for aquaculturists. In Brazil, it is very clear that all fish producers wants to be registered and licensed but the inexistence of an appropriate legal framework is hindering that.

Fish farming in Brazil is entirely based on hatchery production of seed and the use of seed from wild sources is not allowed by the government if the fish is to be stocked in cages. There is no mention in the law of such prohibition if the fish seed is collected in the wild to be stocked in aquaculture ponds.

ECONOMICS

As mentioned in the section on ‘seed industry’, the production of fish seed flourished in the 1980s to satisfy the increased demand for recreational fishing parks. The transition from recreational fishing parks to fish farms as main seed market brought considerable changes in the customer demand. Some fish that were preferred for sports or recreational fishing were substituted by other species more suitable for farming, processing and filleting. Factors that determine the price of seed are: (i) preference by local farmers and final consumers, (ii) demand and supply and (iii) size of the seed. The last factor is very hard to standardize as there is no common agreement within the industry of a clear way to classify the seed by weight or size classes, as mentioned before. For this reason, it is common to find price fluctuations of even ten times among different regions, but prices tend to be more homogeneous within one particular region. In general, seed production is concentrated during the period between October and April and seed are offered at lower prices during this part of the year. After April, as seed become bigger, prices get higher accordingly. Most of the seed producers interviewed in the preparation of this report informed that aquaculture was their main or single occupation and the great majority informed that they intend to increase their production next year, indicating that seed production is a profitable business.

FUTURE PROSPECTS AND RECOMMENDATIONS

With the recent establishment of the Special Secretariat of Aquaculture and Fisheries (SEAP) at the federal level, Brazil has formulated, for the first time, an aquaculture development policy. This demonstrates that aquaculture is now recognized by the Federal Government as an important industry that can contribute significantly to job and income generation and food production. Many things that should have been done in the past, including the establishment of an appropriate legal framework for aquaculture with clear rules that can attract investments, are now underway. Federal investments in the aquaculture sector that were almost inexistent in the last decade are now substantial. In 2005, SEAP invested US$12 million to the whole sector (both marine and continental aquaculture).

Freshwater aquaculture has increased at an average rate of 10.8 percent per year in the last decade and this occurred under a very negative scenario. Although the country has 3.5 million ha of reservoirs, access to public water areas is virtually impossible due to the lack of a good legal and regulatory framework to aquaculture development. This is one major aspect that, together with the access to environmental license, had hindered the development of Brazilian aquaculture at a faster pace. It is expected that these two factors will finally be resolved in 2006 and many investors that are waiting for such resolution will feel strongly encouraged to take up the aquaculture industry.

To maintain sustainable and healthy aquaculture, it is vital that the government puts more emphasis in monitoring aquaculture production practices, particularly on aspects concerning seed, feed and the use of therapeutic substances (i.e. drugs and chemicals). The attention currently given to these factors is inappropriate and the government should formulate other mechanisms to address such issues.

The contribution from capture fisheries have been relatively stable in the last years and it is unlikely to increase in the near future. Aquaculture products, that already represents 26.5 percent of the national fish supply, is expected to increase continuously in the years to come. It is important, however, that the productive sector becomes more organized and that a strong Brazilian Aquaculture Association (ABRAQ) assumes its responsibilities and roles. Although ABRAQ was created more than ten years ago, it was never active as a representative of the industry interests.

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7.3 Freshwater fish seed resources in Cambodia

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So Nam & Haing Leap. 2007. An evaluation of freshwater fish seed resources in Cambodia, pp. 145–170. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fisheries Technical Paper.* No. 501. Rome, FAO. 2007. 628p.

ABSTRACT

Fish is the most important source of animal protein food for the Cambodian population and the potential of fish culture production from earthen ponds, floating cages and various other small water bodies in Cambodia is great. The supply of quality fish seed is a key factor to the expansion of fish farming. Fish seed demand at present is strong, unsatisfied and expected to expand and fish seed business in Cambodia is profitable. This review, based on existing literature and field survey, provides clear understanding of the current status of freshwater fish seed resources for aquaculture development in Cambodia. The review includes information relating to: (i) fish seed resources and supply, (ii) fish seed production facilities and seed technology, (iii) fish seed management and seed quality, (iv) fish seed marketing and seed industry, (v) fish seed support services, (vi) legal and policy framework and (vii) economics of fish seed in Cambodia. Based on the above information, the emerging challenges in Cambodia's freshwater fish seed sector are identified as: (1) broodstock management and species identification, (2) human capacity and training needs, (3) monitoring and evaluation, and indicators, (4) hatchery facilities and equipments, (5) research planning for breeding and weaning of Cambodia's Mekong indigenous fish species, (6) environmental issues, (7) networking, communications and marketing and (8) management and budgets.

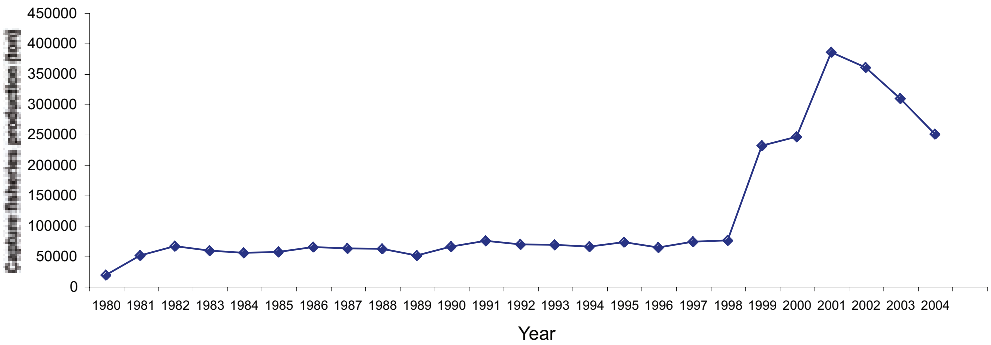
Fish seed supply from Cambodia's hatcheries constitute around 18 percent and much lower than the ones from wild source (26 percent) and imported source (56 percent). The Department of Fisheries (DoF) should request FAO's assistance in preparing a project for submission to an interested international or regional financial institution to support the following: (a) government and private hatcheries to produce and distribute quality fish seed of existing exotic and indigenous species on a commercial basis, (b) to establish farmer hatcheries in all provinces and (c) to rehabilitate and improve earthen ponds and floating cages. The fund received from an interested international or regional financial institution could be a loan and/or grant. The Royal Government of Cambodia through the Ministry of Agriculture, Forestry and Fisheries, MAFF) should support the DoF's ideas and partially provide fund to prepare the project proposal and implement the project.

INTRODUCTION

The fisheries sector plays an important role in the national economy and food security of Cambodia and therefore contributes significantly to national development objectives (So Nam and Buoy Roitana, 2005). Fish is the single most important and affordable food source accounting for over 75 percent of the total animal protein intake. Cambodians are considered one of the highest per capita consumers of fish in the world (a recent estimate revealed a consumption of 66 kg/person/year from household surveys). Fish is also a significant source of employment and income for rural households which comprise almost 90 percent of the country's poor. In recent years, an annual estimate of freshwater capture fisheries production ranges from 300 000 to 400 000 tonnes (Deap, 1998; Ahmed *et al*., 1998). This figure makes Cambodia as the fourth largest country in the world after China, India and Bangladesh in terms of freshwater capture fisheries production. It contributes over 75 percent to the total fisheries production (i.e. freshwater and marine fisheries and aquaculture production). The estimated gross value of freshwater capture fisheries varies from US$250 million to US$500 million, representing considerable revenue (~ 10 percent of GDP) for the government.

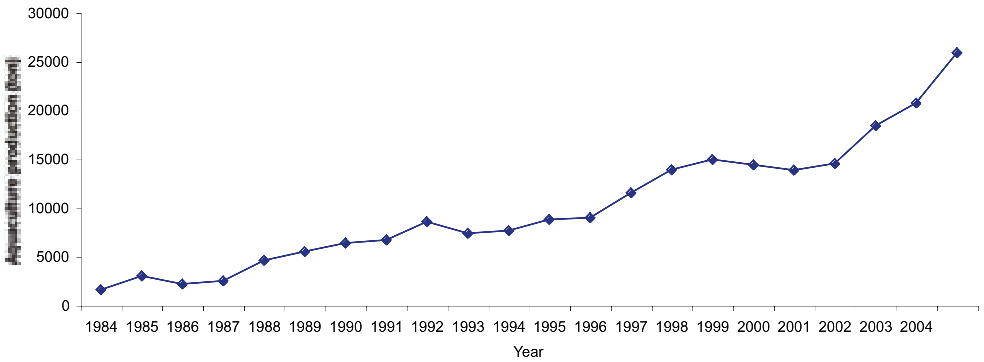
Since the year 2000 when Cambodia adopted reforms in the fisheries sector, inland fisheries took off rapidly (Figure 7.3.1). Freshwater aquaculture production continued to show growth over the past two decades and increased from 1 610 tonnes in 1984 to 20 760 tonnes in 2004 (Figure 7.3.2), representing an 11.9-time increase or a growth of 16.3 percent per year, ahead of annual growth rate (10 percent) of world aquaculture

FIGURE 7.3.1
Trends of freshwater capture fisheries production in Cambodia



Source: DoF Fisheries Statistics (DoF, 2005)

FIGURE 7.3.2
Trends of freshwater aquaculture production in Cambodia



Source: DoF Fisheries Statistics (DoF, 2005) production (Olin, 2000). It represented 8.3 percent of total inland fisheries production in 2004 (So Nam *et al*., 2005). Based on fish seed supply information in this study, the freshwater aquaculture production figure is underestimated. The newly estimated freshwater aquaculture production is between three to four folds of the official figure, around 60 000 to 80 000 tonnes. Therefore, Cambodian aquaculture has expanded, diversified and intensified, its contribution to aquatic food production has increased gradually. It is highly diverse and consists of a broad spectrum of systems, practices and operations, ranging from simple backyard small, household pond systems to large-scale, highly intensive, commercially oriented practices (So Nam and Nao Thuok, 1999; So Nam *et al*., 2005).

The current situation of freshwater cage and pond aquaculture in Cambodia is summarized in the study of So Nam *et al*. (2005). Cage culture is reported to have originated in Cambodia as an activity integrated with fisheries rather than agriculture and its history is going back to the 10th century (So Nam and Nao Thuok, 1999). The number of fish cages remained more or less stable for the last ten years and reached 4 492 cages in 2004, operated in the Mekong basin, including the Tonle Sap Great Lake (42 percent), Tonle Sap River (17 percent), upper stretch of the Mekong River (19 percent), lower stretch of the Mekong River (14 percent) and Bassac River (7 percent). It is entirely dependent on wild fish both as seed and feed (So Nam *et al*., 2005). So Nam and Nao Thuok (1999) estimated that 72 percent of freshwater aquaculture production came from cage/pen culture and the remaining 28 percent from pond culture.

Although Cambodia has no tradition to culture fish in earthen ponds in rural areas due to the difficulty of keeping water in fish ponds during dry season, the number of ponds used rapidly increased from 3 455 in 1997 to 11 509 in 2004 representing a 43 percent increase (So Nam *et al*., 2005). The major fish species produced include indigenous and exotic species and hybrid catfish interbreeding occurs between Asian and African catfishes. In recent years, small-scale pond aquaculture has been introduced by the Department of Fisheries of the Ministry of Agriculture, Forestry and Fisheries (MAFF-DoF) and a number of non-governmental organizations (NGOs) and donors for the purpose of generating alternative livelihoods and securing animal protein source. As a result, small-scale fish culture in ponds has gradually been developed in certain areas, where project interventions were successful.

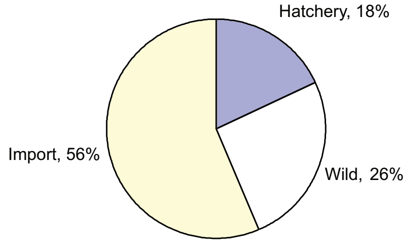
Aquaculture development in Cambodia is clearly constrained by a lack of constant or secure supply of good quality fish seed (So Nam *et al*., 2000). After witnessing good progress in aquaculture operation, seed availability is considered a crucial standpoint to continue its further development. Twenty three potential indigenous fish species were selected during the National Workshop on "Cambodia's Fish Seed Production - Current Status and Logical Framework Analysis" for aquaculture development, fisheries stock enhancement, trade and conservation. In order to provide fish seed to fish farmers, public or government and private or farmer hatcheries should be well established in the country to stabilize and strengthen the aquaculture activity.

The main objective of this study, which is based on the current literature and actual interviews or field visits, is to assess the status of freshwater fish seed resources in Cambodia. The collected information include: (i) fish seed resources and supply, (ii) fish seed production facilities and seed technology, (iii) fish seed management and seed quality, (iv) fish seed marketing and seed industry, (v) support fish seed support services, (vi) legal and policy framework and (vii) economics of fish seed in Cambodia.

FISH SEED RESOURCES AND SUPPLY

Fish seed (fingerling) supply for aquaculture farms in Cambodia comes from three major sources, namely: (1) hatchery source, (2) wild source and (3) imported source. Fish seed supply from hatchery source was significantly lower than the ones from wild

FIGURE 7.3.3
Major sources of fish seed supply in Cambodia (2004)



Source: So Nam *et al.* (2005); DoF Fisheries Statistics (2005); field surveys (2005)

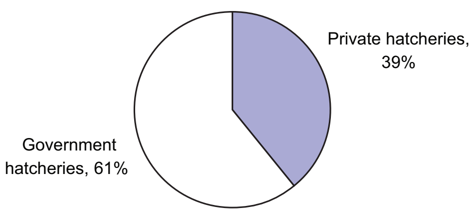
and imported sources, being 18 percent compared to 26 percent and 56 percent, respectively (Figure 7.3.3).

Fish seed supply from hatchery source

Fingerling supply from hatchery source included supply from private (farmer) and public (government) hatcheries (Figure 7.3.4). Private hatcheries annually supplied a lower amount of fingerlings compared to public hatcheries, 39 percent and 61 percent, respectively (Figure 7.3.5). There are five species produced by private hatcheries in 2004, including one

FIGURE 7.3.4
Location of freshwater fish seed hatcheries in Cambodia

FIGURE 7.3.5
Percentage distribution of fish seed supply from hatchery source in Cambodia (2004)



Source: So Nam *et al.* (2005); DoF Fisheries Statistics (2005); field surveys (2005)

indigenous species, silver barb (*Barbonymus gonionotus*) and four exotic species: silver carp (*Hypophthalmichthys molitrix*), common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*) and mrigal (*Cirrhinus cirrhosus*). Public hatcheries produced 12 species composed of: (a) six indigenous species including silver barb, sutchi catfish or river catfish (*Pangasianodon hypophthalmus*), hoven's carp (*Leptobarbus hoevenii*), red tail tinfoil barb (*Barbonymus altus*), walking catfish (*Clarias macrocephalus*) and snakeskin gourami (*Trichogaster pectoralis*) and (b) six exotic fish species including silver carp, common carp (*Cyprinus carpio*), big head carp (*Aristichthys nobilis*), mrigal and rohu (*Labeo rohita*).

Fish seed supply from wild source

This is the first time that fish supply from wild source in Cambodia is being documented. Fish seed locally collected from rivers and lakes or reservoirs during spawning season included snakehead (*Channa micropeltes* and *C. striata*), pangasiid catfishes (*Pangasianodon hypophthalmus*, *Pangasius conchophilus, P. larnaudiei* and *P. bocourti*), *Hemibagrus* catfish (*Hemibagrus wyckioides*) and barbs (*Barbonymus gonionotus Barbonymus altus*) (Table 7.3.1). Fishers know the times when fry or fingerlings are most abundant and will collect them, store them in floating cages and provide feed until sale. Mortality in this system is high and sale price is relatively low. Trade is illegal and laws are poorly enforced. For example, in 2004, an estimate of approximately 20 million fingerlings collected from the wild was supplied for cage culture in Cambodia (Table 7.3.1). The most popular species for cage culture was the giant snakehead *C. micropeltes*, representing 77.1 percent of the total

A private freshwater fish seed hatchery in Takeo Province, Cambodia

COURTESY OF AQUACULTURE DIVISION

A public freshwater fish seed hatchery in Prey Veng Province, Cambodia

COURTESY OF HAV VISETH

TABLE 7.3.1
Fish seed supply from wild source for cage aquaculture in Cambodia (2004)

Fish species**	Total no. of cages	%	Average cage volume (m^3/cage)	Total cage volume (m^3)	Stocking density (fingerling/m^3)	Total no. of fingerling (head)
Channa micropeltes	3 494	77.8	30.4	106 256	145	15 407 048
Pangasianodon hypophthalmus	210	4.7	95.4	20 050	57	1 142 822
Pangasius conchophilus	210	4.7	73.7	15 496	61	945 282
Pangasius larnaudiei	158	3.5	90.5	14 259	30	427 783
Pangasius bocourti	105	2,3	90.1	9 469	66	624 968
Barbonymus gonionotus	79	1,8	63.7	5 017	63	316 095
Barbonymus altus	79	1,8	91.3	7 191	60	431 468
Channa striata	26	0,6	59.5	1 563	12	18 756
Hemibagrus wyckioides	26	0.6	64	1 681	13	21 856
Polyculture*	105	2.3	78.4	8 238	80	659 037
Total	**4 492**	**100.0**	**73.7**	**331 043**	**59**	**19 432 232**

Source: So Nam et al. (2005); DoF Fisheries Statistics (DpoF, 2005)

Note: * Polyculture of *P. hypophthalmus, P. conchophilus, P. larnaudiei, P. bocourti, B. gonionotus and B. altus* and the composition of eachfish species is nearly equal.
** All fish stocked in cages are indigenous species and collected from the wild.

wild collected fingerlings. The second popular species were the four pangasiid catfish species, representing 17.9 percent. The third popular species were the two *Barbonymus* barbs, representing 4.8 percent and the remaining less than 1 percent were *C. striata* and *H. wyckioides*. Aquaculture of such carnivorous and omnivorous fish species highly depends on small, wild fish from inland fisheries for sourcing key dietary nutrient inputs (So Nam *et al*., 2005). Salting, fermentation and/or drying are used to preserve them when the seasonal supply of wild fish declines. Hatchery production of these indigenous fish species is costly, requiring several year-old broodstock and intensive inputs. Some on-going research activities on broodstock development and management, induced breeding, nursing and grow-out are currently confined to two or three large state/NGO or donor-supported hatcheries.

Collection of fry and fingerlings of bagnet or *dai* had been declared illegal in Cambodia since 1994, but the implementation or enforcement was weak. In addition to *Pangasianodon hypophthalmus*, other pangasiids and several cyprinid species are also caught. Only *P. hypophthalmus* are kept alive to supply pond and cage aquaculture and the rest are thrown away or used as feed. Van Zalinge *et al.* (2002) reported the share of catch of *P. hypophthalmus* in Cambodia to be 25 percent. Based on sale figures from two licensed companies, an estimate of 6.6 million *P. hypophthalmus* fingerlings were sold in 2004 to pond aquaculture farmers all over the country.

Fish seed supply from imported source

Cambodia used to export tens of billions of *P. hypophthalmus* fry and tens of millions of *P. bocourti* fingerlings collected from the Mekong River basin to neighboring countries in the 1980s and 1990s (So Nam, 2005a). Nowadays, the country is importing millions of fish seed from neighboring countries to supply the big demand for aquaculture (Table 7.3.2).

Nine fish species were imported in 2004, namely: (a) six exotic species: hybrid catfish (*Clarias gariepinus x C. batrachus*), tilapia, silver carp, mrigal, common carp, grass carp (*Ctenopharyngodon idella*) and (b) three indigenous species: sutchi catfish (*Pangasianodon hypophthalmus*), giant gourami (*Osphronemus goramy*) and climbing perch (*Anabas testudineus*) (Table 2). An estimated 60 million fingerlings were in 2004 and supplied for both cage and pond aquaculture. Viet Nam is the main fingerling exporting country from three major fish seed companies (i.e. En Phean, Gaza and Suy Chea) licensed by MAFF to import fish seed from Viet Nam. Thailand also exports fish seed but to a lesser extent. The two most important imported species were hybrid catfish and tilapia contributing 87.5 percent to the total fish seed imported, i.e. 63.3 percent and 19.2 percent, respectively (Table 7.3.2). It is believed that the proportion of imported hybrid catfish will increase from this year onwards because this species can replace giant snakehead cultured in cages. Giant snakehead cage culture operation was banned by the government in the mid-2005 due to its significant dependency on small, wild fish for dietary nutrient inputs (So Nam *et al*., 2005). Escapes of this hybrid catfish may also bring negative side-effects in the aquatic environment. The third most important imported species was silver carp (5 percent), followed by sutchi catfish (2.5 percent), mrigal (2.0 percent), common carp (1.5 percent), grass carp (1.0 percent), giant

TABLE 7.3.2
Fish seed species imported from hatcheries in Tien Giang province, Viet Nam for pond and cage aquaculture in Cambodia (2004)

Fish species*	No. of fingerling	%
Clarias gariepinus x C. batrachus	41 000 000	68.33
Oreochromis niloticus	11 500 000	19.17
Hypophthalmichthys molitrix	3 000 000	5.00
Pangasianodon hypophthalmus	1 500 000	2.50
Cirrhinus cirrhosus	1 200 000	2.00
Cyprinus carpio	900 000	1.50
Ctenopharyngodon idella	600 000	1.00
Osphronemus goramy	150 000	0.25
Anabas testudineus	150 000	0.25
Total	**60 000 000**	**100.00**

Note: * All nine fish species are imported from hatcheries in Tien Giang province, Viet Nam.

gourami (0.3 percent) and climbing perch (0.3 percent). Ing Kimleang (2004) reported that many unlicensed traders or small companies imported seed mostly from Viet Nam and Thailand to supply both cage and pond aquaculture farmers of the country. Over 200 million fingerlings were annually estimated to have been imported. Plausible reasons for importing fish seed from neighboring countries to supply Cambodian aquaculture were:

- local hatcheries could not supply the demand of seed for aquaculture;
- fish seed supply from local hatcheries was not available for most of the year;
- price of imported fish seed was cheaper than that of local hatchery produced seed due to lower labor, water and electricity costs and higher water availability and quality in exported countries;
- potential for aquaculture development in Cambodia are high leading to higher demand than supply of seed; and
- fish catch from natural water bodies had drastically declined in recent years, so aquaculture is the best option to increase family fish production and consumption.

Plate 7.3.1 illustrates the existing and indigenous freshwater species in Cambodian aquaculture.

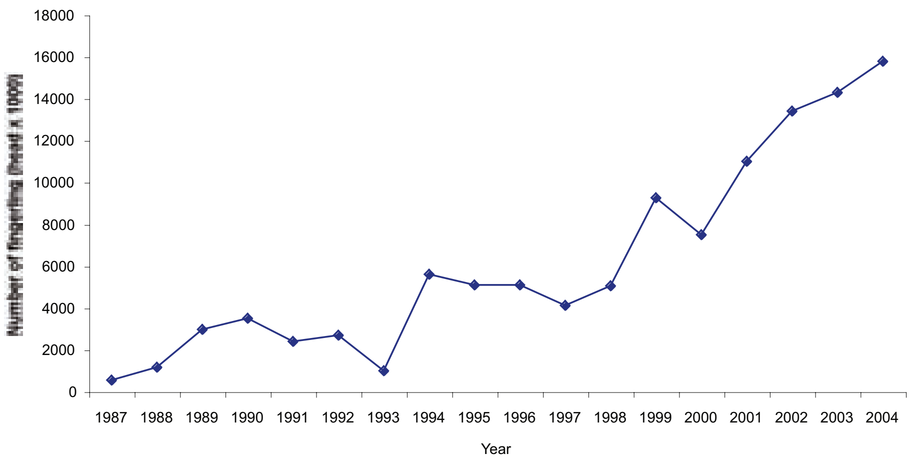
FISH SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

As mentioned above, freshwater aquaculture production in Cambodia increased drastically during the last two decades. Consequently, fish seed production also grew rapidly in recent years, starting from 560 000 fingerlings in 1987 to 15.8 million fingerlings in 2004 (Figure 7.3.8). This national figure included fingerling production from hatchery source only. It is believed that the current figures are underestimates as some fingerling production from private hatcheries have been excluded. Based on the existing number of hatcheries, the newly estimated amount of fingerling production was 18.4 million in 2004, including 11.2 million fingerlings from government hatcheries and 7.2 million from small-scale farmer-operated hatcheries (Table 7.3.3).

Government hatcheries

Of 24 provinces and municipalities in Cambodia, in total, there are 14 government hatcheries located in 13 provinces and municipalities (Table 7.3.3). Of the 14 government hatcheries, there are (a) two DoF hatcheries: the Chrang Chamres Fisheries Research Station (CCFRS) located in Phnom Penh City and the Bati Fish Seed Production and

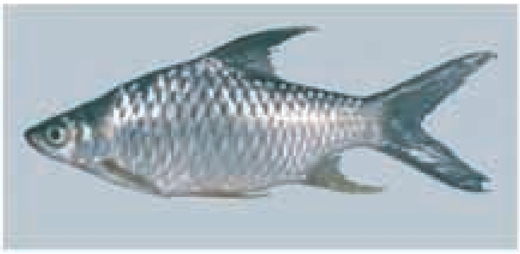
FIGURE 7.3.6
Trends in fish seed production in Cambodia



Source: DoF Fisheries Statistics (DoF, 2005)

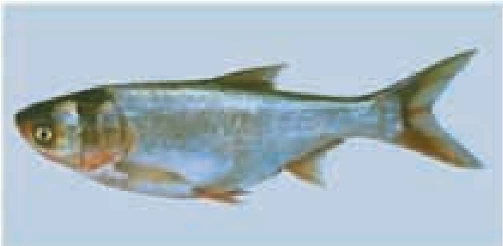
PLATE 7.3.1

Illustration of existing exotic and indigenous freshwater fish species of Cambodian aquaculture



Silver barb

Common carp



Silver carp

Bighead carp

Rohu

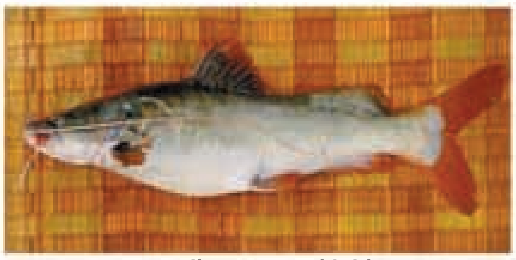
Mrigal

Sutchi catfish

Walking catfish

Pangasius larnaudii

Pangasius bocourti

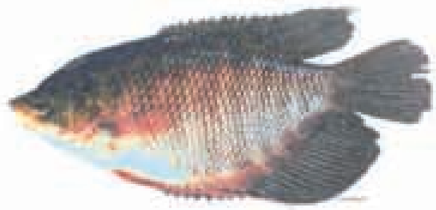


Hemibagrus wyckioides

Pangsius conchophilus

PLATE 7.3.1 (CONTINUED)

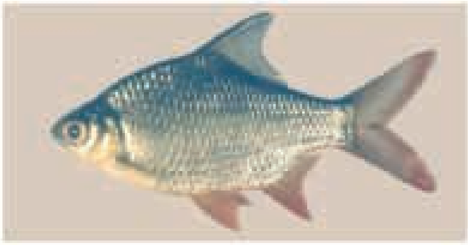
Illustration of existing exotic and indigenous freshwater fish species of Cambodian aquaculture



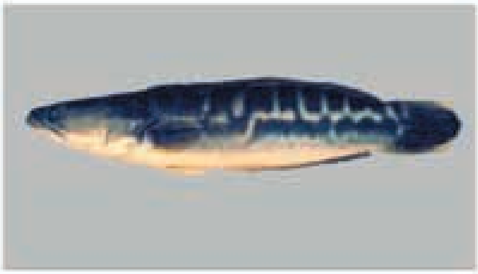
Giant gourami

Nile tilapia

Snakeskin gourami



Red tailed tinfoil barb



Giant snakehead

Snakehead murrel

Hoven's carp

Hybrid Clariid catfish

Climbing perch

Grass carp

TABLE 7.3.3
Existing number of hatcheries and their freshwater fish seed production in Cambodia (2004)

Province/municipality*	Number of hatcheries		Total	Number of fingerlings produced		Total
	Private or farmer	Public or government		Private hatchery	Public hatchery	
Phnom Penh	0	2	2	0	3 500 000	3 500 000
Kandal	8	1	9	1 200 000	3 803 000	5 003 000
Prey Veng	8	1	9	1 200 000	1 938 000	3 138 000
Takeo	8	1	9	1 920 000	500 750	2 420 750
Svay Rieng	24	1	25	1 800 000	405 500	2 205 500
Kampong Speu	6	1	7	656 000	164 000	820 000
Kampong Cham	0	0	0	na	na	na
Kratie	0	1	1	na	nb	0
Stung Treng	0	0	0	na	na	na
Kampong Thom	2	0	2	nb	na	0
Kampong Chhnang	2	0	2	nb	na	0
Pursat	0	1	1	na	200 000	200 000
Battambang	2	1	3	nb	nb	0
Banteay Mean Chey	2	1	3	nb	nb	0
Odar Mean Chey	2	0	2	150 000	na	150 000
Siem Reap	2	1	3	100 000	162 000	262 000
Ratanak Kiri	1	0	1	nb	na	0
Mundol Kiri	0	0	0	na	na	na
Pailin	0	1	1	na	43 000	43 000
Preah Vihear	2	0	2	55 000	na	55 000
Kep	0	0	0	na	na	na
Kampot	2	1	3	200 000	500 000	700 000
Sihanouk ville	0	0	0	na	na	na
Koh Kong	0	0	0	na	na	na
Total	**71**	**14**	**85**	**7 281 000**	**11 216 250**	**18 497 250**

Note: * Cambodia is composed of 24 provinces and municipalities; na, not applicable; nb, no breeding activity meaning that hatchery not operated.

Research Center (BFSPRC) located in Prey Veng province and (b) 12 provincial/municipal hatcheries under provincial/municipal administration (Table 7.3.3). The BFSPRC produced approximately 2.0 million fingerlings in 2004, followed by CCFRS which produced about 1.5 million fingerlings. Two other large-scale government operated hatcheries in the country are Toul Krasang Fish Seed Production Station (TKFSPS) in Kandal province supported by Farmer Livelihood Development (FLD, a local NGO) and Chak Ang Rae Fish Seed Production Station (CARFSPS) in Phnom Penh. The TKFSPS and CARFSPS also produced significant amount of fingerlings for sale, approximately 3.8 million and 2.0 million fingerlings in 2004, respectively. These four large state hatcheries produced around 83 percent of the total fingerling production from government hatcheries during the year.

Six indigenous fish seed species were produced by government-operated hatcheries (Table 7.3.4). The most popular species was silver barb, representing 28.2 percent of the total government hatchery fingerling production in 2004. The second most popular species produced by BFSPRC hatchery was sutchi catfish, representing 7.9 percent. Four species ranked as third most important species produced by CCFRS hatchery, namely: hoven's carp (0.8 percent), red tail tinfoil barb (0.3 percent), walking catfish (0.2 percent) and snakeskin gourami (0.2 percent). In total, indigenous fish seed production represented 37.5 percent or 4.2 million fingerlings in 2004. Furthermore, six exotic species were produced by government hatcheries, i.e. silver carp (12.9 percent), common carp (8.1 percent), bighead carp (4.6 percent), tilapia (20.0 percent), mrigal (15.3 percent) and rohu (1.7 percent). In total, exotic fish seed production contributed 62.5 percent to the total government hatchery fish seed production, or 7.0 million fingerlings. As a result, exotic fingerling production was 1.7 times more than the indigenous fingerling production.

TABLE 7.3.4
Fish seed supply from hatchery source for pond aquaculture in Cambodia (2004)

	Private or farmer's hatchery		Public or government hatchery		Total	
Fish species	**No. of fingerling**	**%**	**No. of fingerling**	**%**	**No. of fingerling**	**%**
Indigenous fish species						
*Barbonymus gonionotus***	1 969 511	27.05	3 158 496	28.16	5 128 006.5	27.61
*Pangasianodon hypophthalmus**	0	0.00	883 841	7.88	883 840.5	3.94
*Leptobarbus hoevenii***	0	0.00	89 730	0.80	89 730.0	0.40
*Barbonymus altus***	0	0.00	30 284	0.27	30 283.9	0.14
*Clarias macrocephalus***	0	0.00	22 433	0.20	22 432.5	0.10
*Trichogaster pectoralis***	0	0.00	22 433	0.20	22 432.5	0.10
*Cirrhinus microlepis**	na	na	na	na	na	na
*Osteochilus melanopleura**	na	na	na	na	na	na
*Channa micropeltes**	na	na	na	na	na	na
*Osphronemus goramy**	na	na	na	na	na	na
*Macrobracium rosenbergii**	na	na	na	na	na	na
*Cyclocheilichthys enoplos****	na	na	na	na	na	na
*Morulius chrysophekadion****	na	na	na	na	na	na
Sub-total	1 969 511	27.05	4 207 215	37.51	6 176 725.9	32.28
Exotic fish species						
Hypophthalmichthys molitrix	735 381	10.10	1 451 383	12.94	2 186 763.8	11.52
Cyprinus carpio	2 211 968	30.38	906 273	8.08	3 118 240.8	19.23
Aristichthys nobilis	0	0.00	512 046	4.57	512 046.2	2.28
Oreochromis niloticus	1 036 814	14.24	2 239 510	19.97	3 276 324.3	17.10
Cirrhinus cirrhosus	1 327 326	18.23	1 713 961	15.28	3 041 287.7	16.76
Labeo rohita	0	0.00	186 190	1.66	186 189.8	0.83
Sub-total	5 311 490	72.95	7 009 363	62.49	12 320 852.5	67.72
Grand total	7 281 000	100.00	11 216 250	100.00	18 497 250	100.00

Note: na, not applicable; * On-going research of brookstock development and/or management, inducing spawning, nursing and/or grow-out at Bati Fish Seed
Production and Research Station, Prey Veng province; ** On-going research of broodstock management, breeding and grow-out at Chrang Chamres Fisheries Station,
Phnom Penh; *** On-going research of broodstock development and inducing breeding at Toul Krasang Fish Seed Production Station, Kandal province.

Among the 14 government hatcheries, three hatcheries (located in Kratie, Battambang and Banteay Mean Chey provinces) were not in operation in 2004 mainly due to the lack of several reasons, mainly:

- lack of financial resources;
- lack of water source and poor water quality;
- lack of, poor quality of, or immature broodstock; and
- lack of human resources.

Besides fish seed production, current research activities are on-going at the three large-scale government hatcheries (i.e. BFSPRC, CCFRS and TKFSPS). On-going research activities at these hatcheries are described below.

Bati Fish Seed Production and Research Center (BFSPRC) hatchery

Research activities supported by the Aquaculture of Indigenous Mekong Species project of the Mekong River Commission (MRC-AIMS) and carried out in 2004-2005 included:

- **Production techniques of the cyprinid *Osteochilus melanopleura*.** The experiments were not successful as MRC-AIMS experienced difficulties breeding them, probably due to low quality of feed (protein, vitamins and fish oil) used for conditioning the broodstock. Some female broodstock matured and no male produced sperm.

- **Seed production of *P. hypophthalmus* from F1 broodstock**. The experiments of inducing breeding and of F1 broodstock and nursing of their hatchling and fry were successful. The results showed that F1 broodstock matures one year earlier than wild broostock. Spawning condition of F1 was easier than wild broodstock, with its fecundity ranging from 4 to 15 percent of body weight. F1 *P. hypophthalmus* can effectively induce spawning by using 2-3 sequences of fractional injection of Human Chorionic Gonadotropin (HCG) hormone at priming and Suprefact plus Domperidon at final injection.
- **Optimization of induced spawning of *O. melanopleurus***. The station got some progress of inducing spawning, about 10 percent of broodstock, fed with conditioning feed of 30 percent protein, vitamins C and E and fish oil, matured; however, only 2 000 fingerlings were produced.
- **On-going researches** include: (a) growth comparison of F1 and F2 *P. hypophthalmus* seed in cement tanks, (b) induced spawning of *Cirrhinus macrolepis* and (c) growth comparison of bottom feeders *O. melanopleura*, mrigal and common carp in grow-out earthen ponds.

The environmental aim of the DoF/MRC/AIMS project is to safeguard the indigenous fish resources quantitatively, as well as in terms of biodiversity, from negative side-effects of continued spreading of exotic species in the aquatic environment. The native species form an important part of the animal protein source for rural population and the promotion of indigenous fish culture is considered a good measure to protect native resources.

Research activities supported by the DoF/MRC-AIMS project and carried out in 2005 included:

- natural induced spawning of *Channa micropeltes* to produce F1 and F2 broodstocks, research is on-going;
- natural induced spawning of *Osphonemus goramy;*
- broodstock development of *Trichogaster pectoralis;* and
- broodstock development of *Macrobrachium rosenbergi*

Chrang Chamres Fisheries Research Station (CCFRS) hatchery

Research activities supported by the DoF/MRC-AIMS project and carried out in 2004-2005 included:

- **Evaluation of breeding and nursing conditions of wild and F1 broodstock of *Leptobarbus hoevenii*.** Results of of fecundity, fertilizing, hatching and survival rates from F0 and F1 broodstock were not significant.
- **Artificial and semi-artificial breeding of *Barbonymus gonionotus* and seed production.** There was no significant difference between the two breeding programs in terms of fecundity, fertilizing, hatching and survival rates, although in terms of financial analysis, the artificial breeding program was significantly lower in expenditure than the semi-artificial one due to less water consumption.
- **On-going research** include: (a) evaluation of protein and vitamin E on the growth of *L. hoevenii* seed in nylon net hapa, (b) investigation of grow-out monoculture of *L. hoevenii* in earthen ponds, (c) propagation of *B. gonionotus* using different suprefact hormone, (d) standardization of propagation of *L. hoevenii* using different hormone injection, (e) monoculture of *L. hoevenii* in grow-out ponds using different feed formulations and (f) optimization of inducing breeding of *B. altus*, *T. pectoralis* and *C. macrocephalus*.

Toul Krasang Fish Seed Production Station (TKFSPS) hatchery

Research activities supported by the FLD project and carried out in 2004-2005 included:

- broodstock development and induced breeding of the cyprinid *Cyclocheilichthys enoplos* and

- broodstock development and induced breeding of the black sharkminnow *Labeo chrysophekadion*.

Breeding experiments for *C. enoplos* and *M. chrysophekadion* were not successful, probably due to poor response to hormone injection, or the lack of spermatozoid from the male or the environment.

Most government hatcheries are now faced with the lack of water source and poor water quality due to rapidly increasing urban development activities. For example, CCFRS was the first site identified for the World Bank Agriculture Productivity Improvement Project (APIP) support, but following a suitability study, it was decided that an alternative site should be identified. The principal reason for such a decision was that the water supply to the station has been severed by the construction of an elevated road. The site is now entirely reliant on rainwater and its storage ability. The station now uses 3 ha ponds (over 2 m deep) for water storage. This water is used to operate the hatchery and is recycled back to the ponds. The reservoirs or storage ponds can also feed about 50 percent of the station's nursery ponds. It is believed that similar problems will be detected at two other large-scale government hatcheries (i.e. TKFSPS and CARFSPS) in the next 5 to 10 years.

Farmer hatcheries

As a result of several state- and NGO/donor-funded development projects, there were 71 small-scale farmer hatcheries located in 14 provinces in 2004 (Table 7.3.3). Small-scale farmer hatcheries have been developed or supported by DoF/AIT-Aqua-Outreach, DoF/AIT-Aquaculture and Aquatic Resources Management (DoF/AIT-READ), DoF/MRC-Rural Extension for Aquaculture Development (DoF/MRC-READ), DoF/MRC-Aquaculture of Indigenous Mekong Fish Species, Partnership for Development in Kampuchea (PADEK), SAO Cambodia Aquaculture Low Expenditure (SCALE), EU-Pole Regional de Researche Appliquee au Development des Savanes d'Agriculture Centrale, Australia People for Health Development Abroad (APHDA), Catholic Relief Services (CRS) and Integrated Pest Management (IPM) (Table 7.3.5). The majority of such hatcheries (around 80 percent) could still produce significant amounts of fingerlings but the range of fish species was limited (Table 7.3.4). Three main ideal characteristics of a species desired by small-scale farmer hatcheries are:

- hardiness;
- ability to mature in ponds fed with relatively low quality diets; and
- simple breeding.

Currently four fish species fit these criteria well, of which one is an indigenous species:

- common carp, representing 30.38 percent or 2.2 million fingerlings;
- silver barb, representing 27.05 percent or 1.9 million fingerlings;
- mrigal, representing 18.23 percent or 1.3 million fingerlings; and
- tilapia, representing 14.24 percent or 1.0 million fingerlings.

Silver carp were also produced from small-scale farmer hatcheries (10.1 percent or 735 381 fingerlings). Since these could not maintain broodstock, they relied on supply of broodstock from larger DoF hatcheries.

Recently, the Freshwater Aquaculture Improvement and Extension Project (FAIEX) began its activities in Cambodia in February 2005. This five-year project is funded by the Governments of Japan and Cambodia and operates through the DoF, under the auspices of the Japanese International Cooperation Agency (JICA). The FAIEX project will develop and support 20 small-scale farmer hatcheries in four target provinces - Kampong Speu, Kampot, Prey Veng and Takeo until 2010 and support research activities at BFSPRC hatchery.

COURTESY OF HAV VISETH

Construction of farmer's freshwater fish seed hatcheries in Takeo Province, Cambodia

COURTESY OF HAV VISETH

Farmers' freshwater fish seed nurseries in Takeo Province, Cambodia

DoF/MRC-AIMS project supported on-farm research activities of breeding, nursing and grow-out of some indigenous fish which were carried out in Kampong Cham, Kampong Thom, Prey Veng and Takeo provinces. On-farm breeding research targeted only fast maturing and small broodstock such as *B. gonionotus, L. hoevenii*, *T. pectoralis* and *O. melanopleura*.

A mobile hatchery was constructed in 2004 with the support of MAAF. The objective of the mobile hatchery was to enhance fish stocks in reservoir and to

TABLE 7.3.5

Summary of past and on-going NGO's and donor's funded development projects on small-scale aquaculture in rural Cambodia (September 2005)

Implementing organization	Funding organization	Name of the project	Major activity	Project period/budget	Site for research and development	Project area: Kandal	Kompong Cham	Kompong Speu	Kompot	Prey Veng	Siem Reap	Svay Rieng	Takeo	Other province	Collaboration
On-going projects															
MRC	DANIDA	AIMS	Aquaculture extension of indigenous fish species in Cambodia, Laos, Thailand and Vietnam. In Cambodia, research and development.	US$ 2.6 million for 5 years from 2000 to 2005 (Phase I) Phase II: 2006-2007	CCFRS and BFSPRS		×			×			×		DoF, MRC, AIT/AARM
SAO	ODA/DFID, EU, Oxfam US, NZ Gov.	SCALE/FLDO	Technical development and formaulation of community fish seed production network	Since 1991 (continue)	Tuol Krasang Fisheries Station	×		×							DoF
FAO	UN		Small-scale aquaculture development as a part of natural resource management program. Support for establishment of farmer's association	Phase I (1994-97), Phase II (1998-2000), Phase III (2002-2005)			×		×		×		×	Battambang	DoF
CRS			Small-scale aquaculture development	Continue								×			DoF, AIT/AARM
APHEDA	AusAID		Fish seed production at Chhouk Fisheries Station	Since 2000 till date					×						DoF/DAFF
GTZ		IFSP	Small-scale aquaculture development	since 2002 till date					×					Kompong Thom	DoF, DAFF
FHI			Small-scale aquaculture development	Since 2003 till date					×						DAFF
Finished projects															
AIT	DoF, SIDA, DANIDA	AARM	Extension of small-scale aquaculture, supporting core farmers to be fish seed producers, supporting natural fish stock enhancement using community fish refuge ponds and building small-scale hatcheries at PLAS and RUA. It has formulated a new phase (2005-2008) and already submitted to SIDA for granting.	Since 1993 and Phase III from 2001-2004: US$ 0.4 million				×				×	×	Phnom Penh, Preah Vihear	SEAFDEC, SEILA MRC/AIMS, PRASAC
World Bank			Support for research facilities and equipments and research of indigenous fish species.	Since 2001 for 3 years, approx. US$ 1 million	BFSPRS					×					DoF
PADEK	OXFAM Belgium, NOBIS FOS		Small-scale aquaculture as a food security measure of remote area. Support for aquaculture extention, on-station and on-farm research, and build capacity of fisheries staff and supervise students' theses. It is planning to formulate a new phase from 2005 - 2008, although details are not determined.	Since 1991 till 2004, terminating supporting BFSPRS in 2002 and aquaculture extention in 2004	BFSPRS			×		×	×	×			DoF
MRC	DANIDA	READ	Examination of aquaculture potnetial using GIS in Cambodia and Vietnam. Establishment of small-scale hatcheries and on-farm research.	1998-2001, US$ 1.95 mil.		×				×			×		MRC/AIMS
PRASAC	EU	PRASAC	Small-scale aquaculture development as a measure of rural development and building Prasaut Fishery Station.	1995-2003			×	×	×	×		×			AIT/AARM, PADEK
APHEDA	AusAID		Construction of Chhouk Fisheries Station and extension activities in 5 districts of Kompot.	1993-2004			×		×					Battambang, Preah Vihear	DoF, DAFF
MCC			Provision of credit with 2% interest. Assist digging of fish ponds, building village hatcheries and providing extension services.	1993-2003						×					PADEK, WFP
UNICEF	UN	CASD	Nutirtional impovement of rural community through small-scale aquaculture.	since 1986											
CARERE	UNDP		Small-scale aquaculture as a part of rural development Construction of Fisheries Stations in Northern provinces.	Mid 1990s till 1999						×	×			Pursat, Battambang, Banteay-Meanchey	DoF, PADEK
ADRA	NZ Gov.		Small-scale aquaculture development.								×			Kompong Thom	DoF, PADEK
SEILA			Small-scale aquaculture as a part of rural development.												AIT/AARM, PADEK DoF, DAFF
CIDSE			Small-scale aquaculture as a part of rural development.								×			Kompong Thom	DoF, AIT/AARM
JICE			Constructing Kompong Speu and Ksoeng Fisheries Stations					×					×		DoF, JICE, PADEK, AIT/AARM

Source: So Nam (2005b).

promote aquaculture of indigenous fish species in community fisheries areas. With semi-artificial propagation and with Suprefact injection, the fecundity, fertilization, hatching and survival rates of *B. gonionotus* were high. On-farm nurseries were carried out by stocking one day-old hatchling and 10 to15 day-old fry of *P. hypophthalmus*, *B. gonionotus* and *L. hoevenii* in cement tanks supplying dissolved oxygen and earthen ponds, respectively. The hatching experiments failed and the survival rate after ten days was very low (~2 percent), while fry were successful with high survival rate detected after 45 days.

Small-scale hatcheries are often located in areas with no available surface water and all such hatcheries visited during this consultancy were reliant on groundwater pumped from tube wells. Lack of water storage limits the ability to maintain large broodstock ponds and consequently the broodstock numbers held at these hatcheries are typically small. Inbreeding of broodstock is inevitable and will be discussed in the following section.

FISH SEED MANAGEMENT AND SEED QUALITY

This section includes information on genetics and broodstock management, diseases prevention and control and health management.

Conservation of genetic resources is not only dependent on the control of exotic fish species. The FAO Code of Conduct for Responsible Fisheries (CCRF) emphasizes that native fish species taken from the wild and domesticated or subject to other genetic modification may also pose a risk to the remaining wild stock from both genetic and disease standpoints.

Government hatcheries

The breeding programs for both exotic and indigenous fish species at all government hatcheries, except BFSPRC hatchery, have not given special consideration to genetic issues due to the lack of awareness of how to manage stocks and the inherent risks of inbreeding. A concern at 13 government hatcheries is that fish were mixed in ponds without tagging. This makes it very difficult to follow broodstock performance. Furthermore, they did not have genetically sound broodstock management plans. The FAO CCRF emphasizes that when managing stocks, careful attention is needed to:

- avoid inbreeding
- maintain stock integrity by not hybridizing different stocks, strains or species
- minimize transfer of genetically different stocks
- periodically assess their genetic diversity (i.e. by laboratory genetic analysis)

There are already some mixing of stocks and species in Cambodia. For example, the NGO SCALE imported *P. hypophthalmus* broodstock from Thailand for breeding, reporting that they were more convenient for aquaculture as they matured at earlier stage than local species. The breeding program of the Thai broodstock was stopped based on the suggestion of DoF officials because of fears of escape to the wild. It is possible that they might interbreed with local wild stocks and dilute the wild gene pool and may cause threats to biodiversity. However, in domestication and genetic improvement programs, mixing, also known as crossbreeding, is a proven method for increasing production. However, this involves good record keeping and evaluation in order to assess accurate benefits. Further, it does not negate the fact that maintenance of the pure stock is required. The impact and risks associated with these (transboundary) movements of live aquatic animals or hatchery or cultured stocks or fingerlings (this review) in Cambodia as well as in the whole Mekong region are unknown. So far, there is little known about genetic structures, although some research in Cambodia on *P. hypophthalmus* (So Nam, Maes and Volckaert, 2006a) and *B. gonionotus* (McConnell, 2004) suggests considerable mixing of stocks and on *Pangasius bocourti* (So Nam, Van Houdt and Volckaert, 2006b) suggests a single stock (i.e. population). Thus some baseline work on the genetics of Mekong fish species are required, upon which to base environmental sound management measures for breeding and movement.

Farmer hatcheries

Small-scale aquaculture operations can rapidly give rise to inbreeding of captive stocks due to their limited capacity to maintain large number of broodstock. Small-scale farmer hatcheries usually have only one or two ponds for maintaining broodstock. Four or five fish species are stocked, with an excessive stocking density of 4 fish/m^2, in the same broodstock pond leading to competition for food. The broodstock ponds are usually underfed or fed with low quality feed. Competition problems between fish species may also limit the potential of each stocked fish species in terms of maturation, fecundity, fertilization, hatching and survival rates. Furthermore, the numbers of each fish species held was typically less than 50 and the original broodstock used to develop these are often far less this number. Farmer hatcheries usually took a proportion of each batch of fingerlings produced and retained them as broodstock. These broodstocks are bred with the original stock, with the same batch of broodstock or with a different batch from the same parents. Hatchery farmers always perform some simple selection on their broodstock. Poor condition or fish with a poor body shape are usually discarded. Genetic management of the small fish stocks which are held in farmer hatcheries is almost impossible because of the following reasons: (1) lack of record keeping, (2) lack of tagging, (3) lack of breeding of individual fish or pairs of fish and (4) mass spawning of fish species and the use of fingerlings produced as future broodstock.

All these mentioned features increase the risk of farmer hatcheries inbreeding their broodstock. The only practical method by which problems associated with inbreeding and genetic drift (loss of potentially useful characteristics) can be reduced is to maintain a ‘minimum effective breeding number’ for each fish species. The ‘minimum effective breeding number’ of fish is the number of fish that are spawned each year from the hatchery stock in order to produce replacement broodstock fish for the future. Thus larger government hatcheries could provide a crucial role in the maintenance of the genetic quality of broodstocks, due to their ability to maintain larger numbers stocks and control breeding. As mentioned above, current controlled breeding is not practiced (or rarely) in most government hatcheries and management of fish is limited to simple selection and breeding of fast growing fish.

Disease prevention and control and health management

Quarantine and health certification for movement of living aquatic animals are new and currently does not exist in Cambodia (So Nam *et al*., 2000). Fish disease represents an important concern and is a recognized source of economic losses to farmers in aquaculture. With both legal and illegal importation of millions of fish seed every year from neighboring countries, disease problems will likely occur (introduction and spread) and necessary measures should be taken to reduce risks. New aquaculture indigenous fish species are also being cultured in farmer ponds and the subject of research at some large-scale government hatcheries (Table 7.3.4). Similar problems of new diseases could emerge and potentially spread within the country. There is a general lack of knowledge in the management of fish health. Chemical therapeutants are more widely used in intensive aquaculture, but are uncommon in small farmer ponds. Since farmers have few available options for controlling fish diseases in their system, disease becomes a risk. Moreover, all hatcheries did not have technical standards or set criteria for good quality fry/fingerlings, appropriate packing and transportation methods and good hatchery health management practices. Hence, some assistance should be provided to further develop health management capacities within Cambodia as well as the riparian countries towards:

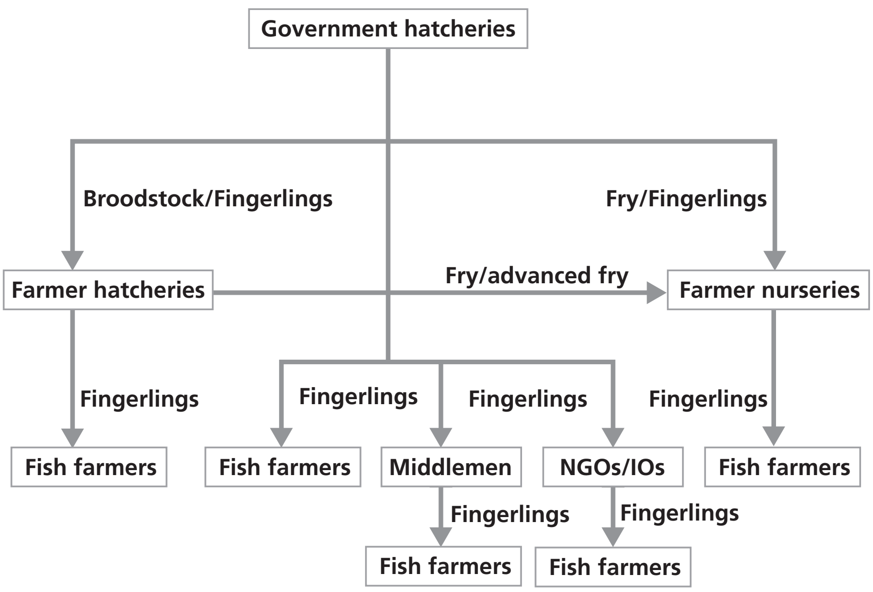
- supporting hatcheries and nurseries in producing healthy fish seed according to a set criteria;
- building both human (appropriate trained staff) and physical (equipments and facilities) capacities for preventative health management, diagnostics, health screening of stocks of fish intended for transfer from one area to another and emergency responses to disease outbreak;
- incorporating basic health management principles in extension messages;
- supporting research on fish disease diagnosis, prevention, management and control and development of appropriate responses to such problems if and when new diseases affect the fish species being cultured; and
- increasing aquatic animal health cooperation within Mekong countries to reduce the risks from disease outbreaks.

FISH SEED MARKETING AND SEED INDUSTRY

At present, fish seed demand in Cambodia is strong, unsatisfied and expected to expand. There are three major sources of fish seed supply, namely: hatchery, wild and import. While sales promotion, distribution mechanisms and types of distribution networks for fish seed marketing were not officially organized in Cambodia, fish fingerling marketing campaign used by TKFSPS hatchery has been very successful. Fish seed marketing and sales promotions were done through newspapers, T-shirts, hats, radio and even television advertising, but newspaper was definitely the most effective. Buyers came from over the country including NGOs and international organizations (IOs), government departments and private buyers, some even flying fingerlings to their home provinces. About 70 percent of the bulk sales of this hatchery were from private buyers. Some of these buyers were traders or middlemen who bought fingerlings from this hatchery to sell on. NGOs bought fish seed to supply fish farmers under their supported development projects. Government departments bought only indigenous fish fingerlings (i.e. silver barb) annually in July to support government fish seed releasing programs in lakes and natural water bodies.

The general flow chart of distribution of hatchery fish seed is shown in Figure 7.3.7.

FIGURE 7.3.7
Flow chart of distribution of hatchery fish seed in Cambodia (2004)



The flow chart shows that all government hatcheries except for the four large-scale (BFSPRC, CCFRS, TKFSPS and CARFSPS) hatcheries were playing only a single role in producing fish fingerlings, i.e. for selling to generate income due to the limited financial resources provided by the government. This leads to market competition with small-scale farmer hatcheries. These fingerlings were sold to five different types of buyers, i.e. (1) farmer hatcheries, (2) farmer nurseries, (3) fish farmers, (4) middlemen and (5) NGOs/IOs. The majority of fingerlings were sold to fish farmers and middlemen, followed by NGOs and Ios. The four large state hatcheries supplied broodstock to small-scale farmer hatcheries and they exchanged broodstock with each other. The provincial government hatchery mostly supply fingerlings to customers within its province and in neighboring provinces. The four large state hatcheries sell their fingerlings to customers coming from all over the country. The amount of fingerlings produced and distribution of fingerlings reflects the good road infrastructure of Cambodia. Means of transportation include motorbikes, cars, pick-up cars, vans and trucks. The transportation distance varied from a few km to over 300 km. All cities and provinces in Cambodia can be reached in less than 12 hrs by pick-up car. It is believed that the direct distribution of fingerlings to households from government hatcheries is not sustainable while the distribution of fingerlings direct to households from farmer hatcheries is sustainable, as depicted in the flow chart (Figure 7.3.8) and described below.

Fingerlings produced by farmer hatcheries are directly and locally sold to fish farmers in villages or communes, while fry and advanced fry are sold to small-scale farmer nurseries to rear them to fingerling sizes for final sale to fish farmers in villages. Common transportation means of farmers in rural areas are bicycles and motorbikes, which are used to transport fingerlings from village hatchery to their fishponds.

Seed supply from both government and farmer hatcheries are not stable for the whole year due to lack of water source, good water quality and broodstock. Therefore aquaculture expansion in Cambodia is constrained by the lack of seed. Importing seed from neighboring countries can provide a short-term solution, although environmental issues (i.e. genetic and disease risks) are current concerns of the country.

Because the demand for seed outstripped supply most of the time, a seed importing company did not have to do any sales promotion. A case in point is Suy Chea, a seed importing company located about 12 km northwest of Phnom Penh, who has many buyers coming from all over the country. About 50 percent of buyers came from Kandal province next to Phnom Penh, especially from Punnhear Leur district, followed by 30 percent from other Mekong floodplain provinces (Kratie, Kampong Cham, Prey Veng, Takeo, Svay Rieng and Kampong Speu), mountain/plateau provinces (Ratanak Kiri

FIGURE 7.3.8
Flow chart of distribution of imported fish seed in Cambodia (2004)

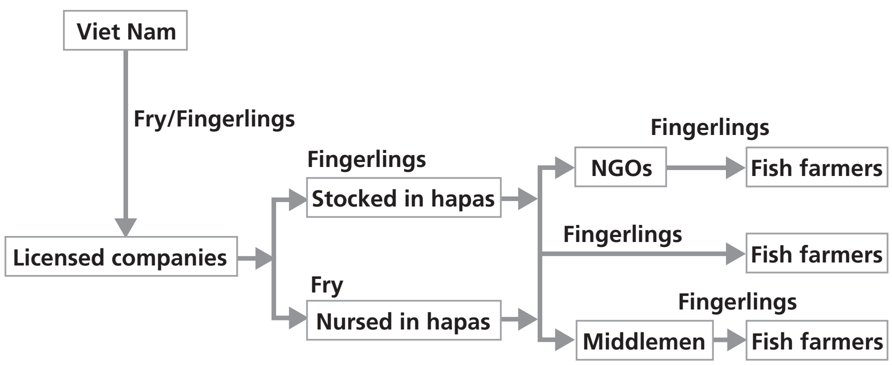
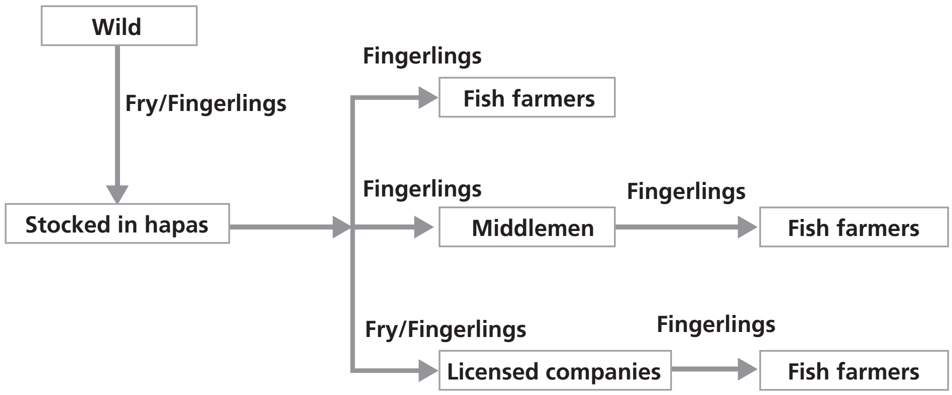


FIGURE 7.3.9
General channels of distribution of fish seed collected from the wild in Cambodia (2004)



and Stung Treng) and coastal provinces (Kampot and Sihanouk ville) and 20 percent of buyers from Tonle Sap Great Lake provinces (Kampong Chhnang, Pursat, Kampong Thom, Battambang, Banteay Mean Chey and Siem Reap). There are two types of buyers, i.e. private buyers and NGOs. Around 95 percent of fish seed buyers aree private buyers and the remaining 5 percent are NGOs. Some private buyers are also middlemen who bought fish seed from this company to sell on.

The general flow chart of distribution of seed imported from Viet Nam by the three licensed companies is shown in Figure 8. Imported fingerlings and fry are supplied by hatcheries in Tien Giang province, Viet Nam. Imported fingerlings are stocked in hapas installed in large earthen ponds and they are sold to three kinds of buyers, i.e. (1) fish farmers, (2) NGOs/IOs and (3) middlemen. Mortality rate of fingerlings from transportation was less than 10 percent for a distance of less than 300 km from Tieng Giang province to Punnhear Leur district, Kandal province in Cambodia. Imported fry, mainly tilapia, were nursed in hapas installed in large earthen ponds for about 30 days. Mortality rate from transportation between Viet Nam and Cambodia was 50 percent and from nursing was 75 percent. It was reported that unfavorable weather conditions such extreme temperatures (too hot or too cold) and rainy season had caused significantly high fish seed mortality. Cambodia's aquaculture development is also constrained by the seasonal supply of fish seed from Viet Nam particularly the seed unavailability during the first three months of the year. This may be due to non-response of broodstock to monthly hormone injection. Another constraint faced by these companies is the non-payment among fish seed buyers. For example, in 2004, Suy Chea Company lost US$25 000 as buyers did not pay the cost of fingerlings after harvesting their fish. Some of these buyers were high ranking government officials. Some were Vietnamese migrating from other places to rent fish ponds to start aquaculture business. Most of these latter buyers did not have houses or places to stay.

Figure 7.3.9 shows the general channels of distribution of fish seed collected from the wild. Fishers collect fry and/or fingerlings from lakes, reservoirs and/or rivers and fish seed are stocked in hapas set in large earthen ponds or in rivers/lakes. Customers are middlemen, licensed companies and fish farmers. The majority of sales were to middlemen or traders, who bought fingerlings from fishers to sell on.

FISH SEED PRODUCTION SUPPORT SERVICES

All Fish Seed Production and Research Stations (FSPRS) currently rely on the DoF (i.e. Aquaculture Division [AD], Inland Research and Development Institute [IFReDI]) and development projects funded by NGOs and other donors to transfer technical information to farmers and to obtain feedback on farmer needs. However, there has been no direct government funding for aquaculture extension and as such services outside of that supported by external funding sources since the early 1990s, are quite limited (Table 7.3.5). The extension activities of these externally-funded projects included the following: (1) transferring aquaculture technologies (knowledge) to farmers through training and demonstration, (2) supporting the establishment of provincial level fish seed production stations and also supporting these stations to carry out extension services, (3) promoting private hatcheries (i.e. small-scale village or farmer hatchery); (4) building capacity of government fisheries staff and (5) in some cases supporting on-farm and on-station research activities (e.g. DoF/MRC-AIMS and JICA-FAIEX). All these organizations are spread in different provinces, district, or communes, but all had some linkages with the DoF. In the case, project offices of the MRC-AIMS and JICA-FAIEX were located within the DoF and most of the other organizations had DoF staff seconded to them. All the organizations had different approaches towards the promotion of aquaculture, with an emphasis on developing fingerling production and nursing. Methodologies ranged from prescriptive, i.e. providing more standardized technical information, to experimental, i.e. seeking to try out what works best under local environments.

In addition, the DoF also interacted with various Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) on extension matters through its Provincial Fisheries Divisions (PFD). These direct interactions are generally project-based and no formal linkages or extension mechanisms/systems currently exist between the DoF and PDAFF. The DoF prepares the extension materials used by the PFD and PDAFF. In cooperation with FSPRS, technical trainings on general aquaculture and particularly fish seed production and nursing have been conducted by the DoF (through the AD and the IFReDI) especially for PFD/PDAFF extension staff, NGO/IOs staff and small-scale fish seed producers. In turn, the extension staff of the PFD and NGOs subsequently provided training on simple topics regarding aquaculture technology directly to fish farmers.

LEGAL AND POLICY FRAMEWORK

Law and regulation

Chapter Ten of the new Fisheries Law (draft, now in the process of approval by the National Assembly) describes aquaculture management comprehensively (DoF, 2004a; quoted by So Nam, 2005a). At present, the following inland aquaculture operations require permission from the Fisheries Administration, through the DoF, namely:

1. a pond or a combination of ponds with a total area larger than 5 000 m^2
2. a pen or a combination of pens with a total area larger than 2 000 m^2
3. a cage or a combination of cages with a total area larger than 15 m^2

Aquaculture carried out in small-scale ponds does not require permission but operators need to register into the Aquaculture Statistic Book through the officers of the Fisheries Administration. This exercise therefore recognizes the activities of small-scale aquaculture farmers (e.g. fish growing, seed production and nursing) and farmers can thus increase family fish production and consumption and generate additional income of rural households.

As for the environmental aspect, the new draft Law indicates that all aquaculture operations shall maintain the quality of land, water, aquatic biodiversity and environment and permission of Fisheries Administration is required for importing aquatic fauna or flora seeds for aquaculture after undergoing quality control by the laboratories.

Policy, plan and strategy

The long-term vision of the Government of Cambodia is to create a cohesive and advanced country, free from the grip of poverty and illiteracy. The long-term strategy to achieve this vision is the Government's Triangle and Rectangular Strategy. The

Government's poverty reduction goals are envisioned in the Triangle/Rectangular Strategy, the medium-term Second Five-Year Socio-economic Development Plan 2001-2005 (SEDPII): National Economic Growth and Poverty Reduction Strategy and the National Poverty Reduction Strategy 2003-2005 (NPRS).

SEDPII and NPRS focus on three national development objectives in the context of broader governance reform and poverty reduction strategies. These are:

- economic growth that is broad enough to include sectors from which the poor derive a livelihood;
- social and cultural development; and
- sustainable use of natural resources and sound environmental management.

The fisheries sector plays an important role in the food security and the national economy of the country and therefore contributes significantly to the national development objectives.

The vision of the fisheries sector as described in the Fisheries Development Action Plan 2005-2008 (FDAP, November 18, 2004) (DoF, 2004b; quoted by So Nam, 2005a) is that of "Ensuring the supply of fish and fishery products will keep pace with increasing demands to safeguard the nutritional standards and the social and economic well-being of communities depending on fisheries for their livelihoods".

The goal of the fisheries sector as described in the FDAP is to maximize the contribution of fisheries to the achievement of national development objectives, especially those related to improving rural livelihoods of the poor, enhancing food security and the sustainable development and equitable use of the fisheries resource base.

The DoF recognizes both the constraints and the potential of the sector and is committed to ensuring that its contribution to the national development objectives is maximized. The overall goal of the FDAP takes into account the wider policy framework defined by SEDPII, NPRS and the Triangle/Rectangular Strategy.

The sixth high priority area defined in order to achieve the goal of the DoF's FDAP is "Improving Livelihood of Rural Poor People through Rural Aquaculture Development". The overall objectives are to improve food security and nutrition and farm income through small-scale aquaculture development in Cambodia. To achieve the overall objectives, the specific objective is to introduce and identify the appropriate aquaculture technologies for different farming systems.

This FDAP is a continuing process from the current Second Five-Year Fisheries Sector Development Plan (2001-2005). The plan is divided in two parts, as described below:

1. Short-term actions (one year, 2005)
   - continuing the introduction of appropriate small-scale aquaculture technologies for different farming systems such as:
     - fish pond culture integrated with livestock.
     - fish culture integrated with rice (i.e. rice-cum-fish culture).
   - continuing the implementation of "fish farmer meets" and exchange activities.
2. Medium-term actions (two to three years, 2006-2008)
   - developing local fish hatcheries in collaboration with farmers
   - developing aquaculture training methods and extension materials

In addition, Cambodia's Draft Master Plan for Fisheries (2001-2011) in Cambodia (DoF, 2001) ambitiously emphasized that supporting the private sector to improve its operational efficiency and effectiveness in aquaculture necessitates DoF to generate the following strategic outputs:

- technology packages, which can support the private sector to invest in aquaculture;
- gene pool of indigenous fish species and fish fry/fingerlings to ensure that the private sector has access to high quality, healthy and disease-free broodstock and stocking materials;

- feeding technologies that are attractive to private sector investments;
- technology packages aimed at improving the overall efficiency and effectiveness of Cambodia's aquaculture industry;
- "best practice" guidelines for the different types of aquaculture and for different habitats;
- localized aquaculture management plans; and
- technical, scientific and general information on aquaculture.

ECONOMICS OF FISH SEED IN CAMBODIA

In general, fish seed production in Cambodia was very profitable. Fish fingerling production at small-scale farmer hatcheries significantly contributed to the total family income. Its average profit margin was approximately 290 percent in 2004. So Nam *et al*. (2000) reported that an estimated profit margin of small-scale fish fingerling production was around 800 percent in 2000 based on hormone and feed costs only. The average profit margin of large-scale fish fingerling production at government hatcheries was slightly higher than that of small-scale fingerling production, being 300 percent for the 11 fish species produced at hatcheries (Table 7.3.4). The profit margin for fingerling production of pangasiid catfish was around 95 percent and significantly lower than the other fish species. The above profit margins of fish fingerling production at both government and farmer hatcheries were estimated based on production costs and income (sale) per fingerling and by excluding costs of broodstock and maintaining broodstock. At the BFSPRC hatchery, an estimated US$600/year was used to feed 50 slow maturing and large broodstock of pangasiid catfish. This is a significant cost for such a hatchery, even as the hatchery has sufficient ponds needed to maintain such fish. Small-scale farmer hatcheries are not likely to have resources for maintaining such fish, implying a role for government hatcheries in maintaining genetically important stocks. Maintainance of medium-maturing and medium-broodstock (e.g. hoven's carp and locally named fish called krom) had been estimated to cost at an average of US$50/yr for feeding 50 fish, while an estimated cost for maintaining fast-maturing and small broodstock (e.g. barbs) was on average at US$ 40/year for feeding 50 fish. Therefore small-scale farmer hatcheries are likely to have resources for maintaining such fish.

The profit margin of companies importing fish fingerlings was approximately 30 percent based on total expenses and income from sales. It is believed that the collection of fry and fingerlings from the wild is more profitable than hatchery fish seed production and imported fish seed when environmental costs and incremental costs for maintaining genetic diversity are not included. What are these costs? Who should bear such costs? Proposals should be developed to study these costs of biodiversity conservation.

In general, the price of fish fingerlings did not vary very much for the whole year in Cambodia, especially for omnivorous fish species such as carp. However, the prices of strictly carnivorous fish fingerlings such as hybrid catfish and snakehead were 30 percent more expensive during high season of small wild fish harvested from the Tonle Sap and Mekong rivers. Government hatchery fingerlings were usually produced for the same price as wild caught and imported fingerlings. There also appeared to be a consideration that local hatchery-produced fingerlings were not as good as wild caught or imported fingerlings. Interestingly, farmer hatchery fingerlings were often 20-30 percent more expensive than government hatchery fingerlings probably due to their higher quality (e.g. short transportation), their scarcity or absence of competition in rural areas.

CONCLUSIONS AND RECOMMENDATIONS

Fish is the most important source of animal protein food for the Cambodian population and the potential fish culture production from earthen ponds, floating cages and other various small water bodies in Cambodia is great. The supply of quality fish seed is a key factor to the expansion of fish farming. Fish seed demand at present is strong, unsatisfied and expected to expand and fish seed business in Cambodia is profitable. In order to meet such huge demand of fish seeds for such potential aquaculture development in Cambodia, the following recommendations are proposed.

The DoF should request FAO's assistance in preparing a project for submission to an interested international or regional financial institution to support the following: (1) government and private hatcheries to produce and distribute quality fish seeds of exotic and indigenous species on a commercial basis; (2) to establish farmer hatcheries in all provinces; and (3) to rehabilitate and improve earthen ponds and floating cages. The funds that will be received from an interested international or regional financial institution could be a loan and/or grant. The Royal Government of Cambodia through the MAFF should support the ideas of the DoF and partially provide fund to prepare the project proposal and implement the project.

The emphasis of government hatcheries should be placed more on which commercial activities could be undertaken that complement the private sector activities. Such commercial services may include: (1) production of fingerlings of indigenous fish species that farmer hatcheries cannot yet produce for stocking, nursing or enhancing natural stocks; (2) maintenance and improvement of indigenous fish broodstock to support small-scale farmer activities; (3) investigating the potential of the 'low-in-the-food-chain' indigenous fish species for aquaculture to avoid the potential impact of the use of inland low value and 'trash' fish for feeding carnivorous species (So Nam *et al*., 2005) and development of diets where more carnivorous species are used; (4) act as a technical resource for development organizations and/or fish culture farmers; and (5) provision of technical advice on breeding, nursing, feeding, disease and other production problems.

The review gave also special attention to environmental issues and provides the following important suggestions, namely:

- preparation of broodstock management plans at government hatcheries, taking into account genetic and disease issues;
- preparation of practical breeding programs (recording keeping, selective stripping of eggs and milt, single use of broodstock pairs where fingerlings produced from that batch form a percentage of the new broodstock) within hatcheries to reduce risks of inbreeding of broodstock;
- acquiring basic understanding or information on genetics of government hatchery broodstock;
- establishing a working group under the DoF to initiate preparation of policy or guidelines on the movement of fry, fingerlings and broodstocks inside the country and on transboundary movement of live aquatic animals, taking into consideration of genetic and disease issues;
- development of a system for disease control and health management under the supervision of the DoF; and
- incorporation of a prepared environment management policy or guidelines into extension and awareness raising activities of the DoF.

The review also indicated that seed marketing channels in Cambodia are disorganized. A systematic fish seed marketing channel and distribution mechanisms or networks and market infrastructure should be developed to supply strong demand of fish seed for the expanding aquaculture in Cambodia.

The existing extension set-up and technology transfer mechanisms are considered to be extremely weak. A participatory extension system is needed in Cambodia. Such an extension system will be helpful for mass motivation and knowledge and technology transfer of the different stages of pond and cage culture operations (i.e. hatchery, nursery, pond/cage production techniques). It is not essential for the DoF and/or PFD officers to make individual contact with the pond/cage fish farmers, which is virtually not possible but instead they can make use of fish seed vendors as extension agents for the purpose of motivation, technology transfer, knowledge dissemination, etc. In the process of farming operations, the farm operators trained at different stages could also work as an extension agents on behalf of the DoF and/or PFD. It is expected that, this extension approach might be efficient, time-saving, cost-effective and beneficial to the fish farm operators. It will enhance the pond/cage fish production as well as other fish farming operations in the rural areas of Cambodia. In addition, mechanisms to develop and enhance linkages between research and extension should be established. These may include: (i) surveys of pond/cage fish farmers problems conducted jointly by research and extension staff; (ii) regular (bi-annual and tri-annual) meetings between research and extension staff; (iii) regular publication of materials provided by research and extension staff; (iv) presentation of jointly developed materials at large workshops; (5) joint training programmes; and (v) field days.

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7.4 Freshwater fish seed resources in Cameroon

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ABSTRACT
The climate, land and water resources of Cameroon, combined with the high demand for fisheries products, makes this Central African country a high potential area for aquaculture. Fingerling availability and quality have been identified as key constraints which hold the sector back from rapid expansion. Nile tilapia (*Oreochromis niloticus*) and sharptooth catfish (*Clarias gariepinus*) are the two most widely cultured species and are often grown in polyculture. Some 32 government hatcheries have been built, but few are functional and none operates at full capacity. Most producers rely on 14 small-scale, private sector hatcheries for their seeds, but supply is irregular and quality remains a serious problem. New policy and research initiatives undertaken by a coalition of government, private sector and international research agencies are underway to address these inadequacies.

INTRODUCTION
Cameroon is located in the crux between West and Central Africa, the tropical rainforest and the Sahel. The wide range of ethnic groups and ecosystems has lead many to refer to Cameroon as "Africa in Miniature". Within this microcosm, are 35 000 km^2 of aquatic habitats, representing many of the key aquatic ecosystems that prevail over the continent (Figure 7.4.1): large natural lakes (Lake Chad), reservoirs on dammed rivers (Lagdo, Mape, Bamindjing), crater lakes (Barombi Mbo, Nyos), large rivers (Benue, Sanaga, Cross, Mungo, Wouri, Dibamba), rainforest rivers (Nyong, Ntem, Kienke, Ndian, Lobe, Lokoundji) and thousands of km of first and second order streams (representing 86 percent of total freshwater resources). Overall, including coastal fisheries in the Gulf of Guinea, Cameroon currently produces some 120 000 tonnes of fish per year, 55 percent from inland and 45 percent from coastal waters, according to the Government of Cameroon.

Within this vast array of aquatic resources reside at least 600 species of freshwater fish, a number of which are suitable for aquaculture, a smaller number of which have actually been produced commercially (Table 7.4.1). Most of these are alien to the basins in which they are cultured, having been introduced by various aquaculture projects.

TABLE 7.4.1
Most commonly cultured fish species in Cameroon

Species	Native range in Cameroon	Introduced to/cultured in
Tilapia, *Oreochromis niloticus*	Benue River, Lake Chad	Sanaga River Basin, All Reservoirs, Lake Nyos, Mt. Cameroon watershed
Catfish, *Clarias gariepinus*	Benue River, Lake Chad,	Sanaga River Basin
Kanga, *Heterotis niloticus*	Benue River, Lake Chad	Nyong River Basin
Carp, *Cyprinus carpio*	none	Northwest, West & Central Provinces
Snakehead, *Parachanna obscura*	nearly ubiquitous	unknown
Banded jewelfish, *Hemichromis elongatus*	nearly ubiquitous	unknown

PLATE 7.4.1
Most commonly cultured fish species in Cameroon

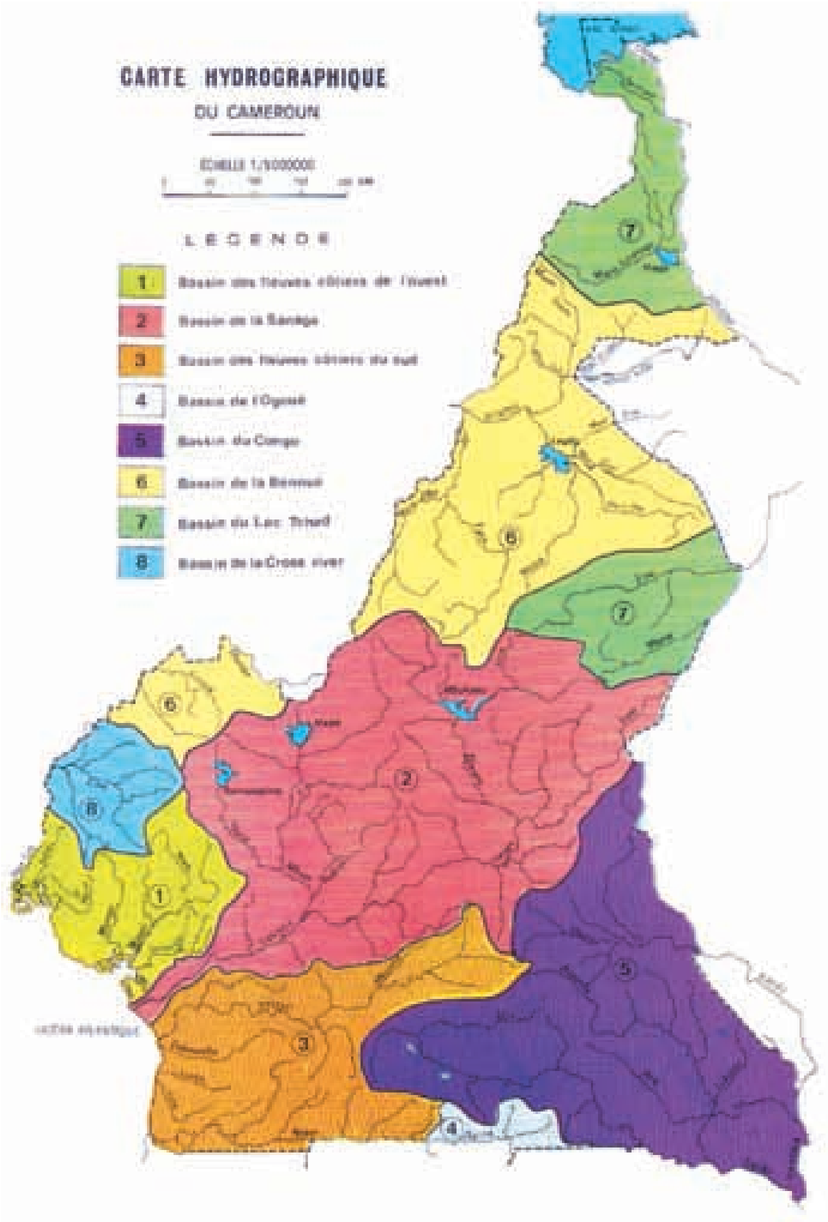
Tilapia (*Oreochromis niloticus*)

Banded jewelfish (*Hemichromis elongates*)

Catfish (*Clarias gariepinus*)

Kanga (*Heterotis niloticus*)

FIGURE 7.4.1
Hydrographic map of Cameroon



Source: Vivien (1991)

Fish farming started in Cameroon in 1948. Its subsequent development can be chronologically summarized as follows:

- 1954: under the French colonial administration, 22 public stations are built to strengthen the action of extension agents; more than 10 000 private earthen ponds around the country.
- 1960: the country is independent. Coffee and cocoa receive most of the government's attention, and support to aquaculture collapses. Competition with fish captured in newly constructed hydroelectric dams reduces economic viability of aquaculture and by 1963 most ponds are abandoned.

- 1968-1976: A United Nations Development Programme/Food and Agriculture Organization of the United Nations (UNDP/FAO) regional project increases the number of extension stations to 32. Foumban station trains more than 150 extension agents. However, financial problems and weak national institutions hindered growth.
- 1980-1990: A number of short-term projects support fish farming: United States Agency for International Aid (USAID, 1980-1984); International Development Research Centre (IDRC, 1986-1990); General Administration for Development Cooperation (AGCD, Belgium); Haskonig (Netherlands), Mission française de coopération et d'action culturelle (MCAC, France). Peace Corps volunteers remain the main manpower for aquaculture extension until 1998 and the remnants of these projects are still visible today.
- In 1994, the government devalued the Central African Franc (CFA) by 50 percent. Availability of fish decreased (from 50 000 tonnes in 1993 to 45 000 tonnes in 1995) while prices rose by an average of 40 percent. The shortage had the most immediate effect on rural fish supplies and created a strong incentive to produce fish locally.
- By 1997, some 5 000 ponds belonging to 3 000 farmers were functioning with a total output of over 300 tonnes of fish, mostly tilapia. The average production was about 1 200 kg/ha/yr. In some projects, production has been temporarily increased by four to six fold.
- leading to the belief that aquaculture might be profitable. The President and a number of other high government officials construct fish ponds.
- In 2000-2005, the WorldFish Center (WFC), the International Institute for Tropical Agriculture (IITA) and the United Kingdom Department for International Development (DFID) implemented a participatory research project in partnership with the Government of Cameroon and a number of local non-governmental organizations (NGOs). By linking small-scale producers to markets, this project managed to increase cash income to rural producers, thus creating a much larger interest in intensified production systems than previously (WorldFish Center, 2005).

In 2005, nearly 49 percent of animal protein consumed in Cameroon, 17 kg/person/yr, consisted of fish. Demand is high and continues to rise with imports passing 53 000 tonnes in 1997, 63 000 tonnes in 1998 and 78 000 tonnes in 1999. In 2002, Cameroon imported 182 000 tonnes of fish, representing 52 percent of domestic supplies, at a total cost of nearly US$90 000 000 (FAOSTAT, 2004). Fish prices remain stubbornly high at around US$3.50/kg live weight on the wholesale market. Through a series of recent consultations facilitated by FAO (April 2003, December 2004) and WorldFish (April 2004, November 2004), access to markets, availability of high quality technical backstopping and regular supply of fish fingerlings have been repeatedly identified as key constraints to growth. According to the government, if these can be overcome, Cameroon has the biophysical potential (i.e. land, water and feed materials) to easily produce 20 000 tonnes of fish per annum through aquaculture and increase over current production of nearly two orders of magnitude.

SEED RESOURCES AND SUPPLY

Of the 32 national fish stations, most of which were designed with the primary objective of producing fingerlings to support the growth of aquaculture, only the Yaoundé Fish Station (supported under the WFC project) and the Institute for Agricultural Research for Development (IRAD) Foumban Research Center continue to produce fingerlings, albeit irregularly and at high prices and variable quality (Figure 7.4.2).

Although these stations listed below are largely dysfunctional, some of the most important of them possess considerable infrastructure and potential for contributing to aquaculture development if either properly managed or transferred to the private sector:

- Ku Bome (26), 35 ponds, 5.9 ha
- Bamessing (29), 13 ponds, 1.5 ha
- Bambui-N'kwen (24), 22 ponds, 1.7 ha
- Foumban (28), 53 ponds, 3.5 ha
- Yaoundé (5), 14 ponds, 2.0 ha
- Ngaoundere (19), 24 ponds, 4 ha
- Bertoua (13), 42 ponds, 12 ha
- Garoua Boulai (15), 9 ponds, 4.2 ha

As these government stations have failed to alleviate any of the main constraints to aquaculture, fish farmers have increasingly turned to other suppliers for information and fingerlings. Since the revision of the laws covering the formation of farmers groups was lifted in 1990, over 90 NGOs and Common Initiative Groups dealing with agriculture and rural development including aquaculture, have sprung up. Many of these offer technical advice on aquaculture and a few have attempted to operate small hatcheries to supply their members with seed. Unfortunately, the level of technology used by these groups is minimal and none of the efforts to overcome the seed shortage have so far produced sustainable outcomes.

FIGURE 7.4.2
Government aquaculture stations in Cameroon (2005)

As a result of the failure of hatcheries to meet demand for fingerlings, most farmers buy or trade amongst themselves, or buy from fishers. Juvenile tilapia, catfish and carp seeds can account for large percentages of total harvest in poorly managed farm ponds. Feral kanga (*Heterotis niloticus*) fingerlings are normally purchased from fishers working in the Nyong River at Akonolinga.

The poor seed supply situation is exacerbated by the lack of critical mass among growers. Without sufficient numbers of growers to buy fingerlings over the course of the year, hatcheries cannot be profitable. On the other hand, without suitable fingerlings, available when needed, producers cannot produce. Since 2002, the WFC project, in conjunction with the Government of Cameroon and a local NGO, *Service d'Etudes et d'Appui aux Populations a la Base* (SEAPB) have focused attention on the linkage between markets, producers and hatcheries with the objective of developing practical, private-sector hatchery, grow-out and marketing strategies that can allow small-scale producers to participate and possibly lead, the growth of fish farming in and around the urban markets of central and western provinces. At present, five private hatcheries (three catfish, two tilapia) engaged in this project are the main suppliers of high-quality fingerlings in the country (Table 7.4.2).

The total number of fingerlings traded is unknown and government production statistics are unreliable as most fish are consumed in villages and do not reach urban markets where they might be counted. According to WFC project datasets, approximately 15 tonnes of fresh catfish were traded on the urban market of Yaoundé in 2004. To produce this amount of fish, 185 000 catfish fingerlings were stocked. Tilapia are stocked at 1.5 fish/m^2, suffer about 20 percent mortality and are marketed at an average of about 80 g. If these values are extrapolated to the government estimates (2002) of 210 tonnes of tilapia and 114 tonnes of catfish, the total number of fingerlings stocked was on the order of 1 400 000 catfish and 3 300 000 tilapia.

TABLE 7.4.2

Private fish hatcheries known to be operating in Cameroon as of November 2005

Farmer	Location	Species	Facilities	Status
Nkoua, Bruno	Nkoabang, Central Province	catfish	hatchery building + seven ponds, 9 000 m^2	active
Etaba, Desiré	Nkolzoa, Central Province	tilapia	11 ponds, 1 430 m^2	active
Diogne, Michel	Batié, West Province	catfish	hatchery building + six ponds, 2 400 m^2	active
Noupimbong, Maurice	Bapi, West Province	catfish, tilapia	six ponds, 700m^2	active
Ndoumou, Antoine	Nkolmesseng, Central Province	catfish	one pond + eight tanks, 2 500 m^2	active
Wouanji, Jean	Bandjoun, West Province	catfish	three ponds, 900 m^2	startup
Youdom, Bernard	Batié-Nsoh, West Province	catfish	ten ponds, 5 000 m^2	startup
Tamo, David	Bafoussam, West Province	catfish	six ponds, 1 200 m^2	startup
Awoa, Lucien	Yemssoa, Central Province	catfish	hatchery building + five ponds, 3 200 m^2	startup
Tabi, Abodo	Mbankomo, Central Province	tilapia, catfish	hatchery building + 19 ponds, 9 500 m^2	dormant
Yene, Joseph	Nkoabang (Lada), Central Province	catfish	12 ponds, 360 m^2	periodic
Yong-Sulem, Steve	Mbankolo, Central Province	catfish	23 ponds, 2 100 m^2	periodic
Oben, Benedicta	Buea, SW Province	catfish	hatchery building + five concrete tanks	periodic
Ebanda, Jeanne	Mbandoum, Central Province	tilapia	17 ponds, 7 000 m^2	dormant

SEED PRODUCTION FACILITIES, TECHOLOGY AND ECONOMICS

Tilapia

Tilapia fingerlings are produced in open ponds of 50-150 m^2 (Figure 7.4.3). The system used at the Nkolzoa Fingerling Centre near Sa'a in Central Provice is typical: broodfish are randomly stocked at a rate of 40 males (average of 210 g) and 40 females (average of 110 g) into 130 m^2 earthen ponds to reproduce. Fingerlings are captured with a fine-mesh seine net beginning 51 days after broodfish stocking and is repeated every 21 days until capture begins to decline (normally after about three months). Harvested fingerlings average about ten grams, are held for two days to recover from the harvest operation and sold at 25 Cameroon Franc (CFA) per piece (US$1 = CFA500).

FIGURE 7.4.3
Nkolzoa Tilapia Fingerling Centre, Sa'a, Cameroon

Catfish

Basic catfish reproduction technology has been well-established over the last 20 years as described by de Graaf and Janssen (1996). In a typical reproduction in Cameroon, 35 female *C. gariepinus* averaging 550 g are injected with 4 000 IU/kg of human chorionic gonadotropine (HCG) to induce final gonadal maturation and stripped after approximately 12 hrs. Eggs of all females are pooled and then dry fertilized with mixed milt from nine sacrificed males. Fertilized eggs are poured onto 70 x 50 cm wooden framed nylon-mesh screens where they adhere and are submerged to 40 cm depth in 1 m^3 hapas installed under the water inlet pipe (to ensure adequate exchange of fresh water) in 150 m^2 earthen ponds (Figure 7.4.4a), or in indoor cement tanks (Figure 7.4.4b). Eggs hatch within 30-35 hrs and are subsequently held in their hapas for two days prior to stocking, by which time they have reached an average individual weight of 2.3 mg. Hatching and survival rate to two days average 95 percent. Production costs for these two-day old larvae are shown in Table 7.4.3. Including a profit-margin, these larvae are sold on the pond bank at five CFA each.

Few farmers, however, want such small seed, 7-10 g being the minimum size to insure decent survival rates. As catfish fry are susceptible to a wide range of predators (Figure 7.4.6) including cannibals, the greatest problems encountered by catfish hatchery operators in the West and Central Provinces concern larval survival.

FIGURE 7.4.4a
Hapa-based, in-pond catfish incubators

FIGURE 7.4.4b
Gravity-fed hatchery tanks

TABLE 7.4.3
Costs for artificial reproduction of Clarias gariepinus (US$ 1 = CFA 500)

Cost Item	Unit Price	Units	Total Cost
Sacrificed ♂ broodfish	2 000	9	18 000
Depreciation on ♀ broodfish (2 yrs)	2 000	35	35 000
HCG	4 500	2	9 000
Disposable equipment (syringes, hapas, etc.)	5 000	1	5 000
Labor	250 (per person-hour)	40	10 000
Depreciation on ponds (10 yrs)	100 000	8	80 000
Total			**157 000**
Total larvae (24 hrs post hatch)			68 700
Cost per larvae			**2.3**

Three basic nursing systems are used:

1. **Low intensity:** Ponds are prepared by drying, cleaning and installing compost cribs comprised of wooden stakes driven into the mud at approximately 10 cm intervals to enclose 10 percent of the pond surface area. Ponds are then surrounded by a 1 m high fence fabricated of locally produced nylon mesh bags or aluminum roofing material to in an effort to exclude frogs, one of the most important larval predators. The compost cribs are filled with 7 kg/are total dry weight (approximately 20 kg wet material) of cut grasses mixed with 0.2 kg/are of wood ash. Ponds are then filled and stocked within three days (to avoid infestation by insects) with two-day old *C. gariepinus* larvae at a rate of 7.5 per m^2. Once per week, the compost is churned using a stick and another dose of grass and wood ash added.
2. **Medium intensity:** Ponds are prepared as in System 1, but instead of compost, ponds are limed with 2.5 kg/are of quicklime (CaO), fertilized with 20 kg/are (dry weight) of chicken manure and fed a daily supplement of wheat bran at a rate of 1 kg/are. Stocking rate is 15 two-day old larvae/m^2.
3. **High intensity:** Ponds are prepared as in System 2, but from Day 11 onwards, are fed twice per day with a 1:1 mixture of wheat bran and palm nut cake at a rate of 1.0 kg/are (2.0 kg/are/day total). Two-day-old larvae are stocked at 30/m^2. As in treatments 1 and 2, a frog fence and last-minute filling are the only anti-predator strategies employed.

FIGURE 7.4.5
Small-scale private catfish hatchery at Bapi, Western Province, Cameroon

Production cost factors are shown in Table 7.4.4 while average results are shown in Table 7.4.5. Survival among systems using only a frog fence and last-minute filling as predation control was about 37 percent, typical for this type of system.

FIGURE 7.4.6
Main predators of catfish larvae

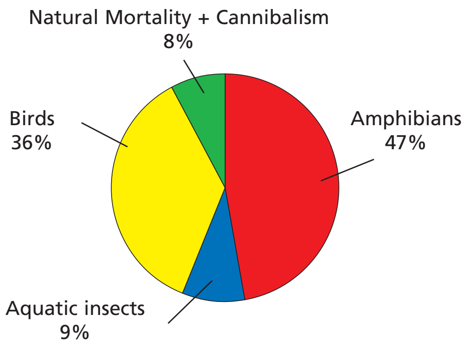


TABLE 7.4.4
Average costs per square meter of pond surface area, for nursing Clarias gariepinus in periurban Yaounde, Cameroon (US$ 1 = CFA 500)

System	Larvae	Pond inputs	Labor	Depreciation on predator fence	Depreciation on ponds & equipment	Total cost Per m^2
1	37.5	7.8	233.3	12.5	15.2	306.2
2	75.0	50.4	373.6	10.3	13.9	523.3
3	150.0	95.1	577.1	12.8	15.3	850.3

TABLE 7.4.5
Fingerling survival, final average weight, number harvested and profitability data per m^2 for *Clarias gariepinus* nursing systems (over 35 days) in periurban Yaoundé, Cameroon. Price of fingerlings is dependant upon size of fingerlings: >5 g = CFA 100, 2-5 g = CFA 75, < 2 g = CFA 50 (USD 1 = 500 CFA)

System	Survival (%)	Final average weight (g)	Number harvested per m^2	Gross revenue per m^2	Net profit Per m^2
1	48.5 ± 26.31	5.9 ± 2.23	3.6 ± 1.97	322.0 ± 163.23	15.8 ± 183.71 a
2	46.8 ± 43.35	5.5 ± 3.23	7.0 ± 6.50	527.4 ± 485.67	4.13 ± 488.83 a
3	28.4 ± 6.12	4.2 + 0.31	8.5 ± 1.84	723.75 ± 268.33	-126.6 ± 275.87 a

SEED MANAGEMENT AND QUALITY

Where small-scale hatcheries have managed to generate significant incomes for the operators and numbers of fingerlings for other farmers, deterioration of the genetic quality of cultured populations was another problem encountered that dilutes impact. The species most commonly produced in Cameroon, catfish (*Clarias gariepinus*) and tilapia (*Oreochromis niloticus*) each presents the hatchery operator with opportunities to mismanage broodstock.

For the highly fecund catfish, there is always the temptation to use the fewest number of broodfish possible to get a certain number of eggs. In addition, male catfish are usually sacrificed and so are used to fertilize as many females as possible (Figure 7.4.7). From these offspring of minimal numbers of parents will be selected the next generation of brooders and after several generations of such mating, bottlenecks lead to inbreeding which can reach levels sufficient to lower growth, decrease fecundity, reduce fitness and generate deformities.

Tilapias present a somewhat different challenge, but the outcome is the same. The typical practice at harvest among small-scale farmers is to sell or eat all fish of a certain minimum size, leaving smaller individuals to be either sold as fingerlings to other farmers or continue growing in the pond.

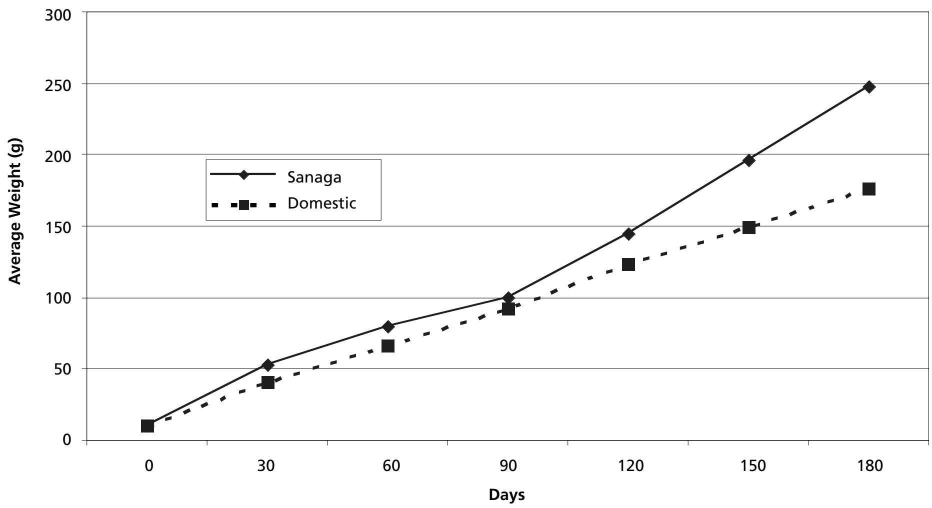
In the case of tilapia, only a part of these small fish are actually fingerlings; many being small are sexually mature adults (Figure 7.4.8). Such selection for smaller adults amounts to inadvertent selection for slow growth and/or early sexual maturation.

Often the numbers of broodfish used are far inferior to the numbers needed to maintain adequate

FIGURE 7.4.7
Sacrificing male catfish to obtain milt

FIGURE 7.4.8
Precocious juvenile (sexually mature at ten cm and < three mos of age) of *Oreochromis niloticus* harvested from a typical small-scale fishpond

FIGURE 7.4.9
Comparison of growth among feral and captive populations of *Oreochromis niloticus* in Cameroon



genetic variability in the population. Also, as male tilapia are highly territorial and competitive for mates, a relatively small percentage of males (the most aggressive and not necessarily the fastest growing) dominate the fertilization of the females. Without some method of ensuring that most males are represented, effective breeding number (N_e) will be less than anticipated and the population can become inbred, reducing growth and viability while increasing phenotypic variation.

Genetic drift, especially the founder effect, is another mechanism that can lead to loss of genetic diversity and the potential for inbreeding. Small founder populations are more common than not in Cameroonian aquaculture and, indeed, aquaculture in general. Being expensive, difficult and often illegal, individuals who seek to acquire exotic broodfish, often resort to minimal numbers, thus building low genetic diversity into their production systems from the outset.

Cumulatively, these various broodstock management mistakes have reduced the growth of tilapia populations held on small-scale hatcheries by about 40 percent (Figure 7.4.9). Although, it was not carefully documented, the replacement of male *Clarias* with feral broodfish at the Yaoundé Aquaculture Station produced offspring exhibiting signs of heterosis (substantially increased growth rate over the parental populations) indicating that the same is probably true for the catfish.

In response to these problems and *in lieu* of a practical broodstock management strategy for small-scale hatcheries, new broodfish populations have recently been acquired through agreements with local fishers to capture and hold both catfish and tilapia. Under the auspices of the WFC office in Yaoundé, these fish are being distributed at cost to local hatcheries. Farmers, having become aware of the growth differences between their existing and the wild fish are not insisting on new bloodline ("*les nouveaux souches*") when they place their orders.

INSTITUTIONAL AND POLICY FRAMEWORKS

The Ministry of Animal Industries and Fisheries (MINEPIA) is charged with the promotion of aquaculture for food security and rural economic development (RDC, 2003). However, current regulations in Cameroon barely mention aquaculture and make no specific reference to fingerling supply or quality. Nevertheless, the government is actively advocating the expansion of aquaculture and there is a long-standing policy of providing some basic support through the operation of the government stations mentioned above (RDC, 1997). Although there are no specifics provided and no funding mechanism identified, the Rural Development Strategy Paper (RDC, 2002) noted several prospective roles for government in the promotion of aquaculture, such as:

- extension of appropriate techniques for aquaculture;
- training of extension agents and farmers;
- development of a functional technical and economic framework;
- advising banks on the viability of aquaculture and opening lines of credit for investors;
- promoting private sector fingerling production;
- involving women and youth in aquaculture;
- organization of restocking programmes.

Although not part of the legal code, the newest policy document that deals with aquaculture is the Poverty Reduction Strategy Paper (RDC, 2003). This document emphasizes "the lifting of constraints to the production of fingerlings and transferring technical solutions to peasant farmers" as main areas of government engagement. Although MINEPIA extension staff are more or less committed to lifting constraints to aquaculture, there currently exists no structure formally charged with the assurance of fingerling or broodstock quality, or any quantitative criteria against which such assurance could be given.

In light of the vague nature of the current regulations, the FAO has recently commissioned a review of the fisheries and aquaculture laws (Kamga, 2005). Although the ways and means are not mentioned, the proposed new regulations charge MINEPIA with stimulating the expansion of aquaculture by providing support to:

- aquaculture investment;
- production and quality assurance of fingerlings;
- production and quality assurance of fish feeds;
- regulating the introduction and movement of aquatic organisms;
- research and extension.

This review of the regulatory environment is a first step in the implementation of a Strategic Framework for Aquaculture in Cameroon developed in 2003 by a consultative group comprised of the Cameroonian Fisheries Department of MINEPIA, the Institute of Agricultural Research for Development (IRAD) of the Ministry of Scientific Research and Innovation (MINRESI), the WFC and the FAO. In this document, the relative roles of government, investors and farmers are elucidated:

Governments:

- provides regular information on sources and prices of good quality seed to producers;
- provides guidelines in producing/ensuring good quality seed through such measures as seed certification;
- maintains broodstock of selected culture organisms corresponding to the identified production systems; and
- encourages commercial farmers and hatcheries to facilitate access to quality seed for the entire sub-sector.

Direct investors (seed producers):

- produce and distribute quality seed;
- sell products at a fair price;
- find mechanisms to facilitate access to high quality seed throughout the sub-sector;
- as appropriate, assist outreach program in promoting good management practices favouring improved yields; and
- monitor results.

Producer organizations:

- serve as a forum for information sharing among stakeholders;
- lobby for collective bargaining and appropriate public sector intervention; and
- link with research organisations.

KEY STAKEHOLDERS

As aquaculture does not play a dominant role in government planning or budgeting, relatively few resources, both human and financial, are available. Most of the key contacts in fingerling production come from the private sector (Table 7.4.2). In terms of institutional support, the main stakeholders are:

Fisheries Department, MINEPIA. (Dr Baba, Malloum Osman, Director; Mr Jean Kouam, Chef de Service for Aquaculture). As mentioned above, MINEPIA is charged with the development and implementation of aquaculture policy. Main activities include the operation of the above-mentioned government fish stations (most of which are defunct) and the payment of extension agent salaries. The MINEPIA Aquaculture Training Centre at Foumban (Figure 7.4.10) produces the majority of extension agents.

National Agricultural Research and Extension Program (PNVRA). This organ was created under a World Bank (WB)/International Fund for Agricultural Development (IFAD) project to provide Training and Visit extension services. Although the structure still exists, the PNVRA has been generally quiet since the end of the project in 2003.

Institute for Agricultural Research for Development (MINRESI). (Dr Vincent Tanya, Scientific Coordinator, Animal Production and Fisheries; Dr.Victor Pouomogne, Senior Aquaculture Scientist; Dr David Nguenga, Fish Reproduction Specialist; Mr Steve Sulem, Aquaculture Research Scientist). IRAD is a semi-autonomous agency with salaries paid by the government, but operating expenses generated through contracts. Although chronically under-funded, IRAD maintains an active program of research and training, based at their aquaculture research station in Foumban. In 2005, IRAD initiated a program of work funded by the Highly Indebted Poor Countries Initiative, focussing directly on training farmers and hatchery operators in catfish fingerling production. A part of this, they are also putting in place a system for the provision of quality broodstock to private hatcheries.

FIGURE 7.4.10
The MINEPIA Aquaculture Training Center, Foumban

Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang. (Dr J. Tchoumboué, Head, Department of Animal Production; Dr Minette Tabi, Assistant Professor of Aquaculture). The main agricultural university has long had a small Bachelor of Science (B.Sc.) degree program in aquaculture with usually fewer than ten students per year. In 2005, the program was expanded to include Master of Science (M.Sc.) and Doctor of Philisophy (Ph.D.) degrees.

FUTURE PROSPECTS

Cameroon has the potential to become an important aquaculture producer. The climate and water are good (although soils and topography are less so), markets are excellent, human technical capacity is modest, but adequate and basic infrastructure exists in the form of an active research program and a functioning training centre. In addition, the policy environment, although currently vague, is generally supportive. Three international agencies (WFC, the French Centre de coopération internationale en recherche agronomique pour le développement and FAO) are currently active in Cameroonian aquaculture and are working closely with the government and each other to ensure that past mistakes are not repeated and best practices are put in place to ensure that future growth of the sector is sustainable.

Despite the general lack of money, the Government of Cameroon has repeatedly expressed its commitment to the development of aquaculture within the country and the supply of high-quality fingerlings has been identified and clearly enunciated as the key constraint. The new IRAD catfish fingerling and broodstock quality assurance program is a step in the right direction and, linked through the Strategic Framework for Aquaculture Development to private sector initiatives, Cameroon is heading towards a resolution of the fingerling supply problem and the creation of a robust aquaculture sector.

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7.5 Freshwater fish seed resources in China

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ABSTRACT

China, one of the countries with the richest aquatic resources in the world, has more than 800 varieties of freshwater fish species. Based on production, the top 10 cultured species are: (1) grass carp (370 million tonnes); (2) silver carp (346 million tonnes); (3). common carp (236 million tonnes); (4) bighead carp (208 million tonnes); (5) crucian carp (194 million tonnes); (6) tilapia (90 million tonnes); (7) blunt snout bream (52 million tonnes); (8) freshwater eel (48 million tonnes); (9) river crab (41.5 million tonnes); and (10) white-leg shrimp (*Penaeus vannamei*) (40 million tonnes from freshwater culture).

According to an investigation report in 2001, there were 16 435 seed production units (hatcheries) and 8 072 were well equipped for hatching and juvenile rearing. Total production from all hatcheries are estimated at 13 385 billion individuals which meet the needs for grow-out production.

The 16th Item of the “Fisheries Law” requires that hatcheries producing aquatic seed are required to get a license from the local government. According to current statistics, approximately 50 percent of aquatic seed are produced by licensed hatcheries.

With respect to seed quality, the following are major issues of concern: (i) fish species with good strain are not currently the lead producers in aquaculture, (ii) lack of high quality seed and (iii) more emphasis placed on licensing than fish seed quality.

There are a number of services which provide support to China’s freshwater fish seed production sector**.** The innovation service is responsible for breeding using selective breeding and newly developed breeding techniques. The examination service is responsible for morphological characteristics and farming performance of freshwater fish seed. The extension service provides extension and demonstration activities for both hatchery and grow-out operators on good breeding techniques, evaluation of risks, testing and expansion of introduced or new species.

There are two major problems which need to be addressed: firstly, hatchery techniques for some important species has not yet been established and secondly, seed exchange and transportation between different places lack a valid surveillance.

Future prospects and recommendations for China’s freshwater fish seed sector are: (i) consider the sustainable development of aquaculture, exploit and utilize aquatic genetic resources strategically, (ii) develop genetic breeding programs and improve the quality of aquatic seed, (iii) train farmers how to get good quality seed for farming,

(iv) reinforce risk assessment on introduced species and minimize their harm to native genetic resources and (v) improve the regulation of seed management and to make it work efficiently.

INTRODUCTION

China is one of the countries with rich aquatic resources in the world. According to current statistics, there are more than 800 varieties of freshwater fish species. At present, more than 50 fish species, 20 shellfish species, ten crustacean species and ten algae species are being cultured. Total culture area reached 728 ha producing 3 209 tonnes in 2004. The Chinese government puts strong emphasis on seed improvement, a crucial requirement for the development of the aquaculture industry.

In 2004, China's aquaculture production reached 30.6 million tonnes, accounting for over 68 percent of national fishery production and 68.9 percent of the worlds' aquaculture production (Figure 7.5.1); aquatic products accounted for 29.8 percent of agricultural exports (Figure 7.5.2). According to an authoritative report in 2002, there were about 16 000 hatcheries in the country, of which about 8 000 are well-equipped for hatching and rearing. This large number of hatcheries meet the growing demand for aquaculture production.

The predominant species cultured in China are black carp, grass carp, silver carp and bighead carp (also called the "four major domesticated fish"), common carp and crucian carp. The production of the "four major domesticated fish" amounts to 57.7 percent of the total freshwater production followed by common carp and crucian carp which produced 22.4 percent of the total freshwater production and few other species including blunt snout bream contributing 3.4 percent and tilapia contributing 4 percent to total production. Some species such as sturgeon, trout, etc. are cultured in a small-scale with limited production (Table 7.5.1).

Most of the freshwater products are supplied live to the market with very little processing. Only about 7.75 percent of the total production were processed in 2003. According to a study conducted by the Shanghai Fishery University, domestic consumption is the main target of the commonly produced freshwater fish species. In more economically developed areas, for e.g. Shanghai, people still prefer low-priced fish. Culture of medium-priced fish such as tilapia and the giant Malaysian prawn is expanding because of good profit. The consumption of giant Malaysian prawn also increased by 50 percent in the late-1990s.

FIGURE 7.5.1
Chinese aquaculture production compared to world production

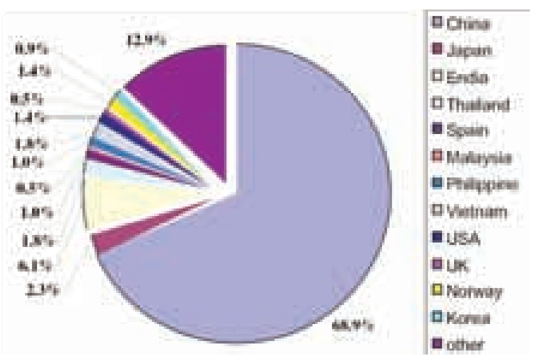


FIGURE 7.5.2
Aquatic products accounted for 29.8 percent of agricultural exports in 2004

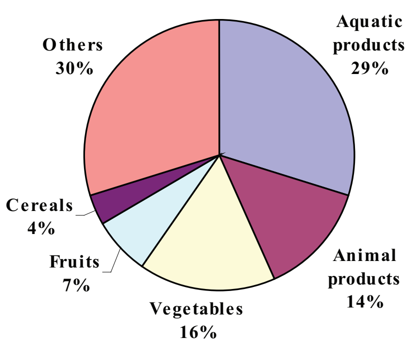


TABLE 7.5.1
The main freshwater species cultured in China

	Name	Wild	Imported	Breeding
1	Silver carp	▲		
2	Bighead carp	▲		
3	Grass carp	▲		
4	Black carp	▲		
5	Common Carp (lens *Cyprinus carpio, Cyprinus carpio var.jian, Cyprinus carpio wuyanensis*)	▲		□
6	Crucian Carp (Pengze crucian, Silver Prussian, Daban crucian)	▲		□
7	Mud carp	▲		
8	Chinese perch	▲		
9	Japan eel	▲		
10	European eel		□	
11	American eel		□	
12	Nile tilapia		□	□
13	Blue tilapia		□	
14	Red tilapia		□	□
15	Hybrid tilapia	▲		□
16	Rainbow trout (Dao's rainbow trout, gold rainbow trout)		□	□
17	Channel catfish		□	□
18	*Ictalurus nebulosus*		□	
19	Pacu		□	
20	Chinese sturgeon	▲		
21	Dabry's sturgeon	▲		
22	*Acipenser schrenckii*	▲		
23	Chinese paddlefish		□	
24	Great sturgeon		□	
25	Siberian sturgeon		□	
26	*Distoechodon tumirostris*	▲		
27	*Xenocypris argentea*	▲		
28	*Plagiognathops microlepis*	▲		
29	Blunt snout bream (Pujiang No.1)	▲		□
30	*Megalobrama hoffmanni*	▲		
31	*Megalobrama terminalis*	▲		
32	*Myxocyprinus* sp.	▲		
33	Ratmouth barbel	▲		
34	Armorhead catfish	▲		
35	Longsnout catfish	▲		
36	Yellow catfish	▲		
37	*Cranoglanis bouderius*	▲		
38	*Clarias lazera*		□	
39	Catla catla		□	
40	*Labeo rohita*		□	
41	*Cirrhina mrigala*		□	
42	Striped Catfish		□	
43	Chum salmon		□	
44	*Micropterus salmoides*		□	
45	*Lepomis macrochirus*		□	
46	Stripedbass		□	□
47	Red fish		□	
48	Walleye		□	
49	Shad		□	
50	Big Mouth Buffalo		□	
51	*Takifugu flavidus*	▲		
52	*Fugu obscurus*	▲		
53	*Fugu xanthopterus*	▲		
54	Amur pike	▲		
55	River perch	▲		
56	*Erythroculter ilishaeformis*	▲		
57	*Spinibarbus sinensis*	▲		
58	Snakehead	▲		
59	*Channa asiatica*	▲		
60	flowergu fish	▲		
61	Rice field eel	▲		
62	Chinese mitten-handed crab	▲		
63	river prawn	▲		
64	Giant Malaysian prawn (*Macrobrachium rosenbergii*)		□	
65	*Cherax quadricarinatus*		□	
66	Chinese turtle	▲		
67	Reeves' Turtle	▲		
68	*Hyriopsis cumingii*	▲		
69	*Cristaria plicata*	▲		

SEED RESOURCES AND SUPPLY

Freshwater fish seed production in China can be classified into three categories. The first is the wild seed. Since hatchery technologies for some species have not yet been established, fish seed come from fishing from natural ground. At present, there are still few species, such as eel and some new cultured species, being captured from the wild. The second is from wild stocks. With the study of propagation physiology and fertilization technology, after catching broodstocks from natural waters, fish seed of black carp, grass carp, silver carp, bighead carp and river crabs can be manually reproduced. Most aquatic seed are produced this way. According to the survey, 86 percent of freshwater fish species rely on using natural parents for seed production. The third category is domestic seed production. Artificially-bred parents are adopted for seed production using current technologies and the number of fish species completely artificially reproduced is increasing (e.g. common carp, crucian carp, bream, salmon trout, tilapia, etc.). So far, most seed are supplied by hatcheries. Seed production technology for 88 percent freshwater fish species are developed and 66 percent of freshwater seed are produced at the industrial level. By 2000, the total number of hatcheries (freshwater and marine water) reached 16 435. Of these, about two thirds (2/3) are private and the rest (1/3) are government or a combination of private/government operation. Fish seed output has already met the basic needs in aquaculture and the seed production industry has thus become an important part of aquaculture (Figure 7.5.3).

SEED PRODUCTION FACILITIES AND TECHNOLOGY

According to an investigation report in 2001, there were 16 435 fish seed production units and of these, about 8 072 were well equipped for hatching and juvenile rearing. Total production of all the hatchery is 13 385 billion individuals which meet the need for grow-out production. There are 8 171 hatcheries of the "four major domesticated fish", 6 700 hatcheries for common carp and crucian carp and 499 for tilapia. The rest of the hatcheries are for river crab (515), reptile (203) and shellfish (1 017). Total investment for all fish hatcheries is about 149.6 billion yuan and employs about 275 539 persons (Plate 7.5.1).

From the 1970s to the 1980s, cross-breeding technology has brought encouraging results as exemplified by common carp (Figures 7.5.4 and 7.5.5). New fish strains such as Heyuan carp and Tri-cross-bred carp were selected and bred. Strains such as Jian carp (Figure 7.5.6), Songpu carp, Prussian carp, etc. were bred through a combination of conventional and gynogenesis technologies. Then a series of new aquatics, such as Xiangyun crucian and Xiangyun carp were reared as a result of polyploid breeding. Blunt snout bream "Pu River No.1" was acquired through conventional breeding method. Meanwhile, there were significant accomplishments on research on transgenic fishes. According to the authorization by the National Certification Committee of Aquatic Wild and Bred Varieties (NCCA-WBV), until the end of 2004, there had been 32 strains, among which were 16 selective strains and 16 cross-breeding strains. Most of them are carp (Table 7.5.2).

Many of cultured species in China are introduced exotic species. According to incomplete statistics, since the 1950s more than 140 species have been introduced to

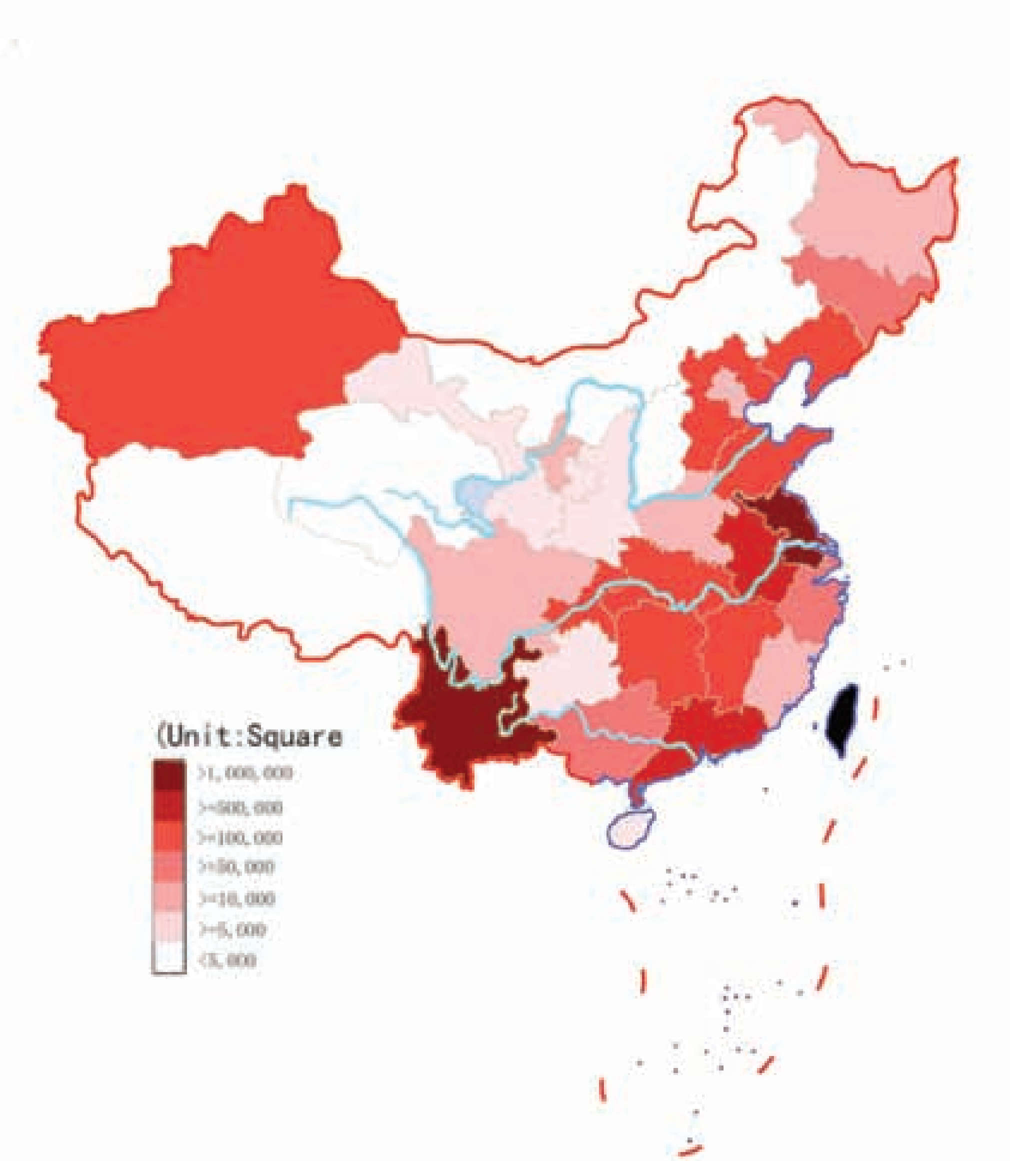
TABLE 7.5.2
Introduced exotic species having obvious economical benefits (in thousand tonnes)

500-1000	100-500	10-100	Below 10
scallop	giant Malaysian prawn	Channel catfish	Rainbow trout
tilapia		*Micropterus salmoides*	Rohu carp
			Clarias lazera
Penaeus vanmamei		*Colossoma brachypomum*	Turbot
		Penaeus monodon	American red fish

Source: Li Sifa (pers. comm.)

FIGURE 7.5.3

Map of China showing the distribution of freshwater fish seed production in different provinces



China. More than ten species show obvious economic value and produce 10 percent of total aquatic production (including marine species) (Table 7.5.3). Because they are very good species, their production accounts for about 20 percent of the total aquatic production value.

SEED MANAGEMENT

The 16th item of the "Fisheries Law" requires that hatcheries producing aquatic seed are required to get a license from the local government. According to current statistics, approximately 50 percent of aquatic seed are produced by licensed hatcheries.

The "aquatic seed management" also defined that the introduction of exotic or foreign seed requires a quarantine license from the local government fishery bureau. Only those without pathogens can be transported and sold. Unfortunately, this regulation has not been seriously implemented.

PLATE 7.5.1

The main freshwater fish species in China

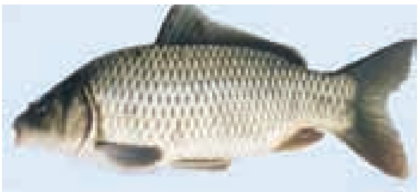

Jian carp


Huanghai Chinese shrimp


Common carp


Triploid carp


Triploid crucian carp

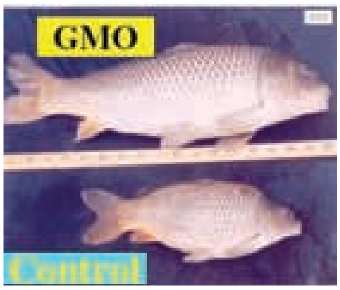

Triploid common carp


Cyprinus carpio singuomensis


Cyprinus carpio wananensis

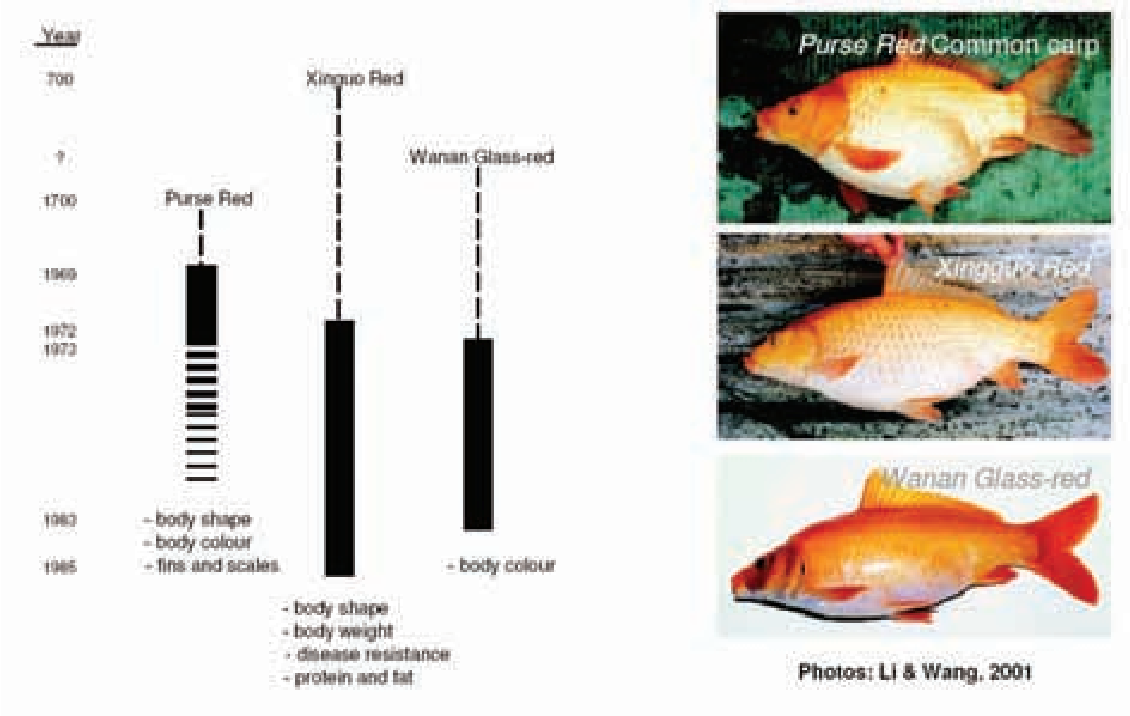

Bluntsnout bream


Triploid hybrid of common carp and crucian carp



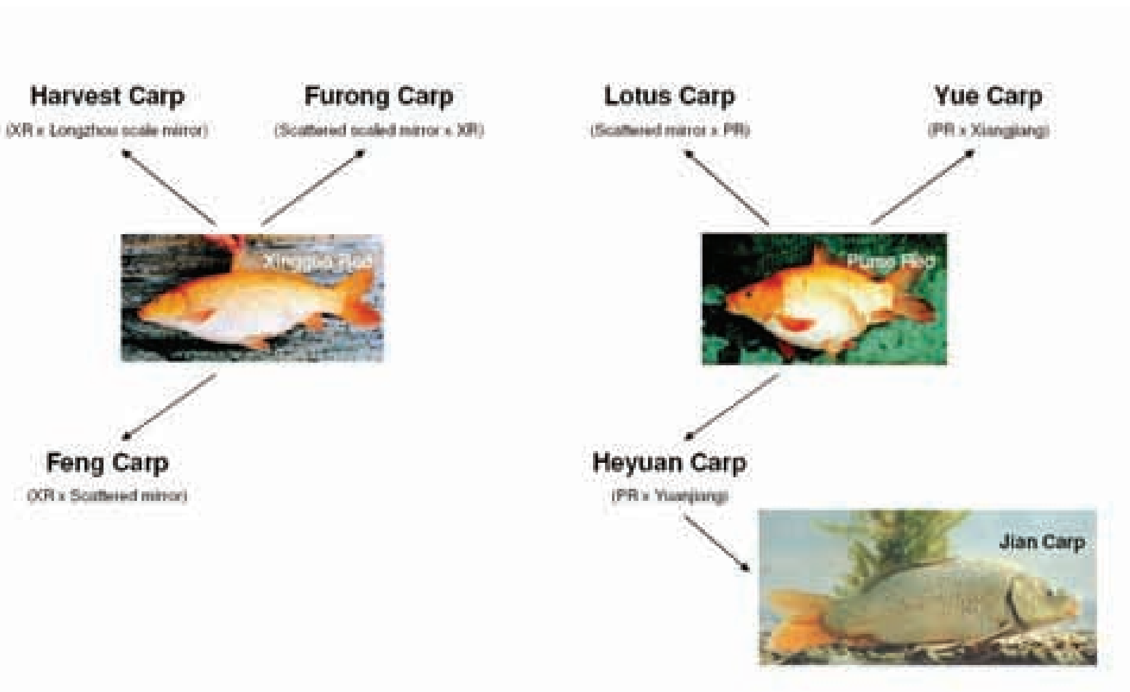
Transgenic common carp in China

FIGURE 7.5.4
Selective breeding of common carp



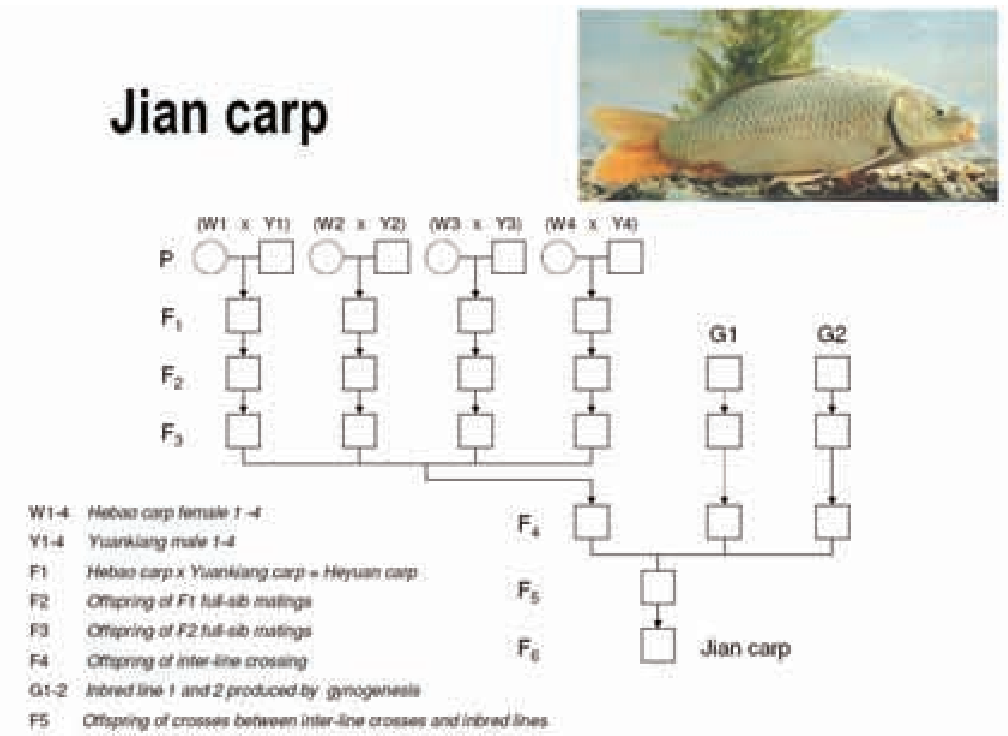
Source: Jorn Thodesen (pers. comm.)

FIGURE 7.5.5
Cross breeding of common carp



Source: Jorn Thodesen (pers. comm.)

FIGURE 7.5.6
Breeding of Jian carp



Source: Jorn Thodesen (pers. comm.)

Since 1990, national and local governments of China have increased investment on the establishment of the National Aquatic Bred and Wild Seed System (NABWSS) which includes the Genetic Breeding Center (GBC), the Wild Variety Collection Center (WVCC), the Wild/Bred Variety Amplifier (WBVA), the Exotic Species Centers (ESC) and the Seed Quality Inspection Centers (SQIC).

In order to match with NABWSS construction, the Ministry of Agriculture, Fishery Bureau successively issued several documents, including "management norms for WBVA", "guide for WBVA construction", etc. which standardized the procedure and operation of WBVA.

SEED CERTIFICATION

The 16th Item of the "Fisheries Law" states that "any new cultured aquatic species can't be produced and extended until obtaining certification by NCCAV followed by approval by the MOA".

The documentation required for certification of good species, include: (i) application report which is the main document which contains original sources of seed, breeding process, major characteristics, extension and evaluation; (ii) other supporting documents consisted of research report, reproduction and seed production technical reports, genetic characterization, inspection report concerning disease resistance by an authority designated by NCCAV, on farm testing report during the last two years.

The government established NCCAV in 1991 under the MOA of China. The NCCAV is responsible for certificating three kinds of cultured species which includes genetic improved varieties (strains), hybrids and exotic species.

The NCCAV consists of scientists with genetics background, who are from research institutes and universities; aquaculture administrators, who are from the

TABLE 7.5.3
List of new varieties and strains approved by national government from 1996 to 2004)

Year	Variety			Total
	New variety	Hybrid	Imported	
1996	*Cyprinus carpio singuomensis, Cyprinus carpio* var. *wuyanensis, Carassius auratus pengzesis, Cyprinus carpio* var. *jian,* *Songpu crucian carp, Cyprinus carpio* var. *wuyanensis,* *German mirror carp (7)*	Blue tilapia, *Orechromis* sp., Ying hybrid carp, Feng carp, Heyuan carp, Yue carp, three-hybrid carp, Furong carp, Allogynogenetic Silver crucian Carp (9)	*Tilapia nilotica, Tilapia aurea, Micropterus salmoides, Colossoma chypomum,* Channel catfish, rainbow trout, Donelson rainbow trout, *Clarias lazera, Cyprinus carpio var. specularis*, Scatter scaled mirror carp, *Labeo rohita,* Giant river shrimp, bullfrog (Rana heckstheri), *Patinopecten (Mizuhopecten) yessoensis*, Pacific oysters (17)	33
1997	"901" kelp, Songpu carp (2)	Gift tilapia (1)	-	3
2000	Bluntsnout bream (Pujiang No.1), *Cyprinus carpio* var. *wananensis* (2)	Big Mouth Buffalo, turbot (2)	-	4
2001	-	*Cyprinus carpio* Triploid, *Carassius auratus* Triploid (2)	-	
2002	-	Red white crucian with long tail, Blue flower crucian with long tail (2)	SPF White Prawn (1)	3
2003	*Fenneropenaeus chinensis* ("Yellow Sea 1"), Songhe carp, Molong carp, *Xiphophorus helleri* (4)			
2004	Huanghe carp	"DalianNo.1"hybrid abalone, "East No.2" hybrid kelp, "Rongfu"kelp(3)	Alligator snapping turtle, *Pangasius sutchi, Hyriopsis schlegerli* (3)	7
Total	16	16	24	56

Bureau of Fisheries, the National Fisheries Technology Extension Center and the Academy of Fishery Science of China, under the MOA. In China, only NCCAV has been authorized by the central government to certify those genetic improved varieties extending to all of the country.

According to NCCA authorization, until end of 2004, there had been a total 32 bred varieties consisting of 16 selective breeding varieties and 16 crossbreeding varieties (Table 7.5.3).

LEGAL AND POLICY FRAMEWORKS

The legal documents in China concerned with aquatic seed are the "Fisheries Law" and "Aquatic Seed Management Measure". The 16th item of the "Fisheries Law" is about the management of aquatic varieties and seed. Details of this can be found in the section on Seed Management.

As the seed is a very important foundation of aquaculture, Chinese central and local governments pay more attention to this field through supporting policies. Since 1998, the national and local governments of China have increased investments continually in the establishment of National Aquatic Seed Production System (NASPS) (Plate 7.5.2), which includes Genetic Breeding Center, Breed Amplifier and Key Hatchery. The first project of NASPS was carried out from 1998 to 2004; a second project is on-going (2005-2010).

SEED QUALITY

The "aquatic seed management" provision of the "Fisheries Law" from MOA defined that the breeders for seed production must be introduced from WBVA or WVCC and

GBC in order to ensure the quality of the broodstock. However, in practical operation there are three problems. The first is the limitation of wild or bred variety production ability. The WBVA cannot produce enough breeders to satisfy the needs of hatcheries in both quantity and varieties. Good strain does not play a leading role quantitatively in aquaculture production. The second problem is seed evaluation techniques. An effective and scientific technique is needed. The third problem is that more emphasis is placed on the license and little on the quality of the seed itself.

SEED MARKETING

Aquatic seed are sold and circulated mainly from the hatchery to independent farmers, hatcheries generally produce seed according to the customer's order. Seed from some large farms in the southern region of the country are transported to farms mainly via air or land transportation. Seed of the northwest and the northeast regions mainly come from southern region. Because farming in these regions are made by small farmers, seed are not easily accessible locally. Therefore, some seed distribution companies emerged and are involved in the seed trade. Exotic seed are distributed by companies who purchase seed abroad, sell them to the farmers through theirs networks or branches such as those practiced in the eel seed business.

SEED INDUSTRY

The seed industry is composed of many small private seed producers. In order to make progress in seed quality improvement, the government invests substantially in the sector therefore making its role in seed production very significant.

The government has already set up 36 national classes and 100 provincial classes of WVCC and WBVA which have been checked and accepted in 2004. Some of them are equipped with advanced technology and known as demonstration base. WVCC is responsible for the collection, conservation and supply of the good wild stock. The selected wild stock is mainly supplied to WBVA. Fourteen national classes of WVCC have been checked and accepted. WBVA is responsible for the acclimatization, selective breeding of good wild varieties, exotic species, as well as bred varieties approved officially. They provide government and private hatcheries and farms with broodstock or seed. Twenty-three WBVAs have been checked and accepted. The ESPC is responsible for the introduction, risk evaluation, quarantine, production testing and extension of exotic species. Twenty-two ESPCs have been checked and accepted.

FIGURE 7.5.7
Flow chart of China's freshwater fish seed production sector

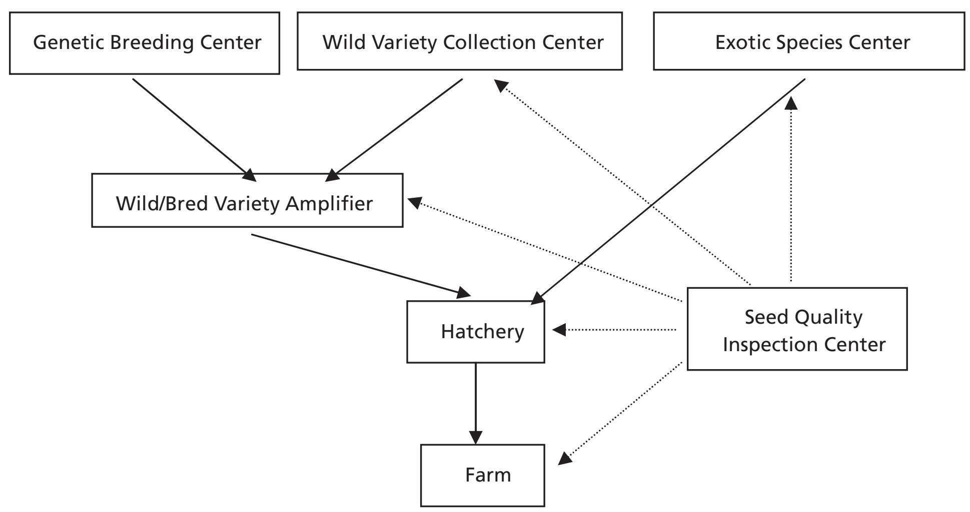


PLATE 7.5.2
Facilities at the National Aquatic Seed Production System (NASPS)


Genetic breeding center indoor tanks


Genetic breeding center indoor tanks


Wild breed variety amplifier


Larviculture tank


Tilapia hatchery in Qingdao


Larviculture tank

Government hatcheries fetching broodstock from WVCC or WBVA, are responsible for demonstrating hatchery techniques and supplying seed to farmers (Figure 7.5.7).

SUPPORT SERVICES

According to functions, support services are divided as follows:

(i) Innovation service is provided by the GBC who is responsible for breeding (both through selective breeding and other newly developed techniques such as genetic engineering) in order to keep up with industry development demand as well as marketing demand. The first GBC, located at Heilonhjiang Fisheries Research Institute (Harbin) was an investment by the central government in 2004.

(ii) The examination service is provided by the SQIC who is responsible for the establishment and improvement of rapid and accurate evaluation techniques to strengthen the germplasm examination. The examination service is concerned with the morphological characteristics, farming performance and other cellular and molecular authentication requirements. Standards for more than 20 species (e.g. grass carp, silver carp, Nile tilapia, etc.) have been issued. The

PLATE 7.5.2 (CONTINUED)

Facilities at the National Aquatic Seed Production System (NASPS)

Wild variety collection center for "major four family carp"

Tilapia stock farm in Guangdong

Man-made lake for preserving breeder

Cement ponds for rearing seeds

Exotic species rearing center

germplasm authentication techniques as well as standard research methods are also in the process of being established. Four centers have already passed the national examination. These are the: (i) Chinese Academy of Fishery Sciences, Yangtze River Fisheries Research Institute (Hubei Jingzhou); (ii) Chinese Academy of Fishery Sciences, Yellow Sea Fisheries Research Institute (Qingdao); (iii) Chinese Academy of Fishery Sciences, Pearl River Fisheries Research Institute (Guangzhou) and (iv) Chinese Academy of Fishery Sciences, Heilongjiang Fisheries Research Institute (Harbin).

(iii) The extension service is composed of five levels of stations such as national, provincial, city, county and country extension stations. The main function is for the extension and demonstration of hatchery and grow-out techniques covering the following aspects: conservation of the germplasm of good breeds, evaluation of risks, testing and expansion of introduced breed/species in the appointed district.

ECONOMICS

So far, there is no specialized organization or individual studying the economics of aquatic seed production in China. However, the aquatic seed market generally follows the market trends, i.e. profits mainly decide the relationship between supply and demand. When a certain fish seed is in shortage, the price will go high and the hatchery will make high profit. On other hand, when a certain fish seed is more than the demand, hatcheries will probably lose money.

In general terms, the main species used in freshwater farming do not change greatly and the seed market is relatively stable. The price is also steady. Whichever the case, the seed production sector is the highest profit making activity of the aquaculture business.

INFORMATION OR KNOWLEDGE GAPS

There are two main problems.

First is that hatchery techniques for some important farmed species has not been established yet. An example is eel aquaculture which is a major and profitable industry. It has an export value of US$860 million in 2004 contributing to 12.2 percent of the total national aquatic product exports and the top position for a single-item agricultural export product. Since the eel hatchery technique has not been developed yet, the seed for grow-out production depend on wild sources. Wild-caugt seed have continuously declined during the successive last few years. Eel seed imports amounted to 51.4 tonnes in 2004 valued at US$ 7.8 million. Because the cost of imported seed have increase, seed cost accounts for 30 percent of the total farming cost.

The second problem is that seed exchange and transportation between different places lack a valid surveillance system. China is a huge country and as such, transfers and movements of many fish species from region to region (e.g. introduction of fish from Yangtze River to Erqishi River in Xingiang Province or vice-versa) within the country has been going on. The biological significance is almost similar to the introduction of a species from one country to another. Such transfers has lead to great damages. An example is the proliferation of the Chinese turtle from Taiwan Province of China impacting the fine genetic resources of China mainland turtle and which also brought new pathogens. Risks exist from nation-wide distribution, repeated introduction and escapees (e.g. rainbow trout).

Although introduction of fish seed is regulated by the “Office Procedure for Fish Seed in Aquaculture” which requires that quarantine procedures be carried out by the local administrative department in charge of fishery and release, transport and sale of seed authorized only after certification – this regulation has not been put into practice rigorously.

FUTURE PROSPECTS AND RECOMMENDATIONS

Future prospects and recommendations for China's freshwater fish seed sector are: (i) consider the sustainable development of aquaculture, exploit and utilize aquatic genetic resources strategically, (ii) develop genetic breeding programs and improve the quality of aquatic seed, (iii) train farmers how to get good quality seed for farming, (iv) reinforce risk assessment on introduced species and minimize their harm to native genetic resources and (v) improve the regulation of seed management and to make it work efficiently.

Some of these recommendations are elaborated below.

Sustainable development of aquaculture, exploitation and utilization of aquatic genetic resources strategically. The following aspects should be considered: (i) selection of genetic resources should be based on geographic characteristics and suitable local species, (ii) market needs and (iii) production needs and trends in international aquaculture development.

Development of breeding programs and improvement of quality of aquatic seed. Compared with crop or livestock industry, the number of good species for aquaculture in the country is very limited. Every year, about 150 new species are approved for the crop industry; in aquaculture, only 2-3 new species are approved. Thus, the next step is to develop good new species. The country will continue to develop new species/variants of the "four major family fish species", crucian carp, common carp, tilapia and others. Innovation in breeding will involve development of species that are high-producing, of high quality, disease resistant, etc.

Determining the appropriate and leading species for China. In determining the most appropriate and leading species of fish to be bred in China, the following needs to be considered: (i) it should be the main species, (ii) it should be consumed by large population in China and (iii) it should also be popular in the international market.

Reinforce risk assessment on introduced species and minimize their harm to native genetic resources. This can be achieved through the following:

- Establish national management and information systems for newly introduced species in aquaculture. This will ensure healthy and systematic production. Such system will be able to trace and manage the introduced species and will allow the formulation of mid-term and long-term plan for such introduced species according to the development of the industry. Reasonable standards based on local conditions, integrated planning and classified guidance will be required. Well-planned introduction of new species in accordance with available resources (in terms of water area, technology, economic conditions) will prevent duplication of efforts.
- Quarantine measures should be strictly implemented to avoid diseases and parasites from introduced species. Introduced species have played a significant role in the country's fishery and aquaculture industries; nevertheless, quarantine should not be neglected as it is one of the most important steps in any species introduction. There are lessons from the past where numerous parasites and diseases have been introduced because of the lack of quarantine enforcement and losses were significant.
- Understanding the ecology of the receiving environment for the introduced species through investigation and research should be carried out. Promotion of such introduced species should be made only when it is assured that the new species will not destroy the environment.
- Introduction of good breeding species and technologies plays an extremely

significant role in increasing genetic resources and improving aquaculture production as well as increasing the economic benefits for the country. Biotechnology can be used to conserve and innovate new genetic resources and in combination with supply of new parents, can be a safe and economic way to promote and utilize foreign species.

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7.6 Freshwater fish seed resources in Colombia[1]

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ABSTRACT

Aquaculture in Colombia started in the early 1950s, with the introduction of rainbow trout *Onchorhynchus mykiss*, followed by common carp and tilapia from Brazil, for which a number of government-operated, pilot-scale fish farming stations were constructed. During the late 1970s and early 1980s, research on native species began, yielding important results which, together with the culture of exotic species helped develop today´s Colombian aquaculture.

Freshwater aquaculture production in Colombia has had marked fluctuations, reaching a maximum in 1999, with 43 000 tonnes and an almost 50 percent drop the following two years due to social unrest in producing regions. Tilapia contributes 80 percent of the total national freshwater aquaculture production, the balance being comprised of native species such as *Piaractus mesopotamicus*, *Colossoma macropomum* and rainbow trout.

Freshwater fish seed production in Colombia is carried out in 65 government-operated and private hatcheries. The annual estimated production of tilapia fingerlings is almost 112 million, followed by rainbow trout (27 million) and native species (7.5 million). Such hatchery outputs meet the national demand, which is lower than the reported national installed capacity.

Breeding and hatchery technologies vary according to the species. For tilapia, semi-natural breeding techniques are employed. Breeders are stocked at 0.3/m^2 with a sex ratio of 1 male:3 females, either directly in 0.08-0.12 ha open earthen ponds, or in 10 x 25 m pens placed within the ponds. Fry are collected and transferred to sex-reversal small ponds, hapas or cages, where they are stocked at 200-500/m^2 and sex-reversed using standard hormones. Fry are raised to 5 g in nursery ponds under high protein pelleted feeds.

Trout fingerlings are produced through dry artificial insemination and incubation in flow-through incubation troughs, while native species are artificially induced to spawn employing homoplastic or heteroplastic hormones, including human chorionic gonadotropin hormone and carp pituitary extracts. Depending on species, fry are stocked in earthen ponds and fed artificial diets.

[1] The original paper, written in Spanish, was jointly translated into English by M.B. Reantaso (FAO), Alday-Sanz (Spain) and A. Flores Nava (Mexico) for purposes of this publication.

Genetic selection is limited to phenotypic approaches, in most species. However, introduction of genetically improved strains of tilapia into the country by private companies is common, although often not officially recorded.

As far as seed quality is concerned, there are no official standards in the country. Supply and demand are the driving forces for producers to improve fingerling performance in terms of survival, growth rate and size homogeneity. Seed buyers, if unsatisfied with the product, will change supplier. Seed certification only focuses on disease prevention and is carried out through random sanitary inspection by fisheries authorities.

Some challenges the industry has to face include seed pricing determined by external factors (i.e. inflation), rather than by factors such as direct input costs, shortage of skilled labour and low economic capacity of producers to incorporate technological innovations, increased oil pollution in seed production zones, genetic deterioration of existing broodstock due to the lack of genetic improvement programmes and seasonal production of native species, which limits production.

INTRODUCTION

The objective of the present study is to describe the present state of the production of freshwater fish seed in Colombia, its strengths, weaknesses, to determine future perspective and to make recommendations for its development.

Information were obtained through: (i) field visits to Meta in the region of Llanos Orientales; (ii) telephone interviews with seed and fish producers in Huila, the Valley of Cauca, Santander and Antioch; (iii) compiled updated information from the Ministry of Agriculture and Rural Development; and (iv) author's personal notes and knowledge.

EVOLUTION OF AQUACULTURE IN COLOMBIA

Aquaculture in Colombia is divided into four periods based on the level of development, modernization and events during the period. The first period was from 1938 to 1975, the second period from 1975 to 1990, third period from 1990 to 2003 and the fourth period from 2003 to present.

First period (1938–1975)

This period is characterized by the introduction of rainbow trout (*Oncorhynchus mykiss)* for sport fishing. In the 1950s, mirror carp (*Cyprinus carpio* var. *specularis)* was introduced from Brazil and in the 1960s, Mozzambique tilapia (*Sarotherodon mosambicus)* and Tilapia rendali (*Tilapia rendalli*) were introduced to develop rural aquaculture in Cauca Valley, the coffee zone of the country. In addition, during this period, induced breeding of bocachico (*Prochylodus magdalenae)* was adopted. Bocachico is a native species in the basin of Magdalena River, widely preferred by consumers and thus, has great commerecial importance in Colombia.

In this period, aquaculture stations were constructed in San Cristobal (Bolivar) and Buga (Cauca Valley) to develop culture technologies for warmwater species. Similarly, stations were established in Santander, Tota (Boyaca) and Huasipongo in Cocha lagoon (Narino).

In 1974, Act 2811, National Code for Renewable Natural Resources and Environmental Protection, was promulgated. This is the first environmental law of the country and includes exploitation of fishery resources and aquaculture.

Second period (1975–1990)

This phase continued with the strengthening of state infrastructure directed towards research and promotion of the culture of both native and exotic species by means of constant extension services and technical assistance. Two of the most important aquaculture stations were built during this period: Repelon (Atlantico) and Alto Magdalena (Gigante and Huila), both of which are still functioning.

Likewise, three other stations were constructed in this period, namely: (1) La Terraza aquaculture station (Villavicencio, Goal), (2) Oiba station (Santander) and (3) Timbio station (Cauca Valley) – for the purpose of strengthening small- and medium-scale aquaculture using the seed produced from Gigante and Repelon.

Additionally, in La Terraza station, research began on the domestication and reproduction of both the white and the black cachamas *(Piaractus brachypomus* and *Colossoma macropomum).*

In the 1980s, Nile tilapia (*Oreochromis niloticus*) and the red hybrid tilapia were introduced with the purpose of developing medium- and large-scale aquaculture. At this time research on the cultivation of the sabaleta (*Brycon henni)* commenced.

Third period (1990–2003)

This period was marked by the promulgation of Act 13 (dated 1990), General Statute of Fishing, which created the National Institute of Fisheries and Aquaculture (INPA). Until 2003 , it was in charge of research and regulation of fisheries and aquaculture at the national level. At the beginning of the 1990s, there was an increase in aquaculture production, i.e. 60 percent more than that produced during the previous decade. Factors such as a technical improvement in the culture of red tilapia, increased number of native species cultured, and the construction of large-scale fish farms in many regions of the country (particularly in Huila, Goal, the Valley of the Cauca and Antioch).

Another outstanding aspect during this period, was the opening of technical, professional and advanced courses in aquaculture by some regional universities and in the capital city of Bogota. This has provided a great supply of technicians and professionals required at different production levels. In particular, the Universidad de los Llanos Orientales (Villavicencio, Meta), the Universidad de Córdoba (Lorica, Córdoba) and the Politécnico Colombiano Jaime Isaza Cadavid (San Jerónimo, Antioquia) established aquaculture stations to: (a) carry out research and to promote the culture of native species in each region, (b) develop some activities for exchange of information and technical assistance for mutual cooperation in the development of technologies, and (c) to further the knowledge on the biology and aquaculture performance of several target species.

In the 1990s, reproduction in captivity and culture methods were developed for the following native fresh water species: yamú (*Brycon siebenthalae* and *B. hilarii)*, capaz (*Pimelodus grosscopfii),* bagre rayado (*Pseudoplatistoma fasiatum* and *P. tigrinum*), yaque (*Leiarius marmoratus)* and nicuro (*Pimelodus blochii)*.

Likewise, in Repelón and Gigante stations, projects on genetic improvement of existing lines of red tilapia used for aquaculture were undertaken, the purpose of which was to maintain and optimize the production of seed and consequently to improve the quality of fish in terms of individual colour and weight at harvest as well as the overall pond yields.

As of 1999, fresh water aquaculture was included in the policy of competitiveness of the farming sector led by the Ministry of Agriculture and Rural Development through the Fish Farming Productive Chain or "Chain", where other public institutions participate (e.g. Ministry of Environment, Housing and Territorial Development; Ministry of Natural Treasury; Ministry of Commerce, Industry and Tourism; National Learning Service, SENA and INCODER), as well as representatives of the private sector (e.g. independent fish farmers and fish farming associations, aquaculture products dealers, feed manufacturers, financial and transport services and others).

Recent studies realized by the "Chain" in the zones with major aquaculture potential (i.e. Huila, Tolima, Santander, North of Santander, Goal, Casanare, Antioch, the Valley of the Cauca and the Cauca) reported that in 1999 Colombia obtained its maximum aquaculture production of 42 969 tonnes, representing an annual average growth of 26.6 percent since 1989.

Unfortunately in 2000, aquaculture production decreased by 50 percent (21 641 tonnes) as a result of the general economic crisis experienced by the country, which led to more than 20 percent unemployment, and unstable public conditions that resulted in the closure of some aquaculture farms. In addition, prices of imported tilapia from Ecuador are lower than that of tilapia produced in Colombia, thus making the local industry less competitive.

Fourth period (2003 to present)

This period was marked with the closure of the INPA as well as of three other organizations within the farming sector that were responsible for rural development and agrarian reform. These functions have now been taken over by the new National Institute for Rural Development or INCODER. Unfortunately, it seems that the fisheries and aquaculture institution does not represent the needs of the various aquaculture stakeholders and it does not have the capacity to respond apropriately to the requirements of the sector at the national level.

Of the five aquaculture stations operated by the INPA, only two continue to function under INCODER, these are Repelón and Gigante. These stations continue to work on projects related to rearing of eggs, larvae and fingerlings, fattening of native species; genetic improvement of red tilapia; production of seed for rural producers and other actions for the promotion of aquaculture and restocking of public water bodies.The rest of the stations have been transferred to regional and private academic organizations.

Currently, the species that are consistently being used for aquaculture in the country are tilapia (red and silver), cachama, trout and yamú, which are sold in local, regional and national markets. Culture of native species is still at the experimental stage and seed are produced for restocking of natural water bodies, while small-scale culture ponds are for home consumption, whose excess production is locally marketed.

According to the last reports of the "Chain" for 2004, tilapia production has recovered, which means that tilapia seed production has increased. In spite of this, some aquaculturists have complained that seed quality is poor, as reflected in high morbidity/mortality rates and high size heterogeneity. This has promoted the Ministry of Agriculture and Rural Development to cofinance projects that foster strategic alliances between the public and private sectors in areas such as genetic improvement, fish pathology and other breeding technologies (e.g. sex reversion).

Seed production is carried out in both private and state hatcheries or fishfarms which posess an established broodstock. The most important species are: red and silverplated tilapia, carp, white and black cachama, yamu and catfish, or else, through imported eggs of rainbow trout. Nevertheless, it should be emphasized that none of the seed produced are certified according to purity or quality by any national organization, either private or public.

Since the 1990s, aquaculture products contributed greatly to the diet of Colombians, although there is no official data available to confim this observation. During the year 2002, INPA and INCODER had great difficulties in collecting and analyzing statistical data. Nevertheless, it was observed that in supermarkets and fish markets there was an increase in the suppy of red and silverplated tilapia (whole and fillet), trout (cut sections and fillet) and gutted cachama.

Similarly, in many restaurants, red tilapia is commonly included in their menu. The period where there are great sales of tilapia includes Fridays (throughout the year) and during Lenten and Easter Season in the months of March and April.

SEED RESOURCES SUPPLY

All seed of different native and exotic species are produced from government aquaculture stations and many private fish farms of medium- and large-scale, that have hatchery facilities. This means that there is no seed used in aquaculture ponds, that comes from natural sources.

In general terms, red and silverplated tilapia, the "Chitralada" strain, as well as cachama, trout, mirror and red carps are produced throughout the year in ponds or hatcheries. The yamu reproduces three times a year, while other native species such as dorada, sabaleta, catfish and capaz, reproduce during the rainy season (May, June, July, October and November) which coincides with their natural breeding season.

The present state of production and marketing of seed of major aquaculture species in Colombia are:

Tilapia: The main cultured species is tilapia (or red and silverplated) with an average monthly production of 500 000 fry. The average farm-gate price is about US$35.24/thousand fry and US$55.07/thousand fry from middlemen. Because of great acceptance from middle- and high-class consumers, fish meat commands a price US$ 2-6/lb. From 2003, the Chitralada variety of Nile tilapia was introduced, and because of its high performance/unit area, it became possible to produce fillet for the international market which has a market value of, on average, US$3.5/lb. The main producers of tilapia are Huila, Tolima, Put, Santander, Cauca Valley and Antioquía.

Cachama*:* The second species of commercial importance is native to Orinoquía where it has been cultured traditionally. In Santander in the northeastern part of the country, there is a high consumer preference for cachama. Average monthly production is about 30 000 fry which are sold at a farm-gate price of US$35.24/thousand fry and US$55.07/thousand fry from middlemen. The price has remained stable during the last 5 years. It should be emphasized that the price of market size fish in supermarkets and fish markets reaches US$2-5/lb.

Trout: Trout is cultivated in the cold climate areas of Antioquía, Santander, Cauca Valley, Quindío, Huila, in the high plateau regions (cundi-boyacense) and the coffee plantation regions. Seed are produced from imported *Kanloop* eggs, 100 percent triploid females, sold at US$36.79/thousand eggs for purchases between 1 to 5 000 eggs and US$35.77/thousand eggs for purchases of more than 5 000 eggs. Depending on the size, fry are sold between US$57.27 and US$171.81/thousand. The market niche for trout is constituted by the population of middle to high class. Prices can range from US$2.50 to US$4/lb. Although attempts have been made to export to the United States of America, the results have not been positive because producers cannot fulfill all of the requirements in terms of quantity and quality certification demanded by the international market.

SEED PRODUCTION FACILITIES AND TECHNOLOGY

Public and private facilities of seed production

INCODER, like other agencies who execute aquaculture programmes, has a total of 22 aquaculture stations located in diverse regions of the country. There were originally five stations under the authority of the INPA, of which only two of the largest remain (Repelón and Gigante) now under INCODER. The other three stations were transferred as follows: (i) La Terraza (Villavicencio) to the National University of Colombia and (ii) San Cristóbal (the Bolivars) and Oiba (Santander) to aquaculture associations of their respective locations.

There are, in addition, eleven other stations managed by autonomous regional corporations (regional environmental institutions) as follows: (i) three stations are inactive due to lack of funds, (ii) three stations under state universities, (iii) one station under a public-private sector partnership and (iv) the rest of the stations are under the Department of Farming and Mining Development of Huila.

Many private producers have their own breeders to supply seed for their fish ponds: tilapia (15), cachama (5), yamú (4), catfish (3) dorada (2), common and red carp (5) and ornamental fish (1).

There are also 24 and two hatcheries for the production of trout and tilapia fry, respectively. Since production and incubation of eggs of native species are made in a hatchery, it is possible to infer that there are as many hatcheries of native species as farms producing such species.

Table 7.6.1 provides a summary of the number of stations and farms producing fish seed of different species in Colombia.

In two private farms in Meta, breeding is done in chambers with a dimension of 10 x 20 x 1 m in earthen ponds of 1 200 to 2 500 m^2 with breeders with a density, for example per 1.5 square meters of water visibility, using a ratio of 1 male for every 3 females. Eight days after seeding, all seed are collected from the mouth of females and brought to the laboratory where seed are incubated using a density of 500 eggs/ml in incubating cones with 3 liters of water with constant water flow in order to obtain an average monthly production of 800 000 fry.

Similar techniques used by government stations are utilized by other producers where average production of 200 000 and 400 000 are achieved by small- and medium-scale producers, respectively.

In 1996, INPA initiated research on genetic improvement of tilapia which was continued by INCODER, using the lines provided by Repelon and Gigante stations as well as other private producers of Huila. On the other hand, other aquaculturists opted to import breeders with the objective of maintaining the purity of genetic lines of the farm.

Trout: Fry production is done in hatchery using incubation trays with constant water flow laboratory starting with eggs imported by Troutladge Inc., 100 percent female triploid of variety Kanloop, 100 percent triploid females variety *Kanloop,* which has a monthly production of 2 million fry.

There are two government stations that produce trout fry, namely: (1) Neusa Lake (Cundinamarca) station and (ii) Cocha (Nariño). Seed are obtained from breeders maintained in ponds consisting of 20 broodfish/m^2 and ratio of 1 male:3 females. Matured breeders are brought to the hatchery for stripping to collect ova and sperm. Dry fertilization is used. These stations produce 150 000 fry every month.

Native species: Breeders in earthen ponds has a density depending on the weight of the fish, in general terms it is about 1 kg weight/m^2. Matured breeders are determined by swelling of the belly or abdomen of the males, sperm are expelled by putting slight pressure in the abdomen, afterwhich they are brought to the hatchery to induce breeding using hormone. Most commonly used hormones are *Extract of Pituitaria de Carpa* (EPC), or human hormones like the Prymogonil, LH-RH or the combination of EPC or one of these two.

For yaque and nicuro, males are operated to remove the mature testicles, macerated to obtain sperms that will fertilize the ova. Other aquaculturists cryopreserve the sperm to avoid sacrificing other breeders.

With respect to catfishes and cachama, since 1998 trials were made to cryopreserve semen of wild broodfish and broodfish from captivity. Results of these trials revealed sperm viability of 50 percent of cryopreserved sperm and can last for 3 years. Inspite of these positive results, it has not been possible to advance the research due to budgetary contraints and also because of institutional transition which occurred between INPA and INCODER in 2003 and 2004. The private sector had expected for the outcomes of the research so that they will have the opportunity to enhance their production.

TABLE 7.6.1
Number of stations and farms producing fish seed of different species in Columbia

Aquaculture Stations	Location	Management	Tilapia	Trout	Cachama	Striped catfish Bagreryado	Yamú	Dorada	Capaz	Yaque	Nicuro	Bocachico	Carpa	Otras especies
State-owned Sector														
Repelón	Atlantic	INCODER	X		X	X						X	X	X
Gigante	Huila	INCODER	X		X				X			X	X	X
La Terraza	Meta	INCODER	X		X	X	X			X	X	X	X	X
San Cristóbal	Bolívar	INCODER	X											
Oiba	Santander	INCODER	X											
Uary	Casanare	Mixta	X		X		X							
Lorica	Córdoba	CAR	X		X	X		X				X		
La Cocha	Nariño	CAR		X										
Neusa	Cundinamarca	CAR		X										
Buga	Valle del Cauca	CAR	X											X
Timbio	Cauca	CAR	X											
Cúcuta	Norte de Santander	CAR	X											
San Silvestre	Santander	CAR	X		X	X		X				X		
Montería	Córdoba	University	X		X	X		X				X		
Unillanos	Meta	University	X		X	X	X			X	X	X		X
Leticia	Amazones	University			X		X							X
San Jerónimo	Antioquia	University, Politechnic	X											X
Aipe	Huila	Ministry of Agriculture	X						X			X	X	
Las Cintas	Boyaca	CAR	Closed											
Los Posos	Boyaca	CAR	Closed											
Berlín	Santander	CAR	Closed											
Apulo	Cundinamarca	CAR	Closed											
Valledupar	Cesar	CAR	Closed											
Prado	Tolima	Tolima	Closed											
Private sector														
	Meta		5		2	2	4	1					2	1
	Huila		5										1	
	Santander		1			1	1		1				1	
	Tolima		2											
	Valle del Cauca		2										1	
	Córdoba		1		2	2								
Private laboratories														
	Meta		2											
	Antioquia			3										
	Cundinamarca			5										
	Boyacá			3										
	Caldas			2										
	Cauca			3										
	Huila			2										
	Norte de Santander			1										
	Nariño			3										
	Valle del Cauca			2										

Broodstock management

Tilapia: In private farms, tilapia broods are not strictly selected according to rigorous genetic definition but based on simple phenotypic observations such as color (e.g. color separation: red, orange, pink or white), presence or absence of black spots and also according to the body length. From 1996 to date, in both Repelón and Gigante, genetic management starts from red tilapia lines coming from diverse zones of the country. This practice results to genetic improvement of broodfish as demonstrated by growth rate and absence of black spots in the body.

Almost all private farms and state farms maintain two groups of selected breeders, especially females. Each group is bred alternately. This sequence stays for 2-3 years afterwhich the whole lot is replaced by new ones. Feeding regime consist of 30 percent protein using pelleted feed for every 2 percent body weight divided in 3-4 rations a day.

Trout: Government stations in Neusa and Cocha maintain their broodfish in ponds and are renewed every 5 years; feeding consist of 45 percent protein using peleted feed for every 3 percent body weight, 4 rations/day.

Due to technical limitations in obtaining succcessful reproduction, 90 percent of private producers without breeders prefer to import eggs. As a result, from 2004, major producers in Antioch and the Cauca presented to the Ministry of Agriculture and Rural Development a project to produce triploid fry (only females), which started in 2005 and will be completed in 2008.

Native species. Due to insufficient number of appropriate tanks to hold the fish, earthen pond are utilized using polyculture system. They are fed with feeds with 28 percent of protein, in a proportion equivalent to 2 percent of its body weight, distributed in three daily rations. Breeders are replaced between 5-10 years after use, by selection from the same batch or by natural means.

Fry management

Tilapia: The fry are harvested from breeding tanks between 12 to 30 days after seeding. At this time, fry weigh between 0.2 to 0.5 g and they are now placed in pens, cages or small earthen jars of 5 m^2 (depending on the system and economic capacity of the producer) using a density between 30 and 500 fry/m^2 (ponds) or equal density per cubic meter (in pens and cages) for sex reversal and conversion of male through the hormone 17 *alfa metil testosterone* mixed with powdered feeds with 35 percent protein. This mixture is provided at 12 percent biomass divided 10 times/day for 28 days in order to gain a weight of 1-2 g. Fry are then transferred to earthen ponds or concrete tanks with a density of 50-100 samples/m^2 for 20 days when they reach 5 g. During this period, they are fed with feed extracts with 35 percent protein at eight percent of biomass using six daily rations.

There are also two private hatcheries which incubate eggs for 10 days in conical incubators with 3 l of constant flowing water until exclusion of the larvae, afterwhich they are placed in bowls or trays until absorption of the vitelline sac. This is followed by sexual reversion in hapas (2 x 3 x 1 m) installed in ponds enriched with primary productivity where the fry feed with powdered feed extracts containing 40 percent protein (first hatchery); the second hatchery use commercial feeds with 35 percent protein, plus hormone *17 alfa metil testosterone* at 12 percent biomass using 14 daily rations for 28 days. Feeds are changed to 35 percent protein until they reach a size of 5 g.

Trout. After hatching, they are placed in nurseries at a density of 200 fry/m^3 where feeding starts. After absorption of the vitelline sac, powdered feed with 50 percent protein are given at 12 percent biomass until they reach 1 g of weight. Then they are transferred to concrete tanks using a density of 150 fry/m^2 feeding with 0.5 inch concentrated pellet with 50 percent protein divided into eight daily portions until reaching 8 g. They are then transferred to rectangular concrete tanks using a density of 100 fry/m^3 with feeding regimen of ¾ inch pellet with 45 percent protein at 8 g biomass divided in eight daily rations until reaching 5 g required for market.

Native species. After hatching, larvae are harvested and placed in aquaria with a density of 500 samples/m^3 until absorption of vitelline sac. Afterwhich they are placed in ponds of 200 m^2 which are just full and rich with primary productivity through chemical fertilization. The fry are ready for market when they reach an average size of 3 g.

SEED QUALITY

About 30 percent of producers provide information on fry production volume and value. After determining the weight, they are classified according to sizes in order to market homogenous size. Also producers monitor which breeders produce fast growing fry, uniform in size and color (in the case of tilapia, color is the ultimate parameter). Despite this, 90 percent of producers complain about the quality and heterogenous size of fry they buy as well as low supply, e.g. package of 100 percent males in red tilapia and Nile tilapia.

Survival rate from hatching to market are: tilapia (75-80 percent), trout (90 percent) and native species (45-55 percent).

Disease and sanitary control

Despite the efforts and advocacy which universities and state entities undertake through development and research programmes in aquaculture and pathology, many producers think that cultured fish do not get sick and only considers this possibility when there is high mortality. This means that it was not possible to develop awareness on the importance of disease diagnosis supported by laboratory findings both in water and fish.

With the support of the Ministry of Agriculture and Rural Development, state universities (Colombia, Llanos Orientales and Cordoba) have identified pathological agents in native and exotic species, in seed production as well as in grow-out due to deficiencies in water management and feed storage and monitoring of feed quality parameters. Instead of going to the laboratory, the common practice is that farmers use chemicals and antibiotics (human or animal) to deal with disease problems, e.g. malachite green in different doses, formaldehyde at 4 or 10 percent, 10 percent methylene blue, furazone or its components; these are applied based on experiences by other farmers dealing with similar disease problems. It is estimated that only 10 percent of medium- and large-scale producers send samples to universities or to the Colombian Institute of Agriculture and Livestock (ICA) for laboratory analysis in order to receive appropriate treatment.

Concerning sanitary and hygiene practices (for equipment, materials used in seed production and grow-out), the common practice is weekly cleaning and disinfection with chlorine, formol, etc.

Concerning feeds, only 10 percent of private producers and state stations have improved feed management practices using the recommendations by feed producers. In the same manner, they have improved water management by controlling water exchange to avoid contamination. On the other hand, 90 percent of producers do not have any water management practice.

SEED MARKETING

The main seed producing areas are Meta, Huila, Santander and Valle del Cauca that cover 80 percent of the national, regional and local demand. Seed producers are not organised which presents a difficulty when they need to communicate with the state, clients and other business relations, as they act independently from each other.

In the 1980s, most of the fingerling supply was originated from goverment facilities. By the end of the decade, aquaculture had developed significantly in certain areas increasing the seed demand for tilapia and cachama which triggered the seed production by the private sector who sold their excess to government facilities that could not satisfy their needs.

In the 1990s, the Municipal Units of Farming Technical Support *Unidades Municipales de Asistencia Técnica Agropecuaria* (*UMATA*) supported aquaculture projects triggering the seed production as a second effect. Departments related to the coffee plantations promoted culture diversification in the coffee plantations including aquaculture as an interesting option. Other institutions, such as SENA promoted aquaculture for food security in rural areas and the National Prison Institute (INPEC) implemented aquaculture projects in some of the prisons where there was enough infrastructure for the prisoners to work.

At the moment seed distribution flow follows some of these routes:

Producer ▸ Medium to small farmer
Producer ▸ UMATA ▸ Small farmer
Producer ▸ Promoting Entity ▸ Farmer
Producer ▸ Intermidate ▸ Small or medium farmer
Producer ▸ Primary intermidate ▸ Secondary intermidiate ▸ Farmer

From the point of view of the financing, Colombia has lines of credit for aquaculture from the Financing Funds of Sector Agropecuario (FINAGRO), a bank that offers resources to small-, médium- and big-scale rural producers. It has been estimated that nearly 10 percent of the seed producers resorted to this system to cover the setting up of all the project, to construct or to improve the physical infrastructure (ponds and laboratory) or to acquire working capital for equipment, furniture, materials and consumables.

The allocation of FINAGRO finance of up to 80 percent of the cost of the project, offers an incentive to rural capitalization equivalent to 40 percent of the total amount of the debt if the production goals are fulfilled; payments are provided to the bank immediately after the first year of credit and in addition, the borrowers have access to the Farming Guaranty Funds (FAG), in case of some problems with the credit.

With respect to the trade system, seed producers usually do not execute strategies of sales promotion to increase the demand, but it is limited to satisfy the demand of the intermediaries and farmers who make direct connection with them. This might be the reason for the stability of the price of cachama fingerlings during the last 5 years.

SEED INDUSTRY

Scale of production

The production of seed of native and exotic species are made at different levels depending on the scale and automation of its infrastructure, systems and volumes of production and places of sale. Similarly, intermediaries can be classified using the same criteria. In the opinion of the author, small producers have minimum infrastructure necessary to produce monthly up to 200 000 fingerlings of red tilapia, or 20 000 fingerlings of native species, including cachama. Grow-out farmers at medium- or big-scale operations obtain their own seed and sells the excess independently of the technological level of culture operations.

There are seven medium-scale producers that sell seed at local, regional and national levels with monthly production between 200 000 and 500 000 fingerlings of tilapia; and annual production between 20 000 to 150 000 fingerlings of cachama and 50 000 fingerlings of carp, yamú, bocachico, catfish, golden, sabaleta or capaz. The minimum infrastructure consists of external and internal laboratories, circular tanks for handling of broodstocks and production of fingerlings.

The bigger producer differs from the médium-scale producers by the volume of production. Big producers obtain more than 500 000 monthly fingerlings of tilapia (exceptionally, a producer can offer monthly nearly a million fingerlings); more than 250 000 fingerlings of cachama monthly or more than 30 000 fingerlings annually of two or more native species. With respect to carp, still its demand is low and therefore a big producer may offer more than 10 000 fingerlings of this species on a monthly basis.

With respect to the producers of trout fingerlings, at national level, there are eight small-, ten médium- and six big-producers. Their business depends on the biweekly provision of imported ovas; those working at large-scale obtain more than two million of fingerlings monthly.

Similarly, intermediaries also classify themselves through the volume of sales, regardless of the species. This means that those who commercialize up to 20 000 fingerlings monthly are small scale, up to 100 000 fingerlings monthly are medium scale and from this number onwards are considered as wholesalers. The wholesale intermediary counts together with national representatives imported trout ovas from North America and distributes fingerlings of several species at national level, with figures over 100 000 fingerlings per month.

RISKS

Seed production entails technological, socio-economic, environmental and sanitary risks that can be mitigated with the incorporation of safety measures in critically important points and the observation of the standard quality.

It is possible that small producers undergo greater risks in optimizing production as they face more difficulties of access to appropriate technologies and economic resources, a situation not faced by those with more resources. Nevertheless, in all cases, the pursuit of traditional practice and over-confidence in their experience can be highly dangerous. The most outstanding risks faced by the freshwater aquaculture sector are:

- inspite of the high demand of seed of diverse species, the prices increase annually based on inflation index and therefore, in smaller proportion than the production costs, particularly of feed costs, thus the margins of the producers are continuously reduced;
- lack of knowledge and incorporation of good practices by the farmers inspite of qualified personnel dispatched by government organizations and universities involved in the subject as well as the lack of economic resources to adapt their facilities according to the technological advances or developments;
- seed and fish producers from different regions in the country are affected by alterations in public order and the occasional petroleum spills caused by irregular groups that contaminate the water bodies;
- genetic degeneration of some lines with which investigations or actions of improvement have not gone ahead, in the case of the tilapia;
- unregistered imports and introduction of tilapia from Ecuador at non-competitive prices with respect to the Colombian tilapia discourages national production and therefore the demand for seed;
- relatively high mortality: in tilapia it ranges from 0.5 percent to 10 percent broodstock and 20 percent in fingerlings from post-larvae to market size; in native species it reaches 1 percent in broodstock and between 40 percenet and 60 percent in fingerlings; in trout 3 percent in broodstock and 5 percent in fingerlings;
- seasonal production of fingerlings: native species such as yamú which reproduces three times a year (cachama is an exception as it generates seed all year round) and since it has a stable demand, seasonal production cannot satisfy the market requirements;

- environmental changes and rainfall events which throw muds in the water, and thus require the use of special equipment to avoid mortalities of fingerlings and fish and not all producers posses such equipment;
- problems in the hydrographic river basins that affect aquaculture directly;
- weakness in the institutional management to solve deforestation problems, sedimentation and contamination.

THE ROLE OF WOMEN IN FRESWATER FISH SEED PRODUCTION

Participation of women is more active in grow-out stages especially in rural areas involved seed production, except in aquaculture stations and private sector farms where in the placement of professional women and students of biological sciences is well-known where they assume fundamental functions in research and production. Although there are no official numbers to sustain this hypothesis, it is estimated that 30 percent of those who participate in obtaining seed are women.

Often, producers have received training and technical support for the establishment and operation of aquaculture farms from state and private advisors, specialized in various phases of production. Big- and médium-scale producers provide technical support to small producers to ensure that seed produced are of good quality.

SUPPORT SERVICES

From the creation of the stations of Repelón and Gigante in 1979, training by goverment and private sector was initiated, as well as the elaboration of extension leaflet whose distribution was initially free.

The state provides continuous service since the 1980s in the production of seed to cover the demand of rural producers. Price of seed from the state excludes Tax Valor Agregado (IVA). Stocking with native species of public water bodies is the state's responsibility.

In the 1990s and the begining of the present decade, the creation of the INPA and the support of the Ministry of Agriculture and Rural Development led to the development of programmes of technology transfer through productive projects that has maximum duration of three years directed to communities of farmers and small scale fishermen who also were useful in validating production packages (e.g. culture of tilapia, cachama and trout) technically, economically and socially before commercialization. Along the same line, INPA elaborated two editions of the book "Foundations of the continental aquaculture" and published additional two books such as "Foundations in nutrition" and "Foundations of marine aquaculture".

Some seed producers (big-scale and wholesale intermediaries), feed producers and independent professionals offer their services and technical support for active and potential farmers in the handling of fingerlings and fish in farms as well as during transport to avoid significant mortality rates.

SEED CERTIFICATION

In Colombia, seed quality certificates have not been made compulsory and therefore no organization has legally assumed this function, except for health issues where ICA is in charge of certifying that the seed for export is free of diseases. ICA is also responsible of verifying the health of the fishing resources (ornamental seed and fish) for import and export. On the other hand, the Ministry of Commerce, Industry and Tourism issues the certificate of origin of the seed that is exported, requirement that is demanded by the buying countries.

In order to obtain a certificate, the exporter asks for a visit to his farm where the ICA representative takes samples from fish and water for laboratory analices which is the basis for approving the health certificate.

LEGAL AND POLITICAL FRAMEWORKS

The legislation that directly and indirectly relates to seed production are described below:

- In 1974, the first norm about aquaculture was released (Decree Law 2811 - National Code of Renewable the Natural Resources and Protection to the Environment). It was the basis to formulate the Law 13 of 1990 - Statute General of Fishing and the prescribed Decree 2256 of 1991, which continued being the legal instrument for the sector. Since 1998, there has been attempts to update the law since it is outdated and also with respect to the reform of the Political Constitution of Colombia of 1991, to the reformed environmental norm from 1993, and the Code of Conduct for Responsible Fisheries (CCRF) as well as other international directives in the matter of production and standards for the quality of seed in aquaculture.
- Credit is governed by Law 16 of 1990 which created FINAGRO and defines the general framework for financing of the farming sector. During the last fifteen years, the National System of Farming Credit has regulated adjustments to the lines of credit and benefits for all level of producers.
- The Political Constitution of Colombia of 1991 contains provisions for handling of natural resources to ensure its sustainable development. It refers to the promotion of the fishing development, investigation, technology transfer and credit schemes.
- Law 99 of 1993 created the National Environmental System and the Ministry of the Environment, responsible for formulating national environmental and renewable natural resources policies.
- Decree 1753 of 1994 of the Ministry of Environment regulates the introduction of "parentales" to reduce to the presence of foreign species of fauna and flora, gives environmental licenses to commercial aquaculture producers. At the moment, farmers are not required any environmental licenses other than permissions to import new exotic species and to transfer species between river basins.
- Law 811 of 2003 stipulates the consolidation of production chain organizations and the definition of sectoral agreements of competitiveness to develop subsectors, with the active participation of its representatives from both public and private sectors.
- Decree 1300 of 2003 created INCODER as a decentralized institute assigned to the Ministry of Agriculture and Rural Development. It has four technical submanagement divisions in charge of (i) agrarian reform, (ii) earth adjustment, (iii) rural development, (iv) fish and aquaculture - functions that until that moment were assumed by INCORA, INAT, DRI and INPA, institutions that were terminated. INCODER has 982 positions representing that representing 56 percent less than the four eliminated organizations combined and a smaller physical coverage as compared to the previous institutions which were located in strategic sites of the country based on the specific mandates.
- Agreement 009 of 2003 of INCODER sets the requirements to obtain permission for fishing and aquaculture activities and the procedures for these transactions.

Is important to emphasize that at the moment a law on water is being debated before the Congress and when approved, this law will have a fundamental impact in the development of aquaclture and consequently seed production.

Although Colombia has apparently not advanced significantly in the application of FAO CCRF, this could be an important instrument of support to standards or guidelines for aquaculture. Article IX establishes that states must promote the responsible development for aquaculture production, use of genetic resources, culture in transboundary aquatic systems and zones subject to national jurisdiction.

There is no updated fishing and aquaculture policy of government nor of the states. The last document dates back from 1997 although it was not fulfilled because of the weakening of INPA, the lack of coordination with other organisms and the little budget for projects. At present, INCODER is formulating a policy document on aquaculture to support institutional policy that focuses on resources and projects in specific areas of rural development. On the other hand, in 2003 a policy document was prepared which transferred the functions of INCODER to regional authorities that already have programmed aquaculture projects, but not fisheries because they recognize their lack of knowledge in the subject and prefer that INCODER continues in charge of such functions.

ECONOMIC CONSIDERATIONS

Based on the information compiled by the author from private producers, the Aquaculture Production Chain and some recent documents, the factors that determine the prices of seed are described below:

- Labour represents 7 percent of the production costs. Since small producers are family-based, mnual labour is usually not quantified; in médium-scale operations, there are three people, whhile in big-scale operations, there are between 5 to 12 labourers.
- Consumables and services for the production are accounted as follows: feed (45 to the 55 percent), transport (12 to the 15 percent), packing (3 percent), medicines (1 percent), energy (1 percent) and administration (18 percent). In general terms, one can calculate that production costs increase US$25/thousand seed produced.
- Price of seed of tilapia, cachama, trout and carp is about US$37.44/thousand, including 16 percent of VAT, tax fee which has become a burden since December of 1998. On the other hand, intermediaries sell seed to grow-out farmers at US$52.86 to US$60.10/thousand, which means that the margin of profit of the intermediaries comes near to 47 percent per hundred seed.
- From the perspective of the supply, the biggest constant suppliers of tilapia seed originate from Huila and Meta; cachama comes from Meta and Cordova, while the red or mirror carp comes from the Valley of the Cauca, Meta and Santander. Trout fingerlings are regularly suppplied from Cundinamarca, Boyacá, Santander and Antioquia.
- Integrated farms (for fingerling production and grow-out) have an income between 40 to 70 percent of the total economic income generated by their aquaculture project.

PRODUCTION LIMITATIONS

There is little inter-institutional coordination to exchange technical information and to improve investments in human, technical and financial resources for research, promotion and administration of aquaculture between seed and fish meat producers.

A similar situation exists in the private sector side as there is no strong union that represent all aquaculture producers at the national level. However, there is the Colombian Federation of Aquafarmers (FEDEACUA) that congregates only one proportion of these players. Although FEDEACUA has five regional associations, not all producers are associated; however, during the last years FEDEACUA has increased the awareness on its importance.

Despite existing credit lines for small-, médium- and big-scale producers of seed and fish through FINAGRO, weaknesses remain in accessibility to farmers, especially small-scale farmers so that they will be aware of conditions and benefits. It has been estimated that throughout the 15 years of existence of FINAGRO, only 5 percent of the small-scale, 10 percent of the médium-scale and 40 percent of the big-scale producers have benefitted from the system.

While feed producing companies have made efforts to satisfy the nutritional requirements for species such as tilapia and cachama, they but have not reached the targeted levels because the same feeds for both species are used, which generates problems in the conversion index and growth of the fish. Some attempts to solve such nutritional weaknesses have been done through research projects by the academic sector, whose efforts at the present time concentrate on the requirements of feeding of native species like cachama and the yamú. Trout does not have such a problem because nutritional formulation has already been established in the United Status of America.

From the economic perspective, production limitations are are centered on: (i) high cost of the feed that represent 60 percent of the production costs, (ii) reduced profit margin, (iii) insufficient supply to generate sufficient quantity exportable and (iv) necessity to develop and to apply technologies that make the culture more efficient and allow to generate profits on a large scale.

STAKEHOLDERS

Tilapia: There are 70 companies concentrated in Huila, Goal, Valley of the Cauda, Antioch, Santander, Casanare, Risaralda, Quindio and Calda.

Cachama: There are 22 companies located in Meta, Casanare, Santander, North Santander, Cordoba, Caqueta and Amazon.

Trout: There are 35 companies located in Cundinamarca, Antioch, Santander, the Cauca, Northe Santander, Boyaca and Tolima.

Other producers, clients and institutions related to seed production are described below:

Farmers: It is estimated that there 125 000 rural farmers that receive free technical assistance from the state and occassionally free fingerlings.

Local institutions. Departmental and municipal secretariats of agriculture, the National Federation of Coffee, professional departments, committees of farming and biological sciences that function like extensionist workers and some NGOs which lend technical support to the small- and médium-scale farmers.

Universities, feed producing companies, commercial farmers and suppliers of inputs for aquaculture production: They participate in promoting the use of improved seed and in the implementation of appropriate technologies.

Médium- and big-scale producers: Farmers at these levels of operation sell excess seed and are in charge to supplying local and regional markets.

Aquaculture stations of Repelón, Giant, the Terrace, the Neusa and the Lagoon of the Cocha: They participate in the development of new lines of seed and projects for genetic improvement. In addition, there are two big private producers of tilapia and 25 producers of native species in the department of Meta who participate in these activities.

FEDEACUA: This association has the mission of organizing associations of fishfarmers such as the Asoacuicola in Antioquia, Acuioriente in Meta and Casanare, Association of Trout Producers of Santander, Andean Association of Trout Producers in Cundinamarca, Asoacuica in Caquetá and Society of Aauqaculturists in Valley of the Cauca. Acuanal organizes shrimp farmers, however some of their members have taken interest in the polyculture of shrimp and tilapia, because of the low prices of the shrimp and the potential of export for tilapia fillet. For this reason, the National Center of Investigations in Acuicultura (CENIACUA) sponsored by Acuanal, is advancing their research on shrimp-tilapia polyculture.

Government institutions. The main actors are the Ministry of Agriculture and Rural Development that formulates the sectoral policy and being implemented by INCODER, although the ministry also participates in other actions. Other related entities according to its competente include the following: (i) ICA that evaluates and certifies the health of the exportable fishery resources; (ii) the Ministry of Environment, Housing and Nacional Development; (iii) the Ministry of Commerce, Industry and Tourism; (iv) National Planning Department; (v) Regional Autonomous Corporation; (vi) INVIMA which regulates the health and standards of quality of processing plants and final products; (vii) COLGIENCIAS which supports research projects; (viii) PROEXPORT which promotes exports; (ix) FINAGRO and BANCOLDEX which finance aquaculture; BANCOLDEX is the center for exports; (x) municipal and departmental secretariats of agriculture that promotes aquaculture; (xi) SENA concerned with capacity building and technical assistance and (xii) Network of Social Solidarity which supports projects in communities INE in qualification and technical attendance and Network of Social Solidarity that supports projects in vulnerable communities in the conflict zones.

Researchers. The principal centres for training of technicians and professionals in aquaculture which conduct basic and applied research are the following universities: National University of Colombia (Cordova in Montería and Lorica), UNILLANOS (Villavicencio, Goal), Polytechnical University of Jaime Izasa Cadavid (Medellín and San Jerónimo, Antioch) and Surcolombiana University (Neiva, Huila).

At the level of international cooperation, at the moment there are no current projects but a mode of assistance is the exchange of experts on specific themes in fisheries and aquaculture. From 1997, technicians of Brazil, Cuba, Mexico, Peru and Norway have supported Colombia in the areas of genetics, pathology, reproduction, nutrition and feeding, adaptation and adjustment of culture technologies and fishing.

RECOMMENDATIONS AND FUTURE PERSPECTIVES

Based on the outcomes of this survey and the author's experience in freshwater aquaculture, the following recommendations and perspectives for the future development of the sector are elaborated below:

- The initial difficulty in this decade provided evidence on the necessity for private and public sectors to unite or join forces to overcome those limitations. The big tilapia producers in Huila, Tolima and Meta are optimistic in exploring export posibilities to the USA. However, a number of things need to be in place, e.g. improvement and modernization of infrastructure, processing and application of better management practices and HACCP. This will create a chaín of benefits also to small- and médium-scale producers of seed and fish in the sense that it will be necessary to generate sufficient volume of production to meet the internal and external demands for fish.
- The results of research in breeding, feeding/nutrition, sanitary control and genetic improvement of tilapia and native species that the academic sector implemented in cooperation with the public and private sectors, will enable improvement of existing culture technologies, culture of new species and optimize the nutritional composition of feed.
- Tilapia producers recognize the importance of supporting the research on genetic improvement started by the academic and public sectors, in order to find solutions to the problem of seed quality by providing seed samples, offering space for practical application of research, or providing financial support to projects.

- Producers of Meta and Huila are concerned with improving production techniques in order to reduce mortality below 10 percent, to increase production and profitability.
- It is recommended that producers prepare strategies for the promotion and publicity to increase their access to potential clients. In addition, scientific and technological advancements will result to improving seed quality that will enable access to international market, e.g. Honduras which has great defficiency in the supply of tilapia fry.
- Producers have expressed their desire to increase production volume that will strengthen their position in the local market and to access international market. In order to achieve this, it is necessary that the state government and private sector producers assist in enhancing capacity and providing technical assistance to small- and médium-scale producers to enable them to produce fish of high quality at commercial scale for the export market. In this way, there is possibility for small- and médium-scale producers to produce their own fry.
- It is recommended that those involved in the chain of aquaculture operation, for example, producers and air and land transporters strengthen their cooperation to obtain the freight cost that will be most advantageous to both parties and to make the business more competitive therefore reducing production cost.
- In order to improve efficiency, it is necessary to strengthen the capacity of aquaculturists to implement production technologies that will result to high quality seed as the final product as well as direct measures to optimize the use of physical infrastructure, and other inputs and economic resources.
- Policy and legislation in aquaculture and environment should be harmonized; the requirements about environmental impacts and permits/licences requested by the Ministry of Environment, Housing and Natonal Development like the Regional Independent Corporations need to be validated. These steps will facilitate streamlining of procedures and will enable a better understanding about the requirements of aquaculture versus environment. Capacity building in the areas of environmental management, control of parental lines, defining the procedures for the introduction or transfer of native and exotic species is recommended.

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7.7 Freshwater fish seed resources in Cuba[1]

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ABSTRACT

Cuban fisheries began in the early 1920s, with the introduction of common carp and black bass which were stocked in small reservoirs and lakes for sport fishing. During the decade of the 1960s, a massive reservoirs and dams construction programme led to the opening of more than 130 000 ha of such commonly owned water bodies. These were stocked with hatchery-reared cyprinids, mostly common carp, and tilapia as food fish for the human settlements around them. The establishment of hatcheries to produce the seed needed, was the start of aquaculture in the country.

There are currently some 400 ha of nursery ponds throughout the country, whose production supports regular restocking of such water bodies, as well as some 1000 ha of fish rearing ponds. Both reservoirs and ponds produced 26.9 thousand tonnes in 2004, 96 percent of which corresponded to carps and tilapia.

Freshwater seed production in Cuba reached approximately 200 million fry by the year 2001, of which carp and tilapia contributed to 82 and 16 percent, respectively, the balance being other species such as *Clarias gariepinuss* and *Ictalurus punctatus*. However, the overall installed capacity amounts to 500 million in the 26 state-owned freshwater hatcheries that operate throughout the country. In general terms, the production of freshwater seed for aquaculture in Cuba amply meets the national demand both for restocking of dams and reservoirs, and for fish ponds and cages.

Breeding techniques vary according to the species. Whilst tilapia and channel catfish are bred employing semi-natural methods in earthen and concrete ponds provided with artificial nests, cyprinids and *Clarias* are hormonally-induced to spawn in more controlled environments. Fry of tilapia and the Asian catfish are reared in green water ponds in monoculture, while carps (common, bighead and grass carp), are reared in polyculture fertilized ponds. Fingerlings of all species are grown until they reach 5-8 g if they are to be stocked in ponds, or between 15 and 18 g, if they are to be stocked in reservoirs. Only in some cases tilapia fry are sex-reversed hormonally employing standard methods, to

[1] The original document was written in Spanish and was translated in English jointly by M.B. Reantaso (FAO), V. Alday-Sanz (Spain) and A. Flores Nava (Mexico) for purposes of this publication.

produce monosex batches. Rearing density of fingerlings vary from $15/m^2$ in the case of channel catfish, up to $250/m^2$ in the case of *Clarias gariepinus*.

There are no national standards set as far as seed quality is concerned. However, recent HACCP-like programmes, provide preventive guidelines to improve quality of the end product, including hatchery processes. Seed certification in the country is limited to pathological aspects, and is required only when seed are to be moved between different regions or when seed or breeders are imported. Zoosanitary inspection is carried out by regional and national fisheries inspection offices.

Fish seed production and distribution are carried out almost exclusively by the government at subsidized or no cost, hence the lack of a market environment does not allow for an objective seed pricing in the country. Distribution is centrally planned o a yearly basis, and is carried out using government transport either directly to open access water bodies, or through aquaculture cooperatives or associations, which in turn redistribute to farmer members.

Support services to the industry include a series of well-established aquaculture training centres, as well as some producer cooperatives and farmers associations which work closely with small farmers and the government, acting as a bridge to trickle down new technology and capacity building. Women play an important role in these processes, since they account for 27 and 43 percent of the total and technical labour force of this sector, respectively.

The lack of indigenous aquaculture fish species makes Cuban aquaculture dependent on exotic species which have long been introduced and for which no genetic selection/improvement programmes are established. More recently, some exotic species, such as the Asian catfish *C. gariepinus*, have been introduced, and regular imports of breeders are common thus posing a threat of introducing alien pathogens into Cuban ecosystems.

INTRODUCTION

Aquaculture in Cuba began during the second decade of the 20th century with the introduction of several freshwater species (e.g. common carp, trout, black bass) with the objective of producing fingerlings for stocking in existing water bodies and to support sport fishing, which was discontinued after a few years.

Freshwater aquaculture production at commercial level began in the 1960s with the introduction of new species, for example tilapias and cyprinids. This was made possible because of the presence of many dams/reservoirs to protect rural population, farms and agriculture from flooding, for irrigation purposes and other socio-economic objectives.

The programme "Voluntad Hidráulica" created an important vehicle for the development of aquaculture with the construction of freshwater dams. At the moment, there are 130 000 ha of freshwater in the country; about 125 freshwater reservoirs grouped according to size, for example, big (if greater than 100 ha) and médium if less than 100 ha.

All these water bodies are utilized to raise fish using extensive and semi-intensive systems. Regular monitoring of these water bodies are undertaken and a programme for integrated management of stocking and capture fishing is being implemented to allow fish utilization in the manner that has been ordered by state, company, cooperative and other relevant authorities. In addition, there exist about 400 ha of fish ponds used for seed/fingerling production, the majority of which are destined for stock enhancement as previously mentioned and about 1 000 ha of earthen ponds and cages for grow-out.

In Cuba, it is not common to differentiate freshwater aquaculture at the industrial or smalll-scale levels since the major part of production is through extensive and semi-intensive systems in dams or reservoirs and in fish ponds which are both

TABLE 7.7.1
Freshwater aquaculture production by species (2003/2004, Bulletin MEP, Ministry of Economy and Planning) and Ministry of Fisheries (MIP)

Species	2003 (million metric tonnes)	2004 (million metric tonnes)
Freshwater species (1)	19.52	24.54
Carpa herbívora	1.69	4.7
Carpa común	0.447	0.470
Carpa plateada	13.133	14. 994
Tilapia	3.342	3.207
Trucha americana	-	0.2
Clarias	0.908	0.969
*Otros fluviales (2)	6.289	8.839
***Aquaculture of other organism (3)**	**8.828**	**9.732**
Total Freshwater (1+2+3)	**28.348**	**34.272**

undertaken at intermediate scale using intensive systems (integrated management of the ecosystem in the case of dams/reservoirs with or without fertilization, and semi-intensive systems in the case of fish ponds with fertilization, feeding and aeration).

The principal species used for freshwater fish seed production belong to the group of tilapias and cyprinids. In addition, there are some work on other species such as *Clarias* sp. which requires artificial spawning and which are destined for 3 stations that are dedicated to breeding, larval rearing and grow-out in earthern ponds. In these stations, the general work involved include maintenance of gene banks and facilities/laboratorios for breeding, water chemistry and nutrition in addition to tanks for larval rearing, nursing and grow-out. Seed grow well through the application of technical management of water, feeding and aeration.

Total annual aquaculture production was in the order of 10.5 million tonnes between 1981 and 1994 and 20.5 million tonnes between 1995 and 2004 and reaching almost 30 million tonnes in 2003 and 35 million tonnes in 2004.

At present, there are 35 species of fish, crustaceans, reptiles and mollusks cultured in the country. Since 96 percent of fish production comes from cyprinids and tilapias, the information presented in this document refer mainly to these two species.

The commercial value of aquaculture production is not quantified accurately since a certain portion of production is destined for self consumption on the part of producers or distributed to institutional network of consumers. Nevertheless, for purposes of comparison with other countries of the region, Cuba produced, in 2004, 35 000 tonnes valued at US$30 million. It is important to note that cyprinid and tilapia products are exported to the Carribean and command a price of US$1 000/tonne.

Aquaculture production from freshwater fishes is destined almost exclusively to the internal market, with possibility of equitable distribution between urban and rural zones for consumption of labourers and supply to hospitals and other consumers. A small part of the production is sold in specialized fish markets, but in this case it is mainly products of cyprinids that do not enjoy much acceptance in the form of fresh or whole fish. In the past, in Cuba, there was no custom of eating freshwater fish, unlike in Asia for example. Many species, introduced during the last decade, has been processed to make it more attractive to consumers.

The annual consumption of fish produced from freshwater aquaculture is estimated at 3 kg per capita, equivalent to one-third of the fishing products that are consumed in Cuba, including marine fish and imported fish.

SEED RESOURCES/SUPPLY

Annual seed production from freshwater fish is more than 220 million fingerlings. For example, production for 2003 was 223 million fingerlings and 226 million in 2004. Almost all of the seed produced from freshwater species come from companies of the Ministry of Fisheries (MIP). The distribution of freshwater fingerling production stations in Cuba are presented in Figure 7.7.1.

FIGURE 7.7.1
Distribution of freshwater fingerling producing stations in Cuba

In general terms, it is possible to say that seed production from freshwater fish is sufficient to satisfy the national needs. All stations and hatchery facilities does not realize that expected capacity of producing 500 million seed using semi-intensive and extensive systems and the possibility of increasing seed production without the necessity of having new investments.

In the future, new stations should be built or the capacity of the existing ones should be increased if stocking density is higher (intensive culture) or there is an expansion of the family operations and therefore an increase in demand for stocking.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Seed production stations

Fingerling production in Cuba began in the 1960s with the construction of three small farms, located in western provinces, for seed production for the purpose of stock enhancement. In the 1970s, one major station was constructed in the center of the island. These stations supply seed to the different regions of the country, especially in reservoirs or dams already producing fish. In the 1970s and 1980s, there was an increase in the construction of fingerling production stations, reaching 26 stations with capacity to supply seed throughout the country based on existing technology.

It is estimated that if necessary, the capacity of existing stations in Cuba can produce up to 500 million fingerlings annually.

The main production comes from tilapias and cyprinids and minor quantity produced from *Clarias* since 2001 as can be seen in Table 7.7.2.

Hatching technology

In the case of cyprinids and bagres, artificial and induced breeding are used. For tilapias, natural spawning is used from broodstock maintained by producers. Broodstocks are renewed on a regular basis from fingerlings that are specially produced for replacement of broodstock in the gene banks of Mamposton Station in the western zone, Pavon Station in the central zone and Paso Malo Station in the eastern zone. In addition, importation of fingerlings of cyprinids and tilapias have been made.

Tilapia and catfish fingerlings are raised in monoculture systems while cyprinids are raised in polyculture until they reach the required size depending on their destination. For stocking in dams or resevoirs, the required size are between 8 to 15 g; for stocking in ponds, the required size varies between 5 and 8 g.

SEED MANAGEMENT

Techniques of reproduction and main species

Tilapias (*Oreochromis aureus, O. niloticus, O. mossambicus and O. rendalis*) and catfish or channel catfish and common carp are spawned naturally. Cyprinids such as *Cyprnius* *cabezona, C. plateada and C. herbivora, Clarias gariepinus and Colossoma* sp. are spawned artificially. Common carp are spawned naturally and artificially.

For channel catfish, tilapias and common carp, spawning are induced when appropriate conditions exist in the ponds, e.g. for catfish – spawning ground; for carps – good vegetation; for tilapia good water condition and temperature. Correct ratio of male and female of the target species to attain effective spawning and to begin with breeders with good quality are necessary.

In the case of tilapias, larvae can be sex-reversed to obtain the required number of males and to obtain faster growth during grow-out. The nursery stage of each species last between 12 and 15 days.

TABLE 7.7.2
Fingerling production from 1995 for the main freshwater species (in million tonnes)

Species	Tilapias	Cyprinids	*Clarias*
1995	115.50	76.70	
1996	87.70	37.20	
1997	64.00	51.40	
1998	67.60	97.00	
1999	60.10	97.00	
2000	57.50	154.30	
2001	27.60	121.50	9.90
2002	35.40	166.80	19.90
2003	47.80	165.70	10.20
2004	36.7	192.50	6.60

Source: Bulletin MEP, Ministry of Economy and Planning) and MIP[1]

Grow-out stage from larvae to fingerling

Larvae can be stocked directly in the pond or in a nursery for 12-15 days up to fingerling size at a density of 0.5-5 million larvae/ha according to the species. In any case, the pond needs to be fertilized to produce enough natural feed.

Feeding

Urea and superphosphate and other organic material from chicken, pig or cow manure are used as fertilizer. The mixture of animal and vegetal materials, flour and trash fish are also commonly used as feed for tilapia and Clarias fingerlings and have better quality.

Fertilization is done approximately one week before stocking of the larvae and for it to be effective, based on experience, during 1-2 months of culture, 2-3 fertilizations are done on average.

FIGURE 7.7.2
Natural egg laying scheme of channel catfish, tilapia and common carp

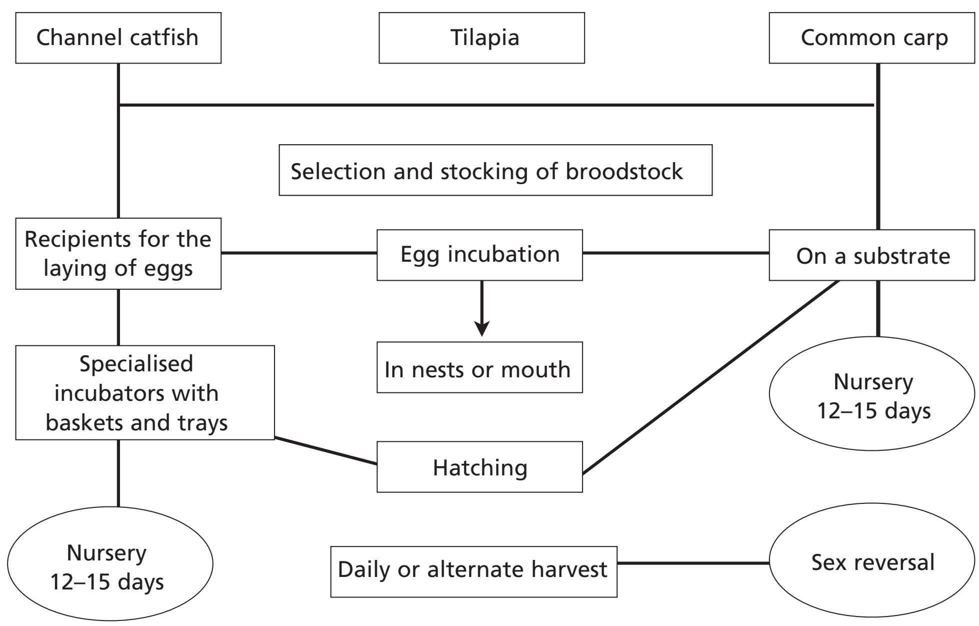


FIGURE 7.7.3
Natural egg-laying scheme of channel catfish, tilapia and common carp

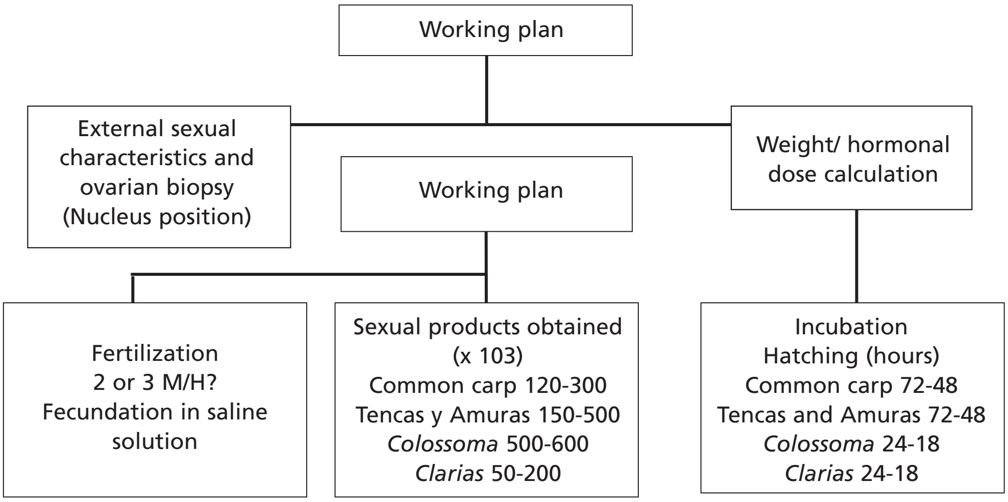


TABLE 7.7.3
Characteristics of fingerling of the main cultured species

Type of culture			***Clarias* sp.**				
Monoculture	***Clarias hibrido***				***Clarias gariepinus***		
density (n. /m²)	100	300	500	800	100	300	500
initial weight (g)				0.005			0.002
final weight (g)	4.34	4.65	3.20	2.85	4.65	4.94	4.88
duration of the culture				42	35	42	46
survival rate	62.0	52.35	44.0	28.2	47.9	55	48
			Cyprinids				
Polyculture	**Silver carp**	**Bighead carp**	**Grass carp**	**Common carp**	*Colossoma macropomun* (Monoculture). In polyculture, it replaces common carp		
density (210-250 n./ m²)	10.0–15.0 (60 %)	3.0–40 (16 %)	1.5–2.0 (8%)	3.0–4.0 (16%)			
initial weight (g)		0.005			0.004		
final weight (g)		6–10			10–20		
duration of the culture		45–60			60		
survival rate		50			60		
Monoculture		**Tilapias**			***Ictalurus punctatus***		
density (n. /m²)	60–80				15–25		
initial weight (g)	5		10		10–20		
duration of the culture	45-50		64		60		

Artificial feed is delivered at least twice a day in semi-intensive systems. It is placed in feed trays or spread freely. In intensive culture systems, feeding is done on average 4 times/day.

SEED QUALITY

In general, in Cuba, for each step of the production process, the Hazard Analysis and Critical Control Point (HACCP) is applied.

The quality of the egg-laying is defined by the amount of eggs and the quality of the sperm of the brooders

In 1992, an instrument of MIP called "Development Program for a System of Diagnosis of Disease and Contaminants in Aquatic Organisms" is jointly implemented with the Institute of Hygiene and Epidemiology of the Ministry of Public Health (MINSAP) and CITMA of the Minister of Science, Technology and Environment. The latter two are responsible for the over-all coordination. The program and its control is made at every phase of the culture process.

There are Standard Operating Procedures for the prevention and control of seed diseases in each of the culture facilities. There is also a communication network in case there is a need for the research centers to intervene.

TABLE 7.7.4
Most common diseases and mortality rates

Species	Disease	% Mortality
Catfish	CCV (virus catfish)	70
Tilapia	Parasites	5–20
Ciprínids	Parasites	5–10
Others	Nutricional	40

There has been some isolated cases of disease in seed as seen in Table 7.7.4.

All the cases of disease outbreak have been isolated and kept under control with no dissemination to other areas.

SEED MARKETING

The marketing takes into account what is supplied by MIP to the national network of commerce that is run by the Company Group INDIPES of MIP. The whole production and comercial cycle is controlled by the same agency while exports is carried out by an export company (CARIBEX).

The export market of seed is scarce and often directed to countries that require help from Cuba such as the program with Haiti for the development of the fisheries sector.

Sales are carried out through the commercial department of the provincial company of the group INDIPES. Seed is sent using a distribution plan annually planned taking into consideration the production needs.

The company trucks carry out distribution. Transport service is offered to other agencies and to the Network of Municipal Council Advisors in the case of "Family Aquaculture". In some ocassions, private transportation is used.

It should be noted that sales are planned the year before for each of the provinces regardless of the type of client.

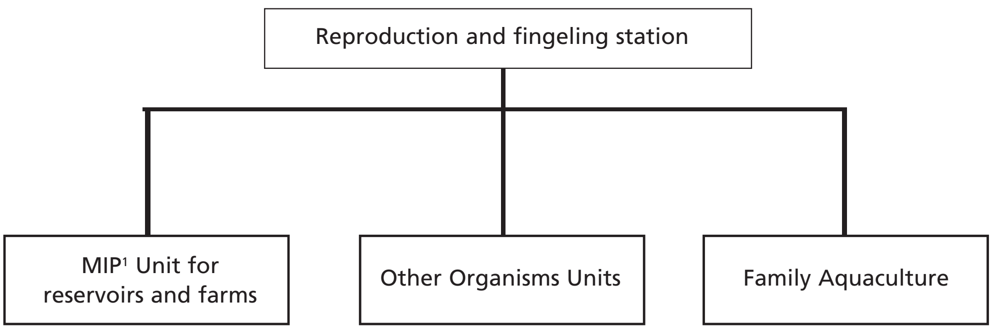
When there is an excess of seed production, it can be sold to private producers that little by little are incorporated into the Family Aquaculture movement.

Seed need to have a health certificate for transportation.

SEED INDUSTRY

Seed are produced in fingerling stations operating all over the country where they are reared to the right size befote stocking in reservoirs, grow-out ponds in the same stations or on their own managed by the fisheries sector. Seed are also distributed to other state entities such as the MINAGRI and the MINAZ and "Family Aquaculture" or "Community Aquaculture".

FIGURE 7.7.4
Flowchart of seed sale



SUPPORT SERVICES

Extension services in the country are efficient in rapidly transferring scientific and technological innovations to the aquaculture production sector. Furthermore, aquaculture research is driven by the needs of producers. It is aimed at sustainable development of the sector, including seed production.

The Aquaculture Training Centre of Mamposton (CEPAM) is a research, development and aquaculture training institution, that offers short, hands-on training courses, as well as post-graduate courses for both technical and management staff involved in the national aquaculture sector. The centre also offers technical assistance to producers and publishes practical aquaculture manuals, handouts and technical papers.

There are a number of training courses dealing with each of the freshwater aquaculture species of the country, which include breeding and seed production.

There is also an institute (Andres Gonzalez Lines Fisheries Institute) that trains aquaculture technicians at the secondary level, with enrolment of students coming from all regions of the country. After completion of their training courses, they are sent back to their communities to support the aquaculture sector. Many of them work in seed production stations.

Both aquaculture farmers and extensión officers are members of the Cuban Association of Animal Production (ACPA), which in turn provides technical assistance and extension services through the Cuban Aquaculture Society. The society disseminates aquaculture technical knowledge, including seed production techniques to farmers and the academia through a variety of means including a technical journal.

There is a managerial protocol for each cultured freshwater species, which describes every step of the production cycle from broodstock selection, through breeding, larviculture and nursery. Such a protocol is printed and distributed among aquaculture farmers and revisions are made according to scientific and technical innovations.

A number of demonstration videos have been developed, which include seed production techniques for species such as channel catfish, cyprinids, *Clarias* and tilapia.

The involvement of women in aquaculture production in the country accounts for 27 percent of the total workforce of the industry, and to 43 percent with respect to the total technical staff of the sector.

SEED QUALITY CERTIFICATION

Seed quality is certified through an official and indispensable certificate provided by the seed supply company, and inspected and signed by the disease group of MIP. Quality is also verified by the producer through routine performance follow-up, and by the provincial and national aquaculture enterprises organizations. This is carried out through routine quality control sampling, backed-up by random samplings by the Provincial and National Fisheries Inspection Services (OPIP).

It is worth noting that the National Aquaculture Enterprises Organization carries out routine inspection throughout every step of the aquaculture production cycle, including seed production. This is realized through the OPIP and the Auditing Directorate of MIP.

The Code of Fishery Products and Practices, Section 16, CX/FFP 004, includes the mandatory use of HACCP protocols for aquaculture seed production. This allows the quality control personnel to focus on food safety, since all other steps of the production process are taken care of through the HACCP programme.

As an example, the breeding process is described in the Aquaculture Management Procedures document. Farmers are expected to follow these procedures for which critical limits (CL) are set so that efficiency and correct application of the procedures are ensured through routine evaluation of aquaculture parameter. If performance parameters exceed critical limits, corrective measures are adopted in a timely manner, to ensure high quality product.

Feeding of breeders, fry and fingerlings is also monitored. Routine inspection of feed manufacturing and raw materials is commonly practiced. Feeding schedules and the overall quality of feed is macroscopically assessed. Also, the Aquaculture Management Procedures document involves seed harvest and transportation procedures, to ensure that the quality of the seed is optimum.

Technical data regarding all monitored parameters are registered in specific logbooks, so that in case of deviations from the established protocols, farmers are adviced, corrective measures introduced, and, if applicable, farmers are fined.

Freshwater fish seed exporters and importers are required to produce a health certificate prior to the movement of organisms. Additionally, in the case of imports, a quarantine period is established by the Institute of Sanitation and Epidemiology of the Ministry of Animal Health (MINSAP). The quarantine protocol is approved only after a preliminary environmental impact assessment (EIA) is submitted and cleared by the CITMA. This latter EIA is required in the case of new infrastructure for seed culture or quarantine.

All these measures have resulted in a drastic reduction in negative externalities caused by aquaculture projects in the country in the recent past.

LEGAL AND POLITICAL FRAMEWORKS

There are a number of legal paths for aquaculture and fisheries development in the country.

1. Act No. 164. "Fisheries Law"

This act is the highest hierarchical legal instrument that regulates the exploitation of fishery resources and the protection of the fisheries environment. It was enacted in September 1996, and includes items regarding seed production such as:

- licensing system for all fishing and aquaculture activities carried out by individuals or companies;
- sanctions applicable to individuals or companies not complying with the law.

2. Complementary regulations

These include norms regarding minimum capture size for juveniles captured from the wild, as well as protected nursery areas.

The national CITMA is an instrument derived from the Environment, Science and Technology National Strategy. Such an instrument also influences aquaculture regulation in the country.

3. Environmental protection strategies established by the Ministry of Science, Technology and the Environment

Act No. 81 relates to the general protection of the environment, and the agency responsible for ensuring compliance to this act is the CITMA. Such a legal instrument is to be observed by all entities of the central state administration. For example, if MIP is to construct new fry production stations, it has to comply with the norms established in the aforementioned Act.

4. Environmental licensing

The same Act No. 81 establishes CITMA as the official agency responsible for analyzing and give authorizations according to the legal framework, concerning any action involving the use of natural resources or modification of the landscape. This includes the construction and operation of breeding and nursery stations.

It is thus compulsory to obtain the environmental license prior to the construction of infrastructure and the operation of aquaculture facilities.

Every step of the culture process, is described in detail in the Aquaculture Management Procedures document (POT), whose application is supervised by nacional state organisms and audited by the ONIP and its provincial offices, as well as by the Auditing Directorate of MIP.

There are also regulations regarding imports and exports of fish seed, as well as the handling and stocking of fry in aquaculture ponds within the Fisheries Law that have to be complied with.

The market for fish seed is regulated through a national annual projection which determines the demand for seed of the different provinces of the country, at a reservoir and even pond level.

Seed distribution both for the public and private sectors, is carried out through government institutions.

ECONOMICS

The seed production stations currently in operation in the country are sufficient to meet the present demand. Furthermore, the overall national installed capacity is 500 million fry, while the current demand is only 223 million fry.

Prices of seed are rather stable and only revised annually to adjust for possible increases in production costs. There is only one national price list for the whole country, given that the transport from the seed production stations to the farms, is an additional cost absorbed by the seed buyers, who seek to buy seed at their nearest seed selling point.

Seed production stations have staff paid by the government. However, these facilities are allowed to sell directly to farmers, which generates additional funds, and in turn, together with their operational budget allocated by the government, constitute the overall running budget of the station.

Moreover, production surpluses are sold and the profit is distributed as an economic incentive to efficient workers. These incentives range from 10 to 15 percentof their monthly wage, and is paid partially in Cuban currency and partially in hard currency.

Farms with grow-out facilities produce their own seed, and sell the surplus production to nearby farmers, in accordance with the production plans stated by the corresponding provincial aquaculture company.

Feed, fry production and energy account for the highest share in the total production costs. Other expenditures include depreciation of infrastructure.

It is estimated that the selling price of seed is between 15 and 20 percent above the production costs, depending on the species and the buyer.

Depending on the species, in order to produce one tonne of fish, an estimated 12 thousand tilapia, 10 thousand carps and 14 thousand *Clarias* fingerlings are needed.

INFORMATION AND KNOWLEDGE GAPS

Seed production intensification and mass production are challenged in the country by the fact that there is a total dependence on exotic species, whose broodstock needs to be renewed periodically, and thus require a close follow-up to avoid the introduction of exotic pathogens into the country. This also entails detailed genetic selection and manipulation for which the country is not yet prepared. Another issue is the availability of seed feeds, which are sometimes limited.

PERSPECTIVES AND RECOMMENDATIONS

Planning at national level has allowed to evenly and thoroughly distribute seed to all provinces, not only to cooperatives and individuals, but also to agrifarmers. This has resulted to a logistics strategy for approaching seed to grow-out farms, thus linking them to the production-processing-commercialization chain.

It is recommended that, even though the demand for seed is currently met by the existing fry production stations of MIP, non-governmental companies are stimulated to produce seed, in order to further increase the current production capacity of the country, in view of future developments of the industry. This could include improved technologies and increased culture densities.

Genetics and nutritional research should be fostered in order to avoid international dependency.

STAKEHOLDERS

Agrifarmers (seed production and exchange). In general, such producers are classified within the technical staff of the seed production stations. There are approximately 3 000 and include technicians and the rest of the qualified staff that operate the stations. There is a small group of rural farmers that use small impoundments and earthen ponds, organized in state cooperatives. There are also a small number of private owners of small farms and households who culture fish in their backyards. They all produce and exchange seed, especially seed of tilapia. It is estimated that the total number of such farmers are above 1 500 in the country. Such farmers produce and exchange small amounts of seed among themselves. It is estimated that approximately 10 percent of the total seed production of each seed station, is destined for small producers.

Local institutions. As previously stated, there exists an Aquaculturists Association (SCA) which is part of the Cuban Association of Animal Husbandry (ACPA). The SCA provides technical assistance to small farmers and promotes the integration of agriculture and aquaculture systems. There are other national programs of extension that also provide training and apply research results. Technical dissemination is carried out through a number of technical fora that are organized nationwide at national, provincial and local levels. Handouts, technical update talks at farm level, as well as technical operation manuals are also distributed to farmers.

Handouts and technical manuals include all parts of the culture process, from broodstock management and breeding, through larval culture, grow-out to harvesting.

Small hatcheries (intended local market). Fry distribution is realized in every town, and responds to a central state planning which organizes aquaculture farmers associations and local people´s councils. The latter takes care of seed needs for households and schools. Seed exchange among these households takes place although in small scale. Only a comparatively small proportion of the seed produced in the country are used by these rural farmers, some of which are intended for stocking small reservoirs and small ponds.

Large breeding and seed production stations (intended for technology innovation). The central government wishes to develop freshwater aquaculture in a balanced manner, so that all regions are capable of producing enough fish protein for their

TABLE 7.7.5
Mean fry (average weight of 8 g) production costs of the main freshwater aquaculture species (costs in US$)

Item	Tilapia	Cyprinids	*Clarias*
Cost of breeders (each)	1.18	1.7	2.3
Fry (thousand)	2.00	3.0	98.14
Feed, fertilizers	7.55	2.65	18.95
Fishing gear	0.09	0.09	0.62
Energy: Water, electricity	1.52	5.1	22.04
Labour	0.91	3.94	0.93
Other expenditures	2.45	4.31	16.93
Indirect costs	1.69	7.31	0.07
Total costs/thousand	17.15	28.10	159.98

population. CEPAM is the main aquaculture research and development centre of MIP and is responsible for technological innovation and technology transfer to both state aquaculture enterprises and extension workers.

Associations. ACPA is the entity that integrates aquaculture producers and provides technical assistance and training. Technical assistance and training are also done by CEPAM and the Fisheries Research Centre (CIP); both institutions belong to MIP.

Government institutions. The state enterprise INDIPES is responsible for commercial production and nationwide distribution of seed to other farmers and for their own use in their grow-out operations. Fish produced by the company are sold only to organizations outside those belonging to the Ministry of Fisheries. Seed market price is fixed. Species such as cyprinids, which are not very popular, are processed as fish balls, smoked fish, etc. to improve its acceptability. There are more than 20 different value-added products derived from freshwater fish species.

Researchers. The Fisheries Regulation Directorate of MIP is the governmental agency responsible for the supervision and control of research activities, including the work by the Science and Technology Forum (agency that organizes technical events for innovation transfers to producers). It has five specialists whose duties are to supervise research programs, which are in turn the direct responsibility of research centres such as that of Mamposton. The state enterprise INDIPES takes up successful research results and implements them for the improvement of their production operations. Currently, MIP runs a specific freshwater aquaculture research program. There are 12 projects, four of which are directly related to seed production. Research programs involve all fields of knowledge related to aquaculture, such as disease control and nutrition. Other relevant areas will be covered within the next few years, such as those related to environmental protection. There is a national program underway, whose main objective involves extension services, especially related to freshwater fish seed production techniques for rural households. There are also other projects in cooperation with non-governmental organizations, aimed at technological innovation and training of state and private producers.

Some examples of these collaborative projects include that of the National Laboratory Animal Production Centre (CENPALAB), which involves a wide range of fields such as nutrition, larval rearing of different fish and shell fish species, automatic control of processes and strategic planning. There are also a number of links with

TABLE 7.7.6
References, websites and persons consulted for the freshwater fish seed survey

Name of entity of person	Website or email address	Documents
Ministry of Science, Technology and Environment	www.medioambiente.cu	national strategies
MIP INDIPES	rmorales@tindipes.telemar.cu	maps of stations
MIP CEPAM -INDIPES Noris Millares (Investigadora) Trabajos AQUACUBA 2005	rmorales@tindipes.telemar.cu	tables
MIP Direccion de Palificacion y Dirección de Contabilidad	nelly@telemar.cu	information bulletins and statistics
MIP DIR. Regulaciones Pesqueras autora del Trabajo: Magali Coto, Especialista, Presidenta Sociedad Cubana Acuacultura – ACPA	mcoto@telemar.cu	compendium of data and analysis
MIP Dir. Pesca y Acuicultura Autor del Trabaho: Wilfredo Acuna Director	acuicola@mip.telemar.cu	compendium of data and analysis
MIP Dir. Regulaciones Pesqueras Dr Julio Baisre	regpes@telemar.cu	MIP strategy
MIP Dir. Relaciones Internacionales	mreyes@mip.telemar.cu	

academic institutions such as universities, the CITMA, the Animal Science Institute, the Higher Institute of Agricultural Sciences, the Centre for Biotechnology and Genetic Engineering and others.

7.8 Freshwater fish seed resources in Ecuador[1]

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Schwarz, L. 2007. Freshwater fish seed resources in Ecuador, pp. 233–240. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fisheries Technical Paper.* No. 501. Rome, FAO. 628p.

ABSTRACT

Ecuadorian aquaculture produced nearly 70 000 tonnes in 2004, 95 percent of which were contributed by marine shrimp and tilapia. The culture of the latter has grown rapidly over the past five years, as a result of increased demand in international markets and as an alternative to the riskier shrimp farming. Currently, there are some 4 000 ha of tilapia ponds in the country. Other exotic species cultured include common carp and rainbow trout. Few other native species including *Dormitator latifrons* are being experimentally cultured with promising results.

There are 90 registered fish farms in the country, all of which have, and operate, a hatchery. Ten of them produce tilapia, 43 produce rainbow trout, and the rest produce native species as well as at least one of the exotic species. There is no available information on the actual annual national seed production. In the case of tilapia, an estimated 0.36 million fingerlings are produced by the six hatcheries located in the southern region.

Breeding and hatchery methods are standard. Tilapia breeders are stocked in 0.1-1.0 ha earthen ponds, employing a sex ratio of 1.5-2 males: 3 females. Weaned fry are collected and transferred to in-pond hapas or small ponds where sex reversion occurs through hormonized feeding. Rainbow trout breeders are held in broodstock raceways and manually stripped. Artificial fertilization in dry conditions is performed. Indoor hatcheries incubate fertilized eggs. Once hatched, weaned fry are reared in nursery concrete tanks. Breeding of native species is still under experimentation.

Large farms own vertically integrated hatcheries. Many small farmers depend on seed sold by middle men who in turn buy seed from commercial hatcheries. Distribution of seed is carried out by the seller.

Seed quality is not standardized nor officially regulated in the country. It is only pathological aspects that are considered whenever seed are to be moved, especially internationally and although there are a number of aquaculture research centres, as well as universities providing training on fisheries and aquaculture, very little attention is paid to freshwater species, in particular regarding genetics, reproduction and hatchery techniques.

Some challenges the Ecuadorian seed production industry has to face include fostering rural aquaculture, through capacity building and start up financial aid to small farmers. The lack of a national plan for freshwater aquaculture development, keeps this sector from benefiting from government support.

[1] The original paper was written in Spanish and was translated to English by M.B. Reantaso (FAO) and A. Flores Nava (Mexico) for purposes of this publication.

INTRODUCTION

The annual aquaculture production of Ecuador is approximately 70 181 tonnes, 95 percent of which consists of white shrimp and tilapia.

The development of other species for aquaculture is limited. The existence of shrimp culture, its profitability and ease of culture, especially during the first few years of development of the industry, has hindered the application of existing technology for other species.

Perhaps the most evident example is the case of tilapia, which was introduced to Ecuador during the 1930s, but it was only until recent years that tilapia became an important cultured species in the country. This is mainly due to the need for species diversification after the shrimp industry of the Taura region was severely hit by the Taura syndrome virus (TSV). Since then, tilapia culture has been adopted and the industry has grown considerably. However, high production costs have discouraged many new small producers. In contrast, big shrimp companies have made large investments in the tilapia sector, thus greatly increasing production. Tilapia farming currently uses 4 000 ha previously used for shrimp ponds. With time, some farms have partially returned to shrimp culture, or have incorporated mixed cultures (tilapia and shrimp polyculture).

In addition, there have been experiments to culture other freshwater fish species related to extension programs targeted for small-scale farmers (Table 7.8.1).

Most of the mountain lakes have been restocked with fingerlings of exotic species, or fish fingerlings hatched from imported eggs. Re-stocking has been carried out by the government, sport fishermen associations, or private initiatives.

Trout was the first introduced fish species in the country. It was brought from the United States for aquaculture purposes. This species has colonized high altitude water bodies. Brown trout (*Salmo trutta* L.) has been successfully introduced in the Province of Azuay, south of the country. Trout populations have not been fully exploited through aquaculture, since they are perceived as slow growers.

FIGURE 7.8.1
Political map of Ecuador

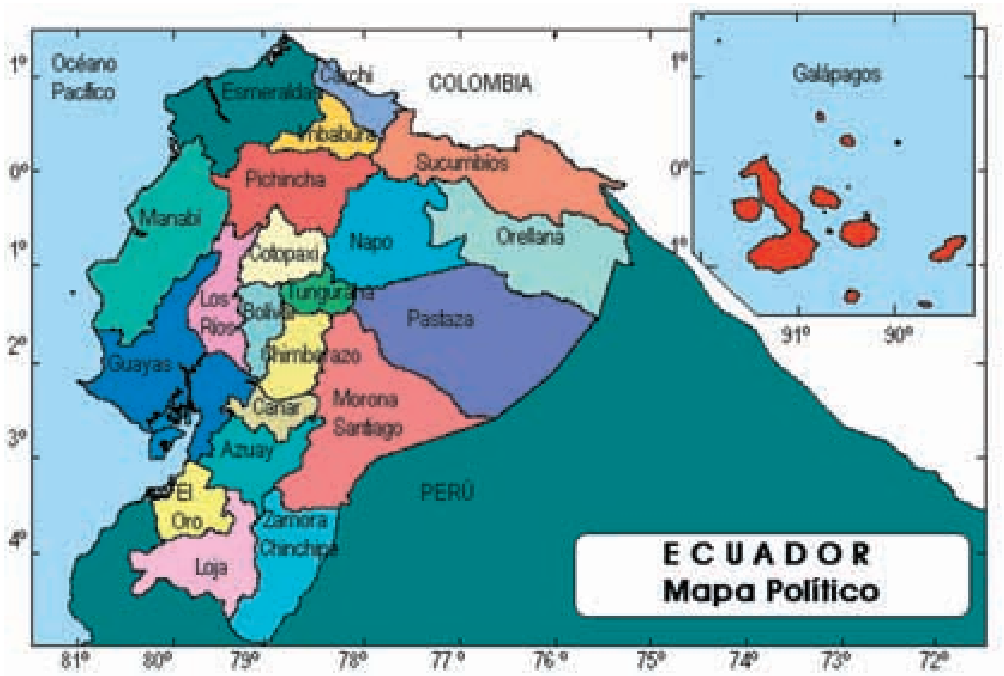

TABLE 7.8.1
Freshwater species cultured in Ecuador

Freshwater species	Location	Species and culture characteristics
Local tropical species		
Chame (*Dormitator latifrons*)	Chone, Bachillero, San Antonio (Manabí Province) Atacames y Quinindé (Esmeraldas Province), Churete and Taura (Guayas Province)	herbivorous and phytoplankton feeder, white flesh representing 70 percent of body mass, distribution in both fresh and brackishwater, high tolerance to poor water quality (<1 mg/l DO), current culture surface area of approximately 200 ha, does not breed in ponds
Bocachico (*Ichthyoelephas humeralis*)	Watershed of the Guayas River	herviborous, low tolerance to poor water quality (DO above 4 mg/l), high commercial value, not registered as an aquaculture species, some culture trials are reported in small ponds, with an estimated total pond surface area of 20 ha, not reproduced in captivity
Vieja Azul (*Aequidens rivulatus*) and other cichlids	Santiago and Amazones Rivers and watersheds	omnivorous, high tolerance to low DO levels, wide geographical distribution in Ecuador, low culture production costs, breeding in ponds reported
Introduced species		
Tilapias, (*Oreochromis niloticus O. mossambicus*)	Coastal area, oriental and mountain areas	Introduced in 1974 by private companies from Brazil, constitutes the second most important aquaculture species of the country, in addition to large-scale commercial farms, an estimated 4 000 small-scale, household-managed ponds are operated throughout the country as a result from extension programs
Common carp (*Cyprinus carpio*), Bighead carp (*Aristichthys nobilis*), Grass carp (*Ctenopharyngodon idella*)	Ronald Ranch (Pichincha Province). PREDESUR Company (Loja and Zamora Provinces)	Introduced in 1978 by PREDESUR, culture technology modified from Asian culture methods, about 20 ha ponds in the country
Local temperate species		
Rainbow trout (*Onchorrynchus mykiss*)	Lakes and rivers along Los Andes Mountains	Offers great fishery potential for the region, currently about 300 ha of waterbodies have been stocked by government with hatchery-reared fingerlings

Statistics are scarce. The only available data for trout comes from 2001 statistics, with a reported annual total production volume of 1 000 tonnes.

The chame (*Dormitator latifrons*), on the other hand, has started to be cultured in the Manabi Province, with some exports reported to Asian countries. This species has traditionally been fished and consumed throughout this region.

Until February 1997, the Undersecretary for Fishery Resources had approved 96 licences for the operation of freshwater fishculture farms, which account for approximately 2 142 ha of culture ponds.

In the western slope of Los Andes mountains, various fish, whose culture information are not known, are being cultivated. These species are:

- Guanchiche (*Hopias microlepsis*),
- Dica *(Curimatorbis boulengerii)*,
- catfish and ornamental fish.

LOCAL FISH CONSUMPTION

There is neither reliable information on fish consumption in the different regions of the country nor in-depth information on the potential of the domestic market, distribution channels, sales mechanisms, product prices, etc.

The lack of information on the marketing of aquatic products within the country is evident. According to statistical data, the supply of "fish and products of the fishing" for the Ecuadorian internal market is about 84 248 tonnes/yr (average from

TABLE 7.8.2
Number of freshwater fish farms authorized by the Fishery Resources Undersecretary until 1997

Province	Species	Number of fish farms	Total surface area (Ha)
Esmeraldas	Chame	2	120
Manabí	Chame	16	598
Guayas	Chame	5	
	Chame/miscellaneous	3	
	Tilapia	10	
	ornamental fish	1	
	Bocachico	1	1 031*
Los Ríos	Chame	1	
	Chame y Bocachico	1	
	Bocachico	1	
	miscellaneous	5	103
Bolívar	trout	2	0.1
Pichincha	trout	6	123
Tungurahua	trout	6	89
Chimborazo	trout	8	11
Cotopaxi	trout	1	0.1
Azuay	trout	17	61
Cañar	trout	2	1
Napo	trout	1	5
TOTAL		96	2 142.2

Source: Directorate General of Fisheries (Registry of Licenses of SRP)

* The area (in ha) used for the tilapia culture has been increased considerably from the last official statistics

1995-1999), out of which an apparent consumption of 7.2 kg/person/yr can be determined (population: 11.7 million)[2].

SEED RESOURCES AND SUPPLY

Freshwater fish production from aquaculture presents an unexplored opportunity for the development of an activity that can produce food rich in protein at low cost. A number of government agencies have implemented projects to strengthen aquaculture activities in some regions of the country.

The area of Babahoyo, located in Los Ríos Province, is inhabited by small-scale freshwater fishermen who face serious problems with food insecurity and deprived living conditions. Here the FAO Telefood Programme, whose objective was to find ways to enhance fisheries activities to contribute to improving the situation, was implemented with the participation of the National Federation of Coooperatives of Artisanal Fishermen (FENACOPEC). Three earthen ponds were constructed and stocked with tilapia fingerlings, with the objective of teaching basic aquaculture to artisanal fishermen of the Babahoyo Fishermen Cooperative .

On the Ecuadorian Mountain region at the center of Chirimachay, province of Azuay, the National Institute of Fisheries is in charge of supplying tilapia fingerlings to fish farmers.

Some non-governmental organizations, have also developed fisheries programs, for example, PREDESUR (Programa Regional Ecuatoriano para el Desarrollo del Sur – Program for the Development of the Southern Region of Ecuador), commenced in 1976 the construction of six tilapia hatcheries for seed production. This program controls the distribution and sale of seed to the fish farmers of this region and neighboring provinces.

[2] The apparent consumption of fish and fishery products considers the total fish production (live weight) plus the imports, less exports and products that are not for direct human use.

Other institutions with similar programs include: (i) CREA in the provinces of Azuay and Napo, (ii) Rancho Ronald supported by Group 4F and the Ministry of Agriculture in the provinces of Pinchincha and Esmeraldas and (iii) SEDRI (Servicio para el Desarrollo Rural Integral - Agency for Integrated Rural Development) in the province of Esmeraldas.

In the case of chame culture, its reproduction in captivity has not yet been successfully achieved despite efforts made by some local research groups. The current culture method relies on wild fry or fry occasionally found in culture ponds for stocking of rearing ponds.

SEED PRODUCTION

Tilapia is the only species bred routinely in ponds. Fry are sex-reversed to producing all-male schools. The sex reversal method consists of feeding fry from its first-feeding stage, with hormonized (17 α-methyltestosterone, at 30-60 ppm) micropellets containing elements that meet the nutritional requirements of the seed. The hormone is fed for 30 days after the fry reaches the first-feeding stage; fry should not be smaller than 13 mm in total length at the beginning of the treatment. The amount of food mixed with the hormone complex is 250 to 400 g for every 1 000 alevines; this will generate 100 percent males in the population.

This procedure requires that fry are kept, for one week, in tanks and not in earthen ponds, in order to exclude natural food so that the exclusive feed they feed on are the hormonized micropellets.

SEED MANAGEMENT

In the case of tilapia, fry are packed in plastic bags containing 2/3 of air and 1/3 of aerated water. Inflated and sealed bags are then packed in cardboard boxes. Fry are transported with a size range of between 17 to 20 mm.

Upon arrival at the pond site, fry are temperature-acclimatized. Stocking density is 20 fry/m^2, stocking fry size ranges between 1 and 5 g. The culture period ranges between 6 and 12 months. At the end of the culture cycle, fish are harvested at between 400 and 700 g. Occassionally, tilapia is polycultured with other species such as carps, colosoma or guabote. In general, it is not necessary to provide artificial food since there is abundant natural food in the pond.

SEED INDUSTRY

Rural fish farmers buy their seed from middlemen. In Guayas Province, for example, a middleman supplies a group of 150 tilapia farmers with 300 million tilapia fry and some broodstock every month.

As an additional activity to agriculture, the residents of the provinces of Guayas and Amazonia, have realized that fish rearing is a profitable business. Aquaculture production is sold in the local market. The main drawback for rural fish farmers, though, is still the lack of sufficient hatcheries to meet the growing demand for seed

Large scale tilapia farmers are vertically integrated, thus having their own supply of seed from self operated hatcheries. Rainbow trout is second to tilapia in terms of number of freshwater seed produced. This species is bred in lakes and rivers at temperatures below 15 °C. There are a number of seed production stations, such as Arcoiris Station in Azuay Province and Chirimachay Station in Pichincha Province; the latter has nine incubation tanks and seven fry tanks and produces 100 000 fry/yr.

SUPPORT SERVICES

There are four universities that offer training programs, such as:

- The School of Biology, Faculty of Natural Sciences
- Higher Education Polytechnical School of the Littoral (ESPOL)

- Machala University
- Loja University (includes hands-on training programs for farming of trouts, carps and tilapias)

Other universities (e.g. The Catholic University of Quito and The Central University of Ecuador) offer academic programs on fisheries and related fields.

LEGAL AND POLICY FRAMEWORKS

The development and administration of fisheries are regulated by the Fisheries and Fisheries Development Law, through Act No. 497 (of February 19, 1974) and its Regulation published in the Official Registry No 613 (of August 9, 1974). These are the central policy instruments in relation to all fisheries and aquaculture activities. In addition, a number of Decrees, Agreements and Resolutions aimed at safeguarding and harmonizing the interests of the fishing sector, have been enacted, among which is the Bioaquatic Species Farming Regulation.

The Ministry of Natural Resources and Energy is the government authority responsible for managing and instrumenting the fisheries policies of the country through the Director General of Fisheries of the Office of the Undersecretary for Fishing Resources.

The School of Fisheries of Manta is responsible for capacity building and training of fishermen; the National Fisheries Enterprise (Empresa Pesquera Nacional – EPNA) is responsible for marketing and post-harvest activities. The National Institute of Fisheries (INP) is responsible for fisheries and aquaculture research.

In addition, particularly pertaining to the seed sector, Article 19 of the Fisheries and Fisheries Development Law provides detailed procedures for the importation of eggs, sperm, alevines; breeding of fish and other aquatic organisms. The law includes norms regarding the inspection of laboratory facilities (both for export and import), the evaluation of biosecurity measures in those laboratories and the qualification of those establishments.

In order to maintain sanitary control of imported eggs, sperm, fry/alevines and broodstock , aquafarmers have to follow the following procedures: (1) notify the INP or the National Center for Aquaculture Research (CENIAC) regarding the location of the certified hatchery from which the seed are to be brought and (2) produce the corresponding import permit from the Undersecretary of Fisheries, indicating the number or amount of eggs, sperm, fry or broodstock to be imported. A representative of the INP or CENIAC supervises the imported organisms at the point of embarkation or entry, to verify that they come from a certified hatchery and that the shipment is accompanied with an international zoosanitary certificate that states that the imported organisms are disease-free .

An initial sampling is made so that the INP or CENAIC can carry-out corresponding analysis (e.g. microbiology, molecular biology (e.g. PCR). While pathological tests are underway, the imported organisms are placed in quarantine until the results are available. If samples test negative, the INP or CENAIC staff approves entry by stamping an official seal of inspection to the container of the imported product.

INFORMATION ON PRODUCERS

There are a number of Ecuadorian private companies dedicated to the commercialization of tilapia, as in the United States and some countries in the European Union as shown in the Table 7.8.1.

TABLE 7.8.1
Ecuadorian companies dedicated to the commercialization of tilapia

Name of Company	Market
AQUAMAR S.A. RUC: 0990556792001 Av. Nueve de Octubre No. 1911 y Los Rios PIS7 Edif. Finansur, Guayaquil – Guayas Tel.: 04-2455200; Fax: 04-452990 central@aquamar.com.ec	Canada, USA, Mexico, Puerto Rico
COMERCIALIZADORA ZURITA RUC: 0912077195001 Alborada 12 ava Etapa Mz - 2 Villa 8, Guayaquil – Guayas Tel.: 593-04-2249787; Fax: 593-04-2249787 juancazb@hotmail.com	Chile
EL ROSARIO S.A. RUC: 0990361320001 Av. Domingo Comin S/N y P.J. Bolona, Guayaquil – Guayas Tel.: 04-2441000; Fax: 04-2441851 lnicol@mail.ersa.com.ec http://www.elrosario.com	USA
EMPACADORA DEL LITORAL SOMAR C. LTDA. RUC: 0990603871001 Km.15.5 Via a La Costa de Lado Izquierdo, Guayaguil – Guayas Tel.: 2870352; Fax: 04-870285 lourdes_dl_pared@empagran.com	
EMPACADORA NACIONAL C.A. ENACA RUC: 0990041989001 Guasmo Norte y La Ria S/N a Lado de Cipresa, Guayaguil - Guayas Tel.: 04-2430600; Fax: 04-2495488 Ext 3 sales@enaca.com.ec	Slovakia, USA, France, UK, Italy, Japan
ETECO DEL ECUADOR S.A. RUC: 0990097577001 Av. Amazonas 6017 Y Rio Coca, Quito - Pichichincha Tel.: 00468600	Canada, USA, Mexico
EXPORTADORA LANGOSMAR S.A. RUC: 0990666253001 Pascuales Avenida 2DA y Malecón del Rio Guayaquil – Guayas Tel.: 04-2894056; Fax: 04-2897383 langosmar@andinanet.net http://www.langosmar.com	Spain, USA, UK, Italy
SOMAR S.A. RUC: 0992178116001 Km. 15 1/2 Via a la Costa, Guayaquil - Guayas Tel.: 04-2870284/2/0; Fax: 04-2870285 lourdes_dl_pared@empagran.com	Spain, USA, France
SOUTH TROPICAL S.A. RUC: 0991472827001 Jose Mascote # 701 y Quisquis, Guayaquil – Guayas Telf.: 593-4-229-0936; Fax: 59342-290932 885910 ebolona@southtropical.com http://www.southtropical.com Fuente: Directorio de Exportadores de CORPEI	

FUTURE PERSPECTIVES AND RECOMMENDATIONS

Ecuador needs a major boost in rural aquaculture to assist in increasing the per capita consumption of protein from fish.

Since agriculture is the main activity in rural areas, due emphasis should be given to programmes that will assist in the development of new integrated systems (agriculture-aquaculture) to generate employment thus preventing the migration of the rural population towards urban centers.

It is important that appropriate extensión services are provided to the community aimed at optimizing and utilizing the use of land not suitable for agriculture, to diversify towards more integrated agriculture-aquaculture activities to improve both the local and the national economies.

Despite the long tradition in shrimp culture in the country, there are no technical guidelines nor appropriate management practices for increasing production. It is assumed that the government sector will provide solutions to the problems generated by the sector. Lack of knowledge and experience of national technicians for the implementation of community projects is one of the main problems that hinder the development of aquaculture in Ecuador.

7.9 Freshwater fish seed resources in Egypt

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ABSTRACT

Freshwater fish seed production in Egypt was reviewed. The development of the activity during the last three decades was assessed. The activity involved the production of seed of six species of finfish and a freshwater crustacean. The study covered subjects related to seed demand and supply, production facilities and technology, management, marketing and economics of the industry.

The study revealed that Nile tilapia is the most important cultured species in Egypt as it represents 40 percent of the country's aquaculture production. More than 1.2 billion Nile tilapia seed were produced by 520 hatcheries in 2004. Production of tilapia seed in commercial hatcheries is a new practice in Egypt. It was until the expansion of the modified semi-intensive and intensive pond aquaculture in the mid-1990s when the first commercial tilapia hatchery was established. Development of tilapia seed production was the reason behind the sharp increase in aquaculture production in Egypt during the last decade.

While most of tilapia seed production is by private hatcheries, seed of both common and Chinese carps are produced by ten governmental hatcheries. Apart from traditional aquaculture activities, carp seed are used for national projects such as weed control in irrigation canals and aquaculture in rice fields. A total of 227 million seed (common carp 138 million and 89 million Chinese carp) were produced in 2004.

The planned expansion of aquaculture to reach a target production of 1 million tonnes requires a parallel increase in seed production. It was concluded that development of seed production requires improvement of production technology, management, legislation and extension services.

INTRODUCTION

Aquaculture was known to Egypt since the beginning of written history. The traditional form of aquaculture "Hosha" known more than 500 years was common until a few decades ago in Northern Delta Lakes Region where it was practiced centuries before.

Aquaculture is considered as the only possible solution to increase fish production in Egypt. The activity is presently the largest single source of fish in the country. It is the fastest growing sector in the field of fisheries and is considered as the only available option for covering or reducing the gap between production and consumption of fish in Egypt.

Total aquaculture production of Egypt was 471.5 thousand tonnes in 2004 with a total local market value equivalent to US$684.2 million (US$1 = EGP5.725) (GAFRD, 2005). Aquaculture production represents 54.5 percent (865 000 tonnes) of the total fish production of the country and 43.3 percent (1.09 million tonnes) of the total fish consumption equivalent to 15.6 kg per capita/annum. At present, about 98.2 percent of aquaculture production is from private farms.

Modern aquaculture expansion started in Egypt only two decades ago. Production increased from a level of 17 000 tonnes in late 1970s to 45 000 tonnes in the mid-1980s. In 1986, aquaculture production was 51 000 tonnes which increased to 60 000 tonnes in 1990 and 72 000 tonnes in 1995. The sector witnessed great developments during the last decade with sharp increase in production from 340 000 thousand tonnes in 2000 to about 500 000 tonnes in 2004-2005. The current rapid development is associated with the application of higher levels of technology and change in the structure of fish farming communities. Aquaculture activities became more sophisticated and diverse supported by the expansion of feed mills and development of hatcheries. The number of fish hatcheries tremendously increased from 14 in 1998 (Barrania *et al*., 1999) to a present figure of more than 480 (GAFRD, 2005). More than 14 fish feed companies have been established during the last six years. Except for very limited and isolated cases, most aquaculture activities are located in the Nile Delta Region.

Majority of fish farms in Egypt can be classified as semi-intensive brackishwater pond farms. Intensive culture, in earthen ponds and tanks, is now developing very fast and substituting the traditional system. The new system depends on smaller, deeper ponds, with higher stocking densities, intensive feeding and aeration and producing on average 17.5-30 tonnes/ha/yr. Intensive cage culture is second in terms of total production. In 2004, more than 50 400 tonnes were produced in freshwater cages (GAFRD, 2005). The harvest is predominantly that of Nile tilapia (*Oreochromis niloticus*) and silver carp (*Hypophthalmichthys molitrix*). Integrated aquaculture in rice fields started in the mid1980s and production in 2004 was 17 200 tonnes, all common carp (*Cyprinus carpio*). Integrated desert agriculture-aquaculture started in Egypt in the late 1990s. This system generally applies intensive tank aquaculture and expanded very fast in the western desert.

Culture-based fisheries depend on the annual supply of fish seed to support wild stock in natural water bodies (e.g. lakes, canals, river). The total estimated production of the activity is about 16 000 tonnes mostly Nile tilapia. This figure is not included in aquaculture production statistics in the yearbook of the General Authority for Fish Resources Development (GAFRD) as it is included in the capture fisheries data.

More than 23 700 tonnes of stocked grass carp (*Ctenopharyngodon idella*) used for weed control were harvested from irrigation and agriculture drainage canals in 2004 (GAFRD, 2005). Hatchery-produced grass carp fingerlings are stocked annually as part of a national program for biological aquatic plants control in Egypt financed by the Ministry of Irrigation. Stocked fish are harvested by fishermen and the production figure is added to the capture fisheries statistics (GAFRD, 2005).

The majority of cultured fish in Egypt are either freshwater species or those that can grow in brackish water. Production of fish and crustaceans in salt water is still in its early stages and its development suffers from technical and economic problems. Presently, 16 different species of fish and crustacea (14 finfish and two crustaceans) are cultured in Egypt. Out of the 16 species, ten are native and six were introduced. The native species are: (1) Nile tilapia, (2) blue tilapia (*Oreochromis aureus*) (1 and 2 comprise 42.2 percent of aquaculture harvest in 2004), (3) African catfish (*Clarias gariepinus*) (0.1 percent), (4) grey mullet (*Mugil cephalus*), (5) thin-lipped grey mullet (*Liza ramada*) (4 and 5 comprise 28.3 percent of aquaculture harvest in 2004), (6) bluespot mullet (*Valamugil seheli*), (7) European seabass (*Dicentrarchus labrax*), (8) gilthead seabream (*Sparus aurata*), (9) meagre (*Argyrosomus regius*) and (10) penaeid shrimp (6,7,8,9 and 10 together comprise 10 percent of the harvest). The introduced species are: (1) common carp (*C. carpio*) (15.9 percent of the harvest), (2) grass carp (*C. idella*), (3) silver carp (*H. molitrix*), (4) bighead carp (*Aristichthys nobilis*), (5) black carp (*Mylopharyngodon piceus*) (12.8 percent of the harvest) and (6) giant freshwater prawn (*Macrobrachium rosenbergii*).

Aquaculture development strategy is targeting a total production of one million tonnes by the year 2017. With limitations in water and land resources, this strategy will depend largely on a gradual change from the traditional extensive to intensive pond aquaculture. Although this approach was successful during the last ten years, it still requires a fast and large development in hatchery seed production and expansion of the fish feed industry.

Presently, there is no clear demarcation between cultured and captured fish, both can be sold for the same price in the retail market. Introduced species (carp and freshwater prawn) are not well accepted by consumers. The price of such species can never exceed 50 percent of the price of native fish except for African catfish which is not commonly accepted by the public. Besides the disadvantage of being a bony fish, carp, which is usually harvested at sizes larger than 1 kg/piece, is not preferred by Egyptians who have a general preference for smaller fish (200 g).

SEED RESOURCES/SUPPLY

Except for African catfish, fish seed utilized for freshwater aquaculture in Egypt are all hatchery-produced.

Tilapia

The Nile tilapia is the most commonly produced freshwater species. Seed production is carried out in commercial hatcheries or in farm-based hatchery units. The main activity of the commercial hatcheries is the production of fish seed (fry or fingerlings) and all its production are sold to grow-out farmers. Some fish farms may have smaller hatchery units sufficient to cover the requirements of fry and fingerlings; surplus production are sometimes sold to other farms. The majority of tilapia seed production comes from private hatcheries. Governmental hatcheries were originally designed for the production of different species of carp. Tilapia seed production is a side activity in the nine governmental hatcheries which produce in total a production of 38.03 million fingerlings (3-5 g) per year (GAFRD, 2005).

To reach the recorded 190 000 tonnes harvest of cultured tilapia, an estimated production of 1.197 billion fingerlings was required. The recorded production of the private hatcheries in 2004 (GAFRD, 2005) was only 109 million fingerlings which is a production figure from licensed commercial hatcheries – only a fraction of the other production units scattered in the country.

The present production of tilapia seed hardly covers the increasing demand of the continuous and fast growing aquaculture sector and is putting a lot of pressure on the supply of seed. As a result, tilapia seed are frequently sold as 0.5-1.0 g fry. Growers commonly carry out the nursing process to reach the required fingerling size for grow-out operations.

Common carp

Common carp seed are mainly produced in government hatcheries. Very limited numbers of common carp fry are produced in some private hatcheries. The total recorded production of common carp fingerlings in 2004 was 137.8 million (GAFRD, 2005). About 75 percent of carp seed are used for integrated aquaculture in rice fields, the rest are utilized for semi-intensive polyculture in ponds. Demand for common carp seed is presently growing to cover the gap in the supply for intensive pond culture which is not fully covered yet by carp.

PLATE 7.9.1
Egyptian freshwater aquaculture facilities

Semi-intensive ponds, Northern Delta Region

Integrated agriculture-aquaculture in intensive ponds and tanks, Western Desert, Egypt

A commercial tilapia hatchery, Northern Delta, Egypt

Indoor facilities of a government hatchery for carp

Indoor facilities of a tilapia hatchery

Indoor facilities of a private hatchery, Eastern Delta, Egypt

Chinese carps

Grass carp. All grass carp seed are produced in government hatcheries. In 2004, a total of 54.6 million fingerlings (10-50 g) were produced (GAFRD, 2005). About 78.5 percent of the produced fingerlings were used by the National Aquatic Weed Control Project (NAWCP) for weed control purposes in agriculture drainage and main

PLATE 7.9.2
Egyptian freshwater aquaculture facilities

Green house tilapia hatchery, Eastern Delta, Egypt

Tilapia seed from a private hatchery being prepared for marketing

Tilapia over-wintering tanks in a private hatchery, Northern Delta

Seed transport truck, purchased seed inspected by farmers on arrival to farm

Water boiler in a tilapia hatchery in Egypt

irrigation canals. A smaller number of fingerlings (0.75 million) were used for stocking inland lakes for weed control. The rest of grass carp seed were used for polyculture in ponds. The level of production and demand for grass carp is strongly affected by the changes in the numbers required by the NAWCP. The number of fingerlings sold to NAWCP in 2005 increased by about 11 percent. The demand is expected to increase greatly forthcoming years as the Ministry of Irrigation, the sponsor of the NAWCP, is negotiating increasing its purchase of seed by 20 percent. This increase can be covered by increasing the production in the government hatcheries and nursery stations.

Silver carp. The demand for silver carp seed increased greatly during the last five years. The fish is gaining acceptance in the market and was rediscovered by fish farmers as an excellent candidate for cage aquaculture. This fish is very attractive to farmers mainly because of its feeding behavior. Silver carps are grown in cages in the fertile waters of the Nile at the end of the western branch of the Delta. Silver carp grows to a large size without the need for artificial feeding, thereby greatly reducing production cost. In 2004, government hatcheries produced about 12.6 million fingerlings (2-3 g) of silver carp. The estimated production of silver carp fingerlings by private sector hatcheries was 33.2 million in 2004 (GAFRD, 2005). The demand is not expected to increase greatly as the maximum allowed number of cages had been reached.

Bighead carp. Although bighead carp was introduced to Egypt at the same time as with grass and silver carps, this fish is not yet well-known to the growers. Seed production of this species occurs in government hatcheries and they are sold principally to government farms. Data available from official documents indicated that the total production of bighead carp seed was 1.3 million fry, all produced by government hatcheries. Harvest of this fish is usually mixed with silver carp and the real demand for the seed of this species has not been evaluated.

Black carp. The success of biological control of aquatic weeds by grass carp encouraged the GAFRD to import black carps for the control of the snail intermediate host of *Schistosomiasis*, a historically widespread parasitic disease in Egypt. Brood fish were imported from Eastern Europe and fry and fingerlings were produced successfully. The production of seed of this species was reduced to a minimum as the Ministry of Health, the main target government client, was not yet convinced of the suitability of this fish to substitute the presently used chemicals to control aquatic snails. Negotiation is still going on, however, the expected agreement with the Ministry of Health will create a demand of about 10-15 million fingerlings annually which can be covered by the present capacity of the government hatcheries.

Freshwater prawn. Freshwater prawn was introduced to Egypt from Southeast Asia more than two decades ago. Seed were produced on a commercial scale in three government hatcheries during the late 1980s until the mid-1990s. Freshwater prawn was grown in many private and government farms but it was faced by marketing problems resulting from the limited acceptance by consumers. Broodstocks are still kept in two hatcheries but the reduced demand for seed resulted in reducing seed production to a few thousand post-larvae annually.

African catfish. The African catfish is a native fish in all the freshwater bodies of Egypt. The species is not commonly appreciated in the local market. In aquaculture, catfish is used to control of tilapia breeding in ponds. Although artificial breeding of catfish was successful on an experimental scale, catfish stocked in ponds are small juveniles collected from the wild. There is no data on the numbers of collected seed or the demand for it.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

There are ten large freshwater fish government hatcheries, five of which are located in the Delta and five located along the Nile in Upper Egypt. The recorded number of commercial private sector hatcheries was 480 in 2004 (GAFRD, 2005) with an estimated total number of 540 hatcheries most of which are located in the delta. Many of the fish farms have a hatchery unit with production dedicated to cover the seed requirements of the farm especially for tilapia. Most of these hatcheries have hapas in ponds; some may have hapas under a green house. The number and production of such units are not exactly known.

Carp hatcheries

The government hatcheries were mainly designed for mass production of different species of carp. Carp hatcheries are composed of three main units, namely: (1) broodstock ponds are earthen ponds each with 400-1 000 m^2 area and about 1.25-1.5 m deep, (2) indoor facilities consist of a building including a large hall with circular broodtanks, aquaria and hatching jars or containers, a laboratory, filtration and water quality control facilities, boilers and staff rooms and (3) nursery facilities include suitable numbers of earthen ponds each measuring 1-1.5 acres and 1.25-1.5 m deep.

Different carp species introduced to Egypt cannot spawn naturally in the local environment. Spawning occurs through induced breeding by injecting the ripe brood fish by locally prepared common carp pituitary extract and stripping of females and males. Fertilization takes place when eggs and milt are mixed in a plastic vessel. Fertilized eggs are then incubated in hatching jars with running water from the bottom to the top. Hatched fry are collected and kept in glass aquaria and then moved to nursery ponds.

Tilapia hatcheries

Tilapia seed are produced in hatcheries using different techniques. The system applied in the majority of industrial hatcheries (private or government) depends on indoor breeding tank systems. This system was developed to facilitate production of tilapia seed one or two months earlier than that produced in outdoor systems. In this system, broodstock are kept in small- to medium-size breeding tanks (2-10 m^3). Nile tilapias belonging to 1+ year group are selected from harvest of fish farms in late autumn. The target of selection is usually the fast growers of the recruits. Selected tilapia are sexed, males and females separated and kept under observation in special tanks for a period of three weeks. Diseased or weak fish are discarded. Broodfish are kept for two to three breeding seasons only and are substituted with younger brood either from the production of the hatchery or from fish farms. In late winter, broodfish are mixed using a ratio of three to four females to one male in each square meter of the breeding tanks. Water temperature is raised to the optimum breeding temperature (26 °C-29 °C) by boilers. Eggs of incubated females are collected with handnets, transferred to hatching jars where eggs are kept until hatching and yolk sac absorption. Fry are then transferred to nursery tanks (small shallow tanks each of 2-3 square meters size) and either fed with normal feed or hormone-treated feed for sex reversal to produce an all male stock. Hormone treatment extends to four weeks afterwhich fry are moved to outdoor nursery tanks (10-20 m^3) in green houses or to nursery ponds (0.25 to one acre). Mixed-sex fry are transferred to outdoor nursery tanks or ponds after three weeks. Depending on season and demands, seed can be sold as fry (0.5-1 g) or as fingerlings (3-5 g). Seed produced in such system are usually available at the beginning of the grow-out season of fish farming in late March or early April.

The second most common system of tilapia seed production is the use of hapas in ponds. This system was introduced from Asia and developed locally to suit local conditions. The hapa system is climate dependent, production starts during the natural breeding season of tilapia when water temperature reaches the levels required for breeding in mid-April until September.

Ponds used for such system varies in area ranging from 0.5-2 acres with a water depth of 1-1.25 m. Hapas made of 1 mm mesh netting material of a 2 × 2 × 0.75 m dimension are fixed in earthen ponds using four wooden poles, one at each corner. Hapas are usually arranged in parallel rows covering most of the water area of the ponds and are kept about 0.25 m above the bottom; broodfish are kept in water with a depth of 50-75 cm. In many commercial units, wooden catwalks are fixed on strong wooden poles that are constructed between the rows of hapas for easy access to each hapa unit.

At the beginning of the breeding season, selected brood fish are stocked in hapas using a ration of three to four females with one male per square meter. Hapas are examined for the presence of free swimming fry which are collected by scoop nets. Collected fry are usually stocked for nursery rearing in earthen ponds. Upon reaching market size, fingerlings are harvested by draining these ponds usually to a catch pond.

A modification of this system is presently expanding in the country for early season fry production. In this system, hapas are fixed in smaller ponds (500-1 000 m^2) or concrete tanks inside a green house. The increase in water temperature in green houses facilitates spawning in tilapia at least one month before the natural breeding season.

SEED MANAGEMENT

Carp

Common carp was first introduced to Egypt in 1936. Few hundred mirror carps were imported from Eastern Europe and kept in freshwater aquaculture research facilities of the Institute of Oceanographic and Fisheries (IOF) near Cairo. The species was successfully reproduced in captivity and the genetic line was kept as the original broodfish until the 1960s when some fish were imported from Russia and Hungary. It is not known if the newly imported fish were mixed with the offspring of the fish introduced in the 1930s. Seed produced from these fish were used by the first modern commercial fish farm in the mid-1960s. No other introduction of carp occurred until the establishment of the first two government hatcheries in 1978, when 400 broodfish were imported from East Germany. With the expansion in building commercial carp hatcheries by the government, more common carp broodstock (about 800 fish) were imported from 1984 to 1986 from Hungary. After some decades, all these fish and the offsprings of the broodstocks introduced earlier were unintentionally mixed together through the aquaculture production process. This occurred as government hatcheries regularly select fish for new broodstock lines from the harvest of the fish farms. Private sector hatcheries did not import any broodfish and built their own stocks from the harvest of the local farms. This is an indication that common carp is suffering from inbreeding which resulted in some problems with growth performance and morphology (individuals covered with scales characteristic of mirror carp). Presently, GAFRD is working on importing 10 000 to 15 000 common carp fry from Viet Nam and China to mix the local strains with new blood and in order to create a new line of broodstocks. The delay in the introduction of new carp strains was a result of legislation problems as introduction of alien species was restricted by a new law.

The three major Chinese carps (grass carp, silver carp and bighead carp) were first introduced from Hungary to Egypt by GAFRD in the mid-1980s. Black carp was introduced mainly as few brood fish and few thousand fingerlings during the mid- and late-1990s from Hungary, Israel and Thailand by GAFRD. In the late 1980s, few hundred brood fish and about 3 000 to 4 000 fingerlings of the major Chinese carps were imported from China. The fingerlings were grown in hatcheries to broodstock and mixed with those previously imported from Hungary. The performance of the three Chinese carps is still acceptable. The performance of black carp is not yet fully examined as only few thousands are produced each year and distributed in the canals of the government fish farms for snail control.

Carp hatcheries are very important to the country to supply the required seed for two major national projects [NAWCP and fish culture in rice fields (FCRF)] and the expected future project for the biological control of schistosomiasis In these projects, the production of marketable table fish is not the main target but rather the improvement of the environment and public health. As a result, broodfish in these hatcheries are kept under restrictive disease control and management programs. Broodfish are kept in isolated ponds with no access to other fish or unauthorized persons. Fish are supplied with specially formulated 30 percent protein-rich manufactured feed and fresh clover to grass carp. Fish collected from brood ponds for induced spawning are usually sedated with tricaine methane sulfonate (MS 222) and kept in indoor facilities under optimum conditions until spawning. After spawning fish are injected with a prophylactic dose of a broad-spectrum antibiotic and treated from any fishing and handling trauma before they are moved to special ponds for spent fish.

All indoor facilities including incubators, tanks and aquaria are treated with strong antiseptic before start of the season. These facilities are also treated with antiseptic after each batch to avoid fungal infection.

Nursery ponds are usually prepared and treated just before the start of the season. Ponds are sun-dried and weeds are removed; dykes and bottom are prepared before soil fertilization program is applied. Water of prepared ponds are then treated with organo-phosphorous pesticides to kill aquatic insects, predatory larvae and crustaceans. Hatched fry are then stocked using a density of 0.5-1 million/acre. Survival rates from hatched larvae to fingerlings vary from 50 to 80 percent depending on management, climate, design of ponds and quality of broodfish. Nursing fry depend on natural feed until 0.3-0.5 g afterwhich grind feeds are given until they reach 1-2 g.

Tilapia

Production of tilapia seed in commercial hatcheries is a new practice in Egypt. Being a native fish that propagates naturally in all fresh and brackish water bodies of Egypt; commercial production of tilapia seed in specially designed establishments was not getting enough attention. It was not before the expansion of the modified semi-intensive and intensive pond aquaculture in the mid-1990s when the first commercial tilapia hatchery was established. The production of this native fish from aquaculture was no more 10-20 percent of the harvest during the 1970s and 1980s. During that time it was very hard for fish farmers to find tilapia fingerlings or fry in the market. All production depend totally on collection of smaller tilapia, fingerlings and fry from the harvest of fishponds and stocking them in nursery ponds until the second grow-out season. Tilapia collected in this way were usually a mixture of the four native species (*O. niloticus, O. aureus, Sarotherodon galilaeus* and *Tilapia zilli*) with at least 50 percent of the population from the inferior *T. zilli* and *S. galilaeus*.

Broodstocks are usually selected from harvests from grow-out farms and hatcheries with grow-out farms. It is usually the fast growers that are picked and kept for broodstock development. In some hatcheries where programs of production of super male broodfish are carried out, the valuable broodfish are well protected. The GIFT tilapia strain produced in research stations are not yet used on commercial scales. Collected eggs or fry are treated with similar techniques as those applied in carp. Nursery operations are carried out in earthen ponds or in greenhouse tanks but ponds are not usually treated with chemicals as in case of carp.

As tilapia breeding season occurs at the same time as the grow-out season, fry produced in summer and autumn are usually grown to fingerlings and kept for over-wintering. Over-wintering is carried out either in the fish farms or in nursery ponds (1-2 acres) in hatcheries. Ponds selected for over-wintering are usually deeper to ensure a water column of 1.75-2 m; this can protect over-wintering seed from sharp temperature fluctuations occurring in the surface water. In Egypt, surface water temperature in the sunny winter days may reach 19 °C to 20 °C followed by a sharp drop in temperature after sunset; at dawn, surface water temperature may reach 7 °C to 10 °C. Under those conditions, fish kept in shallow ponds suffer great stress and large mortalities can be expected. Surviving seed usually suffer from fungal infection and other over-wintering diseases. For economic and logistic reasons, over-wintered tilapia are usually kept in very high densities that result in low growth rates. On the other hand, over-wintered seed usually become sexually mature at the beginning of the grow-out season which is usually associated with uncontrolled propagation in ponds if mixed-sex tilapia is used.

SEED QUALITY

Except for restrictions on marketing or distributing diseased fish seed or seed that are known to carry a disease causing organisms, there is no written orders or legislations related to seed quality. On the other hand, it is the market preference of the product that has the greatest effect. Fish farmers avoid dealing with hatcheries with a known history of inferior quality seed in terms of growth performance, mortality rates, deformities and others. The very fast expansion of aquaculture in general and the uncontrolled increase in the number of hatcheries in a very short period scattered in rural areas was far beyond the capacity of the government extension personnel doing follow-up program. Although it is against the law to establish an aquaculture facility (a farm, cage or hatchery) without a licence from the GAFRD, the current number of licensed hatcheries is no more than 10 percent of the operating units. It is only the government hatcheries and the large commercial private hatcheries that are covered by the quality control follow-up program. Under this program, GAFRD veterinary directorate staff regularly inspect broodstock and seed for disease as well as application of the hygienic measures.

The survival rates from egg to marketed fish are not really known in tilapia produced by many private hatcheries. On the other hand, the recorded mortality rates of tilapia in an extensive study extended to three seasons in governmental and private fish farms (GAFRD, 2002) from fingerlings to market size was 2-5 percent. The same study indicated that losses due to mortalities in nursery (fry-fingerlings) varies greatly between 7-35 percent and mortality in fingerlings was highest during over-wintering.

Seed of common carps produced in many of the government and private hatcheries are having problems with deformities and poor growth performance. This can be due to the long-term inbreeding of the species.

SEED MARKETING

Freshwater fish seed are sold without any limitation on the numbers to farmers from both government and private hatcheries. Prices are fixed in the government hatcheries and are decided by a committee of experts through a decree issued by the GAFRD chairman. Government prices provide guidance to private hatcheries but pricing is totally flexible depending on the supply and demand but it is usually kept lower than the government price. Government prices may change for some species or all species depending on the development strategy.

Tilapia

In most cases, farmers purchase directly from hatcheries. It is a direct and simple procedure where farmers pay the price and carry the purchased goods with no written rules. In this case, farmers usually inspect and examine random samples of seed to check size and quality. Fish farmers have their own choice of hatcheries to purchase seed; close distance of hatcheries for grow-out farms offer an added advantage to sellers. Among the private sector establishments, if a large number of seed are purchased, a verbal or sometimes a written agreement is organized and the hatchery usually delivers the seed to the farm site. This may be in one or several successive days as agreed between the two parties. In this case, hatchery operator covers the cost of losses due to mortalities during handling and transport. Seed are inspected on delivery and numbers are counted. Farmers can refuse any delivery if the size or the quality or numbers do not conform to what has been agreed upon. The refused good can be sent back to the hatchery or an agreement can be reached through a discount offer or others.

In some cases, hatcheries may deliver seed and collect the price after the harvest of the crop from the farm.

Seed prepared for sale are harvested from nursery ponds and moved to indoor marketing tanks or outdoor hapas. Seed in marketing tanks or *hapas* are usually kept in high densities and are starved two to three days before sale. Seed are counted by filling a small handnet, counting the number of fry or fingerlings from three full nets and getting the average count. Counting of the purchased seed is carried out by calculating the number of handnets multiplied by the average number of seed in each net.

Price is usually per one thousand seed and it varies according to sizes which are divided into three categories: (i) fry, from 0.5-1 g, (ii) fingerlings, from 3-5 g and (iii) juveniles, 15-25 g. Price of tilapia seed also differs greatly depending on the time of the year. Over-wintered fingerlings are sold in March for prices that can be seven to ten times its price in October and prices of fry also decrease gradually from April to November.

If small numbers are purchased, seed are packed in plastic bags filled with one quarter of water, inflated with compressed oxygen and transported by cars or pick-up trucks. Bags and oxygen are supplied by the hatchery operators. Other farmers use plastic barrels or small fiberglass or metal tanks on pick-up trucks with compressors or air cylinders. If large numbers are sold, special live fish transport trucks are used. Seed are usually transported either very early in the morning or after sunset to avoid the heat of the sun. In many cases seed are sedated during transport by adding ice to transport water.

Carp

Carp seed are sold to the private sector as in the case of tilapia. In case of large contracts such as those of the NAWCP (54.6 million fingerlings) and FCRF (about 100 million fingerlings), seed are purchased through a pre-negotiated contract signed between the GAFRD and the relevant party. The specifications of seed, numbers and delivery conditions are described in the contract. Representatives from buying parties observe the counting of seed/delivery at every hatchery. The procedure involves several paper works and strict inspections for sizes, quality, species, health conditions and counting. A fleet of more than 30 trucks each with six to eight insulated fiberglass tanks supplied by compressed air are used for transporting and distributing seed over a period of four to five months, 24 hrs and 7 days/week work.

SEED INDUSTRY

As stated before, the activity of seed production for aquaculture involves a wide range of production facilities/establishments that varies from a simple unit designed to supply a single farm to highly sophisticated industrial hatcheries with an annual production of 50-70 million fingerlings per year.

The staff of government hatcheries consist of both of males and females with no restrictions except in the pond fishing and service labor sectors where employees are all men. Women work in hatcheries as engineers, veterinarians, biologists and in administration and are paid equal salaries and have the same duties as men. It is also not uncommon to find female staff in the commercial private hatcheries. In the smaller units where business is a family-operated, all members of the family work together. However, the business of seed production is generally dominated by males.

SUPPORT SERVICES

GAFRD is carrying out extension programs on fry handling and transport. The program targets private fish farmers and young graduates recruited to work in the field of aquaculture. The program was dedicated originally to reduce losses in delicate marine species especially mullets, but it also covers the different aspects of handling larvae, fry and fingerlings. GAFRD also cooperates with the Ministry of Agriculture extension services in the program of integrated aquaculture in rice fields which involve many details on handling of fry. GAFRD also issues a number of extension publications for distribution among farmers; many of which deals with subjects related to seed production and management. Different GAFRD hatcheries and farms found virtually in all areas of aquaculture were established to be extension and production units. GAFRD organizes local and international training courses in applied aquaculture. Other centers, like the Fish Research Center (an Agriculture Research Center unit) and the World Fish Center in Egypt also organize local and international training courses in aquaculture. Research institutes, centers and the Departments of Applied Research of GAFRD, the National Institute of Oceanographic and Fisheries and many universities carry out programs of technology transfer.

SEED CERTIFICATION

There are two kinds of certificates issued, first is the Health Certificate which is issued by the General Authority for Veterinary Services (GAVS) and the Certificate of Origin issued by GAFRD. The health certificate is issued for batches of seed approved as free of contagious diseases and pathogens or parasite or its infectious stages. The procedure involves a series of detailed inspections and laboratory examinations. The certificate of origin defines the source of the seed, brood, establishment and date of production. Both certificates are issued if requested by the buyer especially for export purposes.

LEGAL AND POLICY FRAMEWORKS

Aquaculture activities are regulated basically by Law No. 124/1983 and Presidential Decree No. 190 authorizing GAFRD to issue and implement the acts and decrees organizing aquaculture. Articles 47-51 of the law and Article 38 of Chapter 6 of the Execution List of the same law are aquaculture-related articles.

Presidential Decree Nos. 190 in 1983 and 465 in 1983 define the land and water bodies that the GAFRD can develop and where application of fisheries and fish farming laws will be supervised. The decrees gave authority to GAFRD to lease out wetlands and all lands that are within 200 meters distance of sea and lakeshores. The Fisheries and Fish Farming Organizing Law No. 124 in 1983, Section 3, Articles 47 to 51 includes the different requirements to construct fish farms.

Article 48 of the law states that it is forbidden to construct a fish farm except on wasteland, which is not suitable for agriculture and agriculture drainage or lake waters are the only source of water for these farms and it is strictly forbidden to use irrigation water. Exempt from this rule are government hatcheries, water volume provided to such hatcheries is decided by arrangement between GAFRD and the Ministry of Irrigation (MoI).

Article 48 of Law 124/83 stipulates that no fish farm or hatchery construction will be allowed without a license issued by GAFRD. This requires an approval from the MoI who defines the water volume allowed for, the source, size of inflow sluice and the method of draining.

Item No. 38 of the Executive List of Law 124 defines the required steps for public-land lease and licensing for fish farming such as:

1. The applicant should submit a license application to GAFRD office with the following forms attached:
   - A site map (scale 1/2500) with the proposed farm and its area sited on it.
   - Defining the source of water and the drain
   - A certificate from the area agriculture office stating that the land applied for licensing is wasteland and not suitable for agriculture
   - Detailed design and layout maps for all constructions and excavations.

2. If GAFRD approves the site and design, a copy of the application with site maps, design maps, proposed irrigation source, drainage outlet and specifications of irrigation and draining pumping stations (if required) is to be submitted to the MoI for approval.

When the MoI approves the application, the applicant should apply for the construction works according to the design maps approved by MoI and under the supervision of the irrigation engineers.

In the second chapter of the Law of Fisheries and Aquaculture Organization No. 124/83, Article 17 states that it is not allowed to use or introduce alien fish, eggs or larvae into Egypt for any reason except after obtaining a written permit from the GAFRD and after technical consultation with the National Institute of Oceanographic and Fisheries (NIOF).

ECONOMICS

Although the growing development in aquaculture has created an increased demand for freshwater fish seed, fast development in seed production facilities is covering the present demands. Tilapia, the top cultured species, is a good indicator of the status of supply and demand. However, the overlap between breeding and grow-out seasons has created problems in supply and demand. Accordingly, the demand and prices differ greatly during the year. It was observed that there is usually a shortage in the availability of seed at the beginning of the grow-out season. This is due to the fact that production from indoor tilapia hatcheries and the harvest of over-wintered tilapia are far from covering the demand. Prices usually become higher and buyers may not be very strict in counting the numbers (which could also be a factor in increasing the price), size or the quality of seed. This condition may last during the first six weeks of the season (between 15th of March and 1st of May) where prices start to decline as demand decreases and production increases. The lowest price is encountered during late September when production suffer great losses of fry during over-wintering. Hatcheries which utilize outdoor systems (hapas, etc.) are usually the suppliers of cheaper seed. Nevertheless, they can still have a good profit margin.

Of the different carp species, only silver carp seed used to have increasing demand. Demand is presently lower than supply as many hatcheries had slowed down their culture activities. This had not strongly affected the returns of the producers as production of silver carp is a side activity in tilapia. Prices of silver carp decreased gradually with the increase in demand. Private hatcheries have much more flexibility in pricing. With this advantage, private hatcheries were able to cope with the changes resulting from the increase in supply. This was not the case in government hatcheries where prices are fixed. This had resulted in sharp decrease of sales of silver carp from government hatcheries. On the other hand, government hatcheries have the advantage of being able to take large contracts with national projects and thus gain good profits.

STAKEHOLDERS

GAFRD is the government authority in charge of fisheries and aquaculture development in the country. GAFRD's main mandate is planning, coordination, extension, training and regulating activities of fish production (capture and culture). GAFRD is under the Ministry of Agriculture and Land Reclamation which is responsible for fisheries policy and strategy as a part of the development strategy of the ministry.

There are a large number of government research institutions and university departments specialized in research and studies of fisheries subjects in Egypt (Table 7.9.1). The kind of research, its levels and the degree of specialty varies between applied research or basic science and theories as described in Table 7.9.1 below.

Subjects of research are usually dealing with matters that can help improve production efficiency and solve production problems. Those subjects are decided

TABLE 7.9.1
Government research institutions and university departments specialized in research and studies of fisheries subjects in Egypt

University	College/Institute	Degree
Cairo, Ein Shams, Alexandria, Suez Canal, El Azhar, El Mansura, Tanta, Asuit, Zagazig and Upper Egypt.	Science	B. Sc. M Sc Ph D Marine biology, aquatic science, oceanography and hydrobiology
Cairo, Ein Shams, Alexandria, Suez Canal, El Azhar, El Mansura, Tanta, Asuit, Zagazig, El Fayum and Aswan.	Agriculture	Fish husbandry, production, genetics, feeding, aquaculture
Cairo, Alexandria, Suez Canal, Asuit and Zagazig	Veterinary medicine	Fish disease, food hygiene, aquaculture hygiene
Academy of Scientific Research	National Institute for Oceanographic and Fishery	Research only
Agriculture Research Center	Aquaculture Research Center	Research only

usually through direct contact between the research institutions and the producers or GAFRD or both or the Egyptian Aquaculture Society. Conferences, workshops and meetings are frequently held and producers are invited to discuss production problems with scientists.

Depending on the kind of research, methods and requirements, on-farm participatory research is very common both in the government pilot farms or hatcheries and in private enterprises (farms, hatcheries and feed mills). Results of work are usually published in scientific journals, but simplified forms are published in magazines and other publications of the local aquaculture societies. This can be the source of information for educated farmers, experts and technicians. GAFRD extension and training directorates are in charge of transferring information to traditional and uneducated farmers. GAFRD publishes a large number of simple extension papers for distribution to farmers. Free training courses are also offered by GAFRD on different subjects of aquaculture technology.

Although the major part of seed production is from private sector hatcheries, most of the producers are not organized in associations or cooperatives. The sector is still not fully organized and information on its organization is not as developed as its activity. As the exact number of production unit is not yet known, much effort and work should be carried out to study this sector especially those related to socio-economic aspects.

FUTURE PROSPECTS AND RECOMMENDATIONS

The GAFRD aquaculture development strategy which is part of the National Agriculture Development Strategy 1997-2017 (NADC, 1996) is targeting an annual production of 1 million tonnes of cultured fish by the year 2017. The target production for freshwater cultured species is 750 000 tonnes. This production is about 1.6x more than the production for 2004. This will require a large increase in freshwater seed production especially of tilapia.

NPAWD is planning to duplicate the number of required fingerlings by 2010, which is anticipated to be the maximum forecasted requirement for grass carp seed. The expected start of the National Project for Snail Control will require at least 20 million fingerlings by 2010.

Current trend in tilapia seed production goes in two parallel directions: the first is improving the indoor seed production and the second is developing better over-wintering techniques. Expansion the use of water recycling system is expected to reduce production cost (e.g. heating water) dramatically. Further development of over-wintering methods can reduce losses and thereby increase availability of seed. Such development is expected to encourage more investments in the field of fish seed production.

It is strongly recommended to improve the GAFRD licensing systems and the data collection techniques to cover the present gap resulting from the very fast increase in the number of hatcheries. This will greatly improve the implementation of regulations concerning quality control and extension.

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7.10 Freshwater fish seed resources in Ghana

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ABSTRACT

The present study has provided an evaluation of a basic and important requirement of the industry: hatcheries to produce fingerlings for farmers. The information presented in this paper consists of different aspects of the freshwater fish seed sector in Ghana such as resources and supply, production facilities and technology, management, quality, marketing, certification, economics and a brief description of the seed industry, legal and policy frameworks, support services and stakeholders.

A well-planned and coordinated action is required to solve the major constraints in the sector so that an orderly and rapid progress can be achieved. Among the recommendations include: (i) contract with some private companies with the capability to produce seed for the industry to be given incentives and contracts drawn up against the government and the farmers, (ii) there should be a re-focusing of research and training programmes at all levels to cater for the emerging needs, (iii) development of stocks better suited for local conditions and management to maintain genetic integrity in the light of potential fish transfers, (iv) efforts to ensure all-year round supply of quality fish seed, (v) inclusion of aquaculture objectives in national and international agricultural seed development funding programmes or projects and (vi) strengthening of technical manpower, provision of equipment and other logistics to facilitate hatchery production and delivery of fingerlings to farmers.

The study concluded that while it has become evident that producing seed is not a major problem, good management of the entire process will be a major challenge. The country needs to be updated with some of the latest technology in order to ensure that Ghana remains competitive and is able to produce the fast growing fish required in commercial aquaculture – and also to provide enough protein through aquaculture to meet the needs of the people.

INTRODUCTION

Aquaculture was introduced to much of the African continent five decades ago as an innovation that would improve the economic and nutritional well-being of producers. Fish ponds were foreseen as an ideal component of integrated farming systems, a fish crop grown using by-products from the home and farm. Indeed, from Kenya to Sierra Leone thousands of ponds were built, many only to be abandoned after a few years of meagre production.

Ghana is fairly well-endowed with a bountiful supply of water resources, but there is a high variability in the amount of available water within the year and over several years. The resources include rivers, streams, lakes, underground waters, lagoons, ponds and marshes. All these are dependent on precipitation.

The country is drained by three main surface water systems and the wetlands. The surface water systems are the Volta, Southwestern and Coastal systems. About 70 percent of the total land area of Ghana is drained by the Volta river system, which flows directly into the sea. The Volta Lake covers approximately 8 482 km^2 while the tributaries, which are seasonally flooded, total 1 684 km.

The areas outside the Volta drainage basin are the southwestern and the southern coastal basins, which are drained by a number of rivers and streams flowing directly into the sea. These cover 22 percent and 8 percent, respectively of the total areas of Ghana.

The wetlands (lagoons, salt marshes and mangrove swamps) are important components of the estuarine and coastal water systems in Ghana. There are about 89 coastal lagoons representing about 0.15 percent of the total land area of Ghana. They form an ecologically important unit providing feeding, roosting and nesting sites for thousands of migratory and resident birds. They also provide nesting and breeding sites for marine turtles and some marine fishes.

The water resources of Ghana are utilized for drinking water, fishing, irrigation agriculture, industrial, transport, power generation, livestock watering, salt production, recreation and for waste disposal purposes.

Ghana's freshwater fish fauna includes 28 families, 73 genera and 157 species. Of the species, 121 have been recorded from the Volta river system (Ghana portion) which drains more than two-thirds of the country. The Volta system in Ghana includes the Volta River, the Volta Lake and their tributaries such as rivers Oti, Pra, White Volta, Black Volta and Asukawkaw.

Outside the Volta system, the major inland water system includes the Densu, Ayensu, Okye, Kakum, Pra, Ankobra, Tano and Bia river basins and Lake Bosumtwi.

Nine species, namely: *Barbus subinensis* (Cyprinidae), *Irvinea voltae* (Schilbeidae), *Chrysichthys walkeri* (Claroteidae), *Synodontis arnoulti*, *S. macrophthalmus, S. velifer* (Mochokidae), *Limbachromis robertsi*, *Steatocranus irvinea* (Cichlidae) and *Aethiomastacembelus praensis* (Mastacembelidae) are endemic to freshwater systems of Ghana (Dankwa, Abban and Teugels, 1999).

According to Dankwa, Abban and Teugels (1999), 81 species are economically, of food importance and the species of culture importance include: *Heterotis niloticus* (Osteoglossidae), *Clarias gariepinus*, *Heterobranchus longifilis* (Claridae), *Chrysichthys nigrodigitatus* (Claroteidae), *Oreochromis niloticus* (Cichlidae) and *Lates niloticus* (Centropomidae).

Although a wide variety of fish have been tried in culture environments, the most common pond-raised fish in Ghana are tilapias (i.e. various fish from the genera *Oreochromis* and *Tilapia*) and catfishes (i.e. *Clarias, Heterobranchus* or their hybrid). Initially the catfish was a victim of the scarcity syndrome by requiring extraordinary hatchery techniques. Fortunately, today it is now possible to produce *Clarias* seed using farmer-friendly techniques in most farms.

In spite of this, tilapia remains the most frequently cultured fish and the fish about which more complaints are made with respect to small harvest size, stunting, etc. To attempt to address this problem, a variety of techniques have been used in Ghana to raise all-male tilapia which grow to a larger size (than females). Hand-sexing to obtain an all-male stock is the most user-friendly method. At some sites sex-reversal using methyltestosterone is employed, but this requires access to the hormone and slightly higher technology.

Other aquaculturists have sought to improve tilapia systems by improving the fish, either by identifying a new culture species or by genetically improving existing culture species.

SEED RESOURCES AND SUPPLY

Currently, there are about 2 000 fish farms throughout the country with over 1 000 fish farmers. These are made up of private farms, government fish farms and parastatal fish farms. These farms rely mostly on three sources for their fish seed, i.e. (a) from the wild where the farmers buy the fingerlings from fishermen, (b) some of these farms produce their own fingerlings, while (c) others rely on specialized farms for their stock of the fingerlings.

Local fishermen usually scoop up "clouds" of fry as they school in the shallows (wild) or remove young fry from their mother's mouth and sell to the farmers who in turn transfer them to some type of rearing container and feed them.

Majority of farmers use mixed-sex tilapia systems to generate their seed. That is, they use the customary techniques where the fish is harvested in the pond after six months, selling or eating the larger fish and keeping the smaller individuals for restocking. However, since extreme care is not taken, the individuals that are used for restocking are usually already sexually mature and begin reproducing almost immediately after stocking.

Another alternative method used is to hold broodfish in a net enclosure (*hapa)* where their spawning is closely monitored. In this way, the age of the fingerlings are well known and the risk of stocking sexually mature individuals is eliminated. The *hapas* are usually placed in the farmer's grow-out ponds. Now, some farmers are specializing in seed production where *in lieu* of *hapas*, small earthen ponds are being used.

Regardless of the technology chosen, it can be concluded that on-farm (private) production of fish seed is now feasible for the most common culture species. The most suitable culture fishes in Ghana should continue to be *O. niloticus*, *C. gariepinus* and *H. longifilis.*

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

A major constraint to successful aquaculture among producers is the poor and erratic quality of fish seed available for stocking. Local infrastructure, for aquaculture development and to support the primary beneficiaries, is limited in the country. Two major factors influence the cost of fish seed in the country. These are the high cost of production from government breeding centres and insufficient supply. Pilot fish hatcheries were established in Accra, Akosombo and Kumasi to make available to farmers seed fish species that are relatively easy to handle. The Accra Centre started operating in 1993 with a target of 180 000/yr but by 1999, it was producing a paltry 40 000. The Akosombo Centre started operating in 1996 with a target of 100 000 seed/yr. In 1999, it was producing 100 000 seed/ year and this success was attributed to the fact that it was being operated by a research institute with special interest in aquaculture. The Kumasi Centre became operational in 1997 with a target of 100 000 seed/yr and by 1999 it was producing only 4 000 seed/yr. The shortfalls in the production targets were attributed to predation, cannibalism, theft and storms killing brooders. Though the fish seed prices are subsidized by governments as they are produced at public facilities, the costs remains high and constitute a major operating cost for aquaculture development in the country.

In all these facilities, the fish of choice for production were *O. niloticus* and *C. gariepinus.* Others include the tilapias and *H. longifilis.*

However, if the seed production is contracted to private companies it will ensure more continuity in the seed production in Ghana. Large commercial farms like Crystal Lake Fish that have excess capacity to produce seed are being under utilized. They already have the infrastructure in place to produce over three million fry a month.

There is a need for dialogue by the government to put in place some sort of contract between the private sector and the government.

PLATE 7.10.1
Aquaculture facilities at Crystal Lake in Ghana

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SEED MANAGEMENT

The development of fish farming like all other ventures requires an appreciable investment in basic supporting services (Pillay, 1987). In this regard, while it is essential that centres be established to produce adequate and quality seed for timely delivery to farmers, the resources used in the process become specialized and complex. Therefore, economic, commercial and financial considerations are required to directly optimize investments in the sub-sector to the most efficient levels. In a study conducted in 1999 on the economic indicators for catfish hatcheries in Accra, Akosombo and Kumasi centres, the sensitivity analyses revealed that it was only the Akosombo Centre that gave a positive net present value (NPV) while the Accra and Kumasi centres gave negative NPV values which is indicative that the projects had low prospects of being viable. The poor economic indicators for the catfish hatcheries could be attributed mainly to:

1. the use of imported brine shrimp *Artemia* as the sole feed for the larval stages of the catfish;
2. the lack of appropriate equipment and facilities;
3. inadequate experience on the part of the hatchery operators in hatchery management practices.

Thus, while demonstrating the ability to adapt the techniques, the incorporation of additional distinct resources required in managing and putting the techniques to productive uses were not given due consideration. These resources include among others institutional structures and linkages, expertise and experience.

SEED QUALITY

The quality of fish seed, or young fish, is a vital element for successful aquaculture production. Simple pond fish culture by small-scale farmers is an activity often encouraged by national fisheries programmes or non-governmental organizations (NGOs). Such projects are intended to provide an additional source of food or income to the farm household. However, despite good intentions, such projects can often fail because, even on a very small scale, there is a great deal more involved than simply digging a hole and filling it with water and fish. Water quality is an essential consideration but the siting and shape of the pond are also important. But even if these factors are satisfactory, poor stock will result in poor yields.

Private companies that have established facilities can be given contracts to supply quality seed to would-be farmers.

One way of ensuring seed quality in the country is the proper management of aquatic animal diseases. Healthy seed ensure healthy stocks, hence, there is the need for more equipment and more clinics which can provide diagnostic facilities for farmers; good husbandry practices and continuous research on developing new methods which can help in the development of rapid diagnostic facilities.

Solving the problems of environmental impacts and sustainability of aquaculture farms require improved culture technologies and systems, good fish nutrition coupled with fish disease control and prevention. Also the genetic improvement of fish stock, maintenance of quality of seed and brooders and the improvement of the quality of fishery products are all husbandry practices that ensure the seed quality.

Already established farms with adequate resources can be given incentives to provide these services as they have the infrastructure in place.

SEED MARKETING

Seed marketing in any aquaculture venture is an important aspect of the enterprise. Seed produced must be sold to prospective farmers so that the business flows. In this regard, aggressive marketing strategies must be evolved by the seed producers to ensure that whatever investment they have made is recouped after the sales. In this regard, hatchery managers would have to strengthen linkages with their clients (farmers) and formulate realistic arrangements that would programme activities on both sides, such that pond harvesting and restocking are done on a regular basis. The channel of communication between the hatchery managers and the farmers must not be broken. This requires massive investment in infrastructure in the fields of roads and telecommunication which are currently lacking on most farms.

Hatchery workers should, in addition, have to recognize the fact that farmers occasionally encounter obstacles that pose difficulties to the marketing of food-size fish. One report indicated that when such obstacles are ameliorated and a reduction in the gap between fingerling availability and stocking periods is attained, the socio-economic viability of the hatchery output could easily be proven, thus, raising farmers' confidence in the hatchery activities and the acceptance of the output emphasize the need for the integration of financial, economic and social aspects of the venture.

SEED INDUSTRY

The fish seed industry is at the heart of the aquaculture development as a whole since it is a multidisciplinary science that includes biology, engineering, nutrition, feed technology, genetics and economics among others.

Much biotechnological research has been undertaken in Ghana in the field of aquaculture which aims at improving productivity per unit area of water, e.g. the sex reversal in the Nile tilapia *O. niloticus* using hormones to produce all-male tilapia fingerlings which grow faster and bigger that the female tilapias.

There is an urgent need to develop improved genetic seed, e.g. through advance selection and super-male breeding programmes.

The development of super-male production would have to be a government initiative.

Also, different techniques have been introduced into seed production of the various fishes farmed in the country. All these are aimed at increasing production of cultured fish.

Several training courses have been organized by scientists from the CSIR Water Research Institute's Aquaculture Research and Development Centre in Akosombo, the Fisheries Directorate and the FAO for fish farmers, extension officers, hatchery managers both in the public and government farms. These training sessions are helping to improve the seed base of the aquaculture industry in the country. Unfortunately, these initiatives are not up-to-date with the latest technology.

SUPPORT SERVICES

In the context of extension services, their organization and efficiency in most of the countries in the region are similar. Aquaculture and capture fisheries are placed in a single administration, usually the Department of Fisheries, which is within the Ministry of Agriculture, Rural Development, or Animal Production. However, in Ghana, aquaculture is directly under the Ministry of Fisheries.

The smooth and orderly development of fish farming in Ghana is hampered by a number of problems which include:

- weak extension services;
- inadequate supply of good quality fingerlings;
- lack of knowledge of fish pond management;
- high cost of pond construction;
- inadequate access to transport and equipment;
- lack of funds.

It is important to note that commercial fish farming is not very common in West Africa. The farmers have taken the risk to establish farms and have successfully established farms should be given incentives to act as advisors to new comers hoping to establish fish farms.

However, aquaculture is now considered an integral part of development activities that fall under the agriculture sector and a proposed Aquaculture Policy focusing on:

1. increased private sector productivity of all types of farm inputs (i.e. improved seed, breeding stocks, farm labour and management);
2. diversification of range of products and services; and
3. increased farm yields and improved access to marketing with a view to increasing farm incomes, contributing to poverty reduction and creating the image of aquaculture as a viable economic activity.

Due to the stratification of extension services staff, most of the work in the field is being undertaken by personnel with little training themselves. In Ghana, extension agents are recruited and trained on-the-job. On-the-job training is appropriate when facilities exist and are operational and also where senior staff or colleagues have the possibilities to perform their duties. At present, however, in the country, these conditions are lacking or are inadequate. Most extension services in Ghana are overstaffed relative to their present needs. This may be due to a concentration on the Training and Visit (T and V) System as the method to provide training and advice to farmers on their own farms.

Extension agents, particularly field workers, have limited opportunities for career advancement. This is due to the lack of training institutions in the country and to the lack of basic qualifications to pursue training outside the country. Even those who have the opportunity to train externally, such as the trainees of the UNDP/FAO project at Arac fail to further their career advancement because of the lack of follow-up by the institutions concerned, e.g. the failure to issue to the trainees with transcripts of their results and diplomas or certificates of qualification.

Three levels of core personnel required for aquaculture have been identified as senior aquaculturists, technicians and extension workers by UNDP and FAO. However, in Ghana, all three levels of trained personnel are lacking. In cases where senior aquaculturists exist their efficiency and work performance as supervisors of extension workers, who include technicians as well, are constrained by insufficient managerial and technical experience due to minimum exposure to the industry.

FAO organizes specialized in-region or in-country training courses through bilateral or international arrangements. In 1987, the Commonwealth Secretariat ran a 6-week fish culture course in Ghana for 20 technical officers. It also ran a Workshop on Aquaculture for Commonwealth Countries in the region in 1985 at Freetown, Sierra Leone.

SEED CERTIFICATION

This is a very important aspect of fish farming. Seed certification is critical to ensure healthy farms are established in the country. Unfortunately this does not exist in Ghana.

LEGAL AND POLICY FRAMEWORKS

The development of fisheries policy in Ghana has followed the development of the fishing industry. The legal basis for fisheries management in Ghana evolved from ordinances into laws and regulations. The law was continuously reformed to:

- contract with some private companies with the capability to produce seed for the industry to be given incentives and contracts drawn up against the government and the farmers;
- sustain and regulate the exploitation of national fishery resources;
- improve Ghana's access to international markets within the domain of the international fish trade;
- obtain optimum benefits for Ghanaians as owners of fish-related enterprises, as employers of the fishing industry, as consumers of fish products and as beneficiaries of foreign exchange earnings from fish trade;

- enhance investment in a private sector-driven industry; and
- improve the fishery management system.

Currently, the law on fisheries in Ghana has been consolidated into the Fisheries Act of 2002 (Act 625).

With regard to fish production, it is noteworthy to observe that the current Fisheries Act (2000) conforms to the relevant sections of the FAO Code of Conduct for Responsible Fisheries with particular emphasis on gear selectivity and an effective institutional framework. The Fisheries Act also gives legislative backing to the recently established Monitoring, Control and Surveillance Division of the Fisheries Directorate with clearly defined legal powers to regulate fishing operations. The Division draws strength from the inclusion of a number of security agencies, especially the Ghana Navy, in its surveillance operations.

The Directorate of Fisheries under the Ministry of Fisheries has also elaborated fishery management plans for marine and Lake Volta fisheries. A new set of fisheries regulations to give effect to the Fisheries Act 625 (2002) is under preparation.

ECONOMICS

There are both public and private fish breeding centres, in the country supposedly ostensibly to produce fingerlings and particularly for the tilapias. There are about 2000 fish farms/breeding centres in the country. However, due to lack of funds for operation and maintenance and adequately trained management, the production from many centres is extremely low.

This accounts for the irregular supply and high cost of fingerlings in the country. Also some of the fish ponds were not properly constructed hence they dry up in the dry seasons and only bounce back in the rainy season. Demands for fingerlings therefore fluctuate with the seasons and those farmers that rely on sales of fingerlings for their livelihood tend to lose income at certain times of the year. The fish seed sector has therefore been unable to prove its economic viability and is plagued with insufficient seed supply, inadequate management and lack of technical support.

Many farmers are also not able to prepare viable and bankable dossiers and local banks do not have adequate expertise to evaluate loans in the sector. In some cases, due to the weakness of the extension services, farmers are unaware of the existence of credit facilities.

INFORMATION OR KNOWLEDGE GAPS

There is also an associated need to strengthen institutional capacity to manage the fish seed sector and to expand the knowledge base in order to enable sustainable development policies and plans. There is a general recognition of the need for interdisciplinary and intersectoral approaches to development and resource management in aquaculture. Moreover, it is becoming increasingly clear that sustainable aquaculture development cannot be regulated solely by governments but they must also involve many interest groups at the national, regional and international levels, including new institutional arrangements and partnerships (consultative frameworks). This is being highlighted by ongoing structural change, namely privatization and the contraction of governments' role in development.

STAKEHOLDER

The various stakeholders involved in fish seed production includes government fish farms (Afife fish ponds and the Libga fish ponds), parastatal fish farms (WRI-Aquaculture Research and Development Centre, Akosombo and the Institute of Renewable Natural Resources fish farm, Kumasi) and private fish farms (Crystal Lake Fish Limited and Pacific Farms Ltd.).

The Council for Scientific and Industrial Research (CSIR) Water Research Institute (WRI) organized courses for NGO's (Ghana Rural Reconstruction Movement and the

African Centre for Human Development) involved in fish farming and cooperative fish farming groups from the Akwapim North and the Kadjebi Districts to disseminate the practice of all-male tilapia culture in ponds. There were lessons in the rudiments of fish farming, pond preparation, stocking, fertilization, feeding and harvesting.

Private fish farms in all the regions in the country are now upgrading their knowledge in fish seed production in order to meet the demands for fingerlings on their farms and for sale to smaller farms.

Larger hatcheries such as the WRI-Aquaculture Research and Development Centre at Akosombo develop and produce new varieties and strains of fish seed for sale and distribution to other farms.

Fish Farmers Associations are now springing up in the districts and in the regions but these splinter groups are yet to come under one umbrella to champion the cause of fish farmers in the country.

The WRI-Aquaculture Research and Development Centre, Akosombo, the Institute of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, The Fisheries Department of the Ministry of Fisheries and other research Institutes are collaborating to provide the legal and policy framework for the fish farming and seed industry and thereby eliminate all bottlenecks that hamper the smooth functioning of the sector.

Several donor agencies have been collaborating with research institutions in Ghana. Notable among them are FAO, German Development Organization (GTZ), International Centre for Living Aquatic Resources Management (ICLARM), Danida, International Development Research Center (IDRC) and many others. The fields of collaboration include organizing workshops for both scientists and farmers, field demonstrations, funding of research activities and provision of grants for training.

FUTURE PROSPECTS AND RECOMMENDATIONS

The development of aquaculture in Ghana rests on a well planned and co-ordinated action to solve the major constraints to the orderly and rapid progress of the industry. Although the technical aspects of aquaculture have been and continue to be discussed by experts, planning of the industry in the country has not received more than a cursory attention.

The present study has provided an evaluation of a basic and important requirement of the industry: hatcheries to produce fingerlings for farmers. It has been shown that, in all except one, the activities of pilot hatcheries were not viable.

To redirect the fish seed industry in Ghana, the following recommendations are provided:

- contract with some private companies with the capability to produce seed for the industry to be given incentives and contracts drawn up against the government and the farmers
- there should be a re-focusing of research and training programmes at all levels to cater for the emerging needs
- development of stocks better suited for local conditions and management to maintain genetic integrity in the light of potential fish transfers
- efforts to ensure all-year round supply of quality fish seed
- inclusion of aquaculture objectives in national and international agricultural seed development funding programmes or projects and
- strengthening of technical manpower, provision of equipment and other logistics to facilitate hatchery production and delivery of fingerlings to farmers.

CONCLUSIONS

It has become evident that producing seed is not a major problem in Ghana but good management of the entire process has become very challenging. There is a need for the country to become up-to-date with some of the latest technology. This will in the long run ensure that Ghana remains competitive and is able to produce the fast growing fish required in commercial aquaculture – and also provide enough protein through aquaculture to meet the needs of the people.

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7.11 Freshwater fish seed resources in India

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ABSTRACT

India is the sixth largest producer of fish in the world (6.41 million tonnes) and second in world aquaculture production (2.22 million tonnes). About 95 percent of India's aquaculture production comes from inland aquaculture. Of late, inland fish production has surpassed marine fish production. India produces about 17 000 million fry annually. Among the different states, West Bengal is ranked first in inland fish production as well as fish seed production (8 400 million fry).

Indian freshwater aquaculture is based mainly on polyculture of Indian major carps, such as catla, rohu and mrigal and three exotic carps, namely, silver carp, grass carp and common carp. Fish seed destined for aquaculture are obtained from three sources, i.e. rivers, bundhs and hatcheries. During the period from 1964 to 1965, 92 percent of the country's fish seed were obtained from rivers, while in the 1980s, bundhs contributed to 63 percent of the total seed source.

Rivers are traditional sources of fish seed for aquaculture. The Ganga River system is the largest river system and is the home to Indian major carps. Fertilized eggs, spawn, fry and fingerlings constitute riverine seed. Spawn/fry collection is undertaken in few States. Among coldwater fish seed resources, trouts (exotic) and mahseers are found in the Himalayan region and the Peninsular Indian rivers that originate in the Western Ghats.

Presently, hatcheries account for 95 percent of seed source. A steady increase in fish seed production from the 1980s can be attributed to the use of Chinese type carp hatchery technology and the application of ready-to-use spawning agents. There are more than 420 carp hatcheries, producing about 34 292 million spawns (17 000 million fry). The Chinese type carp hatchery is most widely used, followed by the jar hatchery. Ovaprim is the most popular spawning agent and ovatide is the next best. Fish pituitary extract also finds use in some states. Carp seed are also produced in bundhs by simulating riverine conditions during monsoon. Of the two types, dry bundh breeding is more widely practiced as it leads to the production of pure seed and is more economical.

The source of broodfish is mainly seed farms or grow-out farms. Broodfish is normally fed with the traditional feed of rice bran and oilcake as well as special feed consisting of locally available ingredients, with fishmeal being an essential component. Carp seed rearing is carried out in two stages: nursery and rearing, where the survival of

fry is only 30 percent and 50 percent, respectively. Larval feeds used are mostly rice bran and oilcake. Natural food is promoted through manuring.

Availability of quality fish seed at the right time is important for sustainable aquaculture. The causes of poor quality fish seed are: (i) poor pond hygiene, (ii) presence of pests, (iii) inbreeding, (iv) poor management of broodfish and seed, (v) transportation stress, (vi) mixed breeding and (vii) diseases and parasites.

Until the 1980s, the Fish Seed Syndicate in Kolkata was the only source of carp seed. Thereafter, several states started producing seed and some states are now self-sufficient in seed production. There is no organized fish seed trade in India. However, the best seed trade exists in Kolkata. Carp seed production in hatcheries and bundhs are found to be profitable. No definite seed certification exists in the country. Although the Indian Fisheries Act exists, it is not possible to enforce/implement policy matters.

The traditional method of transportation of fish seed is the open system, which uses earthen/aluminium/galvanized iron or tin containers for seed transportation. The closed method of transportation of fish seed in plastic bags with oxygen and water is more widespread. Broodfish are transported in open FRP tanks/plastic pools/tarpaulins mounted in trucks. Hatchery production of sterile common carp fry is now receiving increased attention.

INTRODUCTION

India is the sixth largest producer of fish (6.4 million tonnes) in the world and second in inland fish production. The fisheries sector contributes Indian Rupiah (Rs.) 19.56 billion to the national income which is 1.2 percent of the total Gross Domestic Product (GDP) and 4.2 percent of the agricultural GDP of India (Ayyappan and Biradar, 2004). India, with a total aquaculture production of about 2.22 million tonnes (5.2 percent) is ranked second in world aquaculture production, next only to China which occupies the first place with a staggering production of 27.76 million tonnes (68 percent) from aquaculture (Crespi, 2004). Carps constitute the bulk of the world aquaculture production, with silver carp, grass carp and common carp occupying third, fourth and fifth places, respectively (Crespi, 2004). The widely cultivated Indian major carps, namely, *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* occupies thirteenth, fourteenth and sixteenth place, with 0.57, 0.55 and 0.52 million tonnes, respectively (Crespi, 2002). About 95 percent of India's aquaculture production has been reported through inland aquaculture and per capita consumption of fish also increased from 5 kg to 16 kg during the last 50 years (Ayyappan and Biradar, 2004). For the year 2003-2004, inland fish production has been estimated to be 3.46 million tonnes, as against the marine fish production of 2.94 million tonnes. Over the years, the proportion of inland fish production showed an increase, while the marine fish production showed a decline (Table 7.11.1). A viable technology for freshwater fish culture in rural India which emerged over the years significantly contributed to an increase in the country's inland fish production (Figure 7.11.1).

TABLE 7.11.1
Trends in fish production of India (million tonnes)

Year	Marine	Inland	Total	Percentage of inland fish
1996-1997	3.00	2.10	5.10	41.20
1997-1998	2.95	2.44	5.39	45.30
1999-2000	2.90	2.70	5.60	48.20
2000-2001	2.78	2.84	5.63	50.40
2001-2002	2.83	3.13	5.96	52.50
2002-2003	2.99	3.10	6.09	50.90
2003-2004	2.94	3.46	6.40	53.60

Source: *Fishing Chimes* 24(7): 31

FIGURE 7.11.1
Proportion of inland fish to total fish production

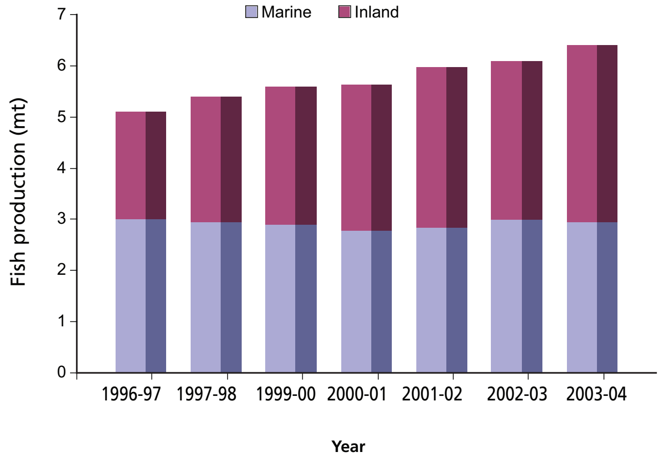


FIGURE 7.11.2
Map of India showing different states and union territories and neighboring countries

Source : www.indiastat.com

Among the different states and Union territories (Figure 7.11.2), West Bengal is ranked first in freshwater fish seed production (Table 7.11.2). The State of Andhra Pradesh, which witnessed a revolution in carp culture and seed production during the 1980s, is placed third in fish seed production (Table 7.11.2). The data (for the year

1995 to 1996) showed that in many of the states of the country, there is a deficit of fish seed (to an estimate of nearly 6 000 million fry), with the exception of the States of West Bengal, Assam and Himachal Pradesh, which have a surplus of fish seed (Table 7.11.2).

India has vast freshwater resources in the form of ponds, tanks, lakes, reservoirs, rivers, *bheels*, canals, swamps, marshes, etc. Ponds and tanks account for about 2.25 million ha. Lakes comprise 26 million ha, while reservoirs (major and medium) have spread over an area of 3.0 million ha. Rivers have a total length of more than 27 000 km. Canals and channels and their network run up to 112 000 km. *Bheels* (water bodies formed due to the serpentine course of a flooded river), marshes and swamps constitute 7.9 million ha. Hence, India is one of the richest in terms of freshwater resources.

Carps are the most widely cultured freshwater fish in India. Mixed species culture is most common where the three species of Indian major carps (IMC) (Plate 7.11.1), i.e. catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) are stocked together. Sometimes, along with the three IMCs, three exotic carps (Plate 2), namely, silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) are also stocked. However, the number of species and their combination vary depending on seed availability, consumer acceptance and ability to grow well in different environments. Although these carps possess all the prime requirements of ideal species for aquaculture, with the exception of common carp, they do not satisfy one important quality, i.e. ease of reproduction in confined waters. They spawn naturally only in flooded rivers and also in tanks, where riverine conditions are simulated during the southwest monsoon months of June to September.

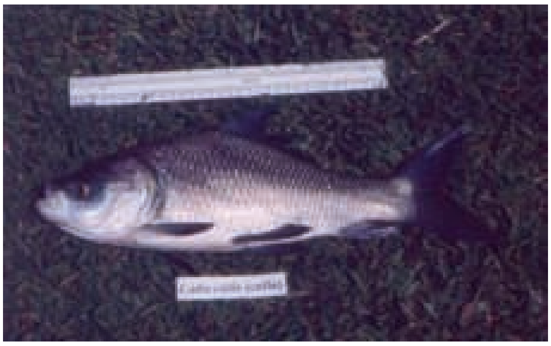
Fish seed destined for aquaculture in India is being obtained from three sources: (i) riverine collection, (ii) bundh breeding and (iii) hatcheries (through induced breeding). In addition to these sources, common carp seed produced without hormone injection, was initially included as the fourth source and was accordingly categorized as 'common carp breeding' until 1964 –1965. Since then, the data of the common carp seed is included with that of the other carps produced through induced breeding.

TABLE 7.11.2
State-wise fish seed requirement and production (1995–1996)

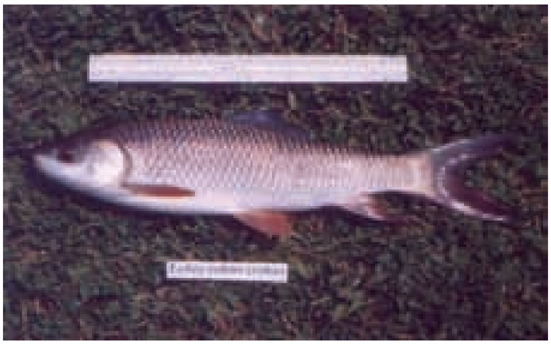
State	Carp seed requirement (million fry)	Carp seed produced (million fry)	Deficit/surplus
Andhra Pradesh	3 020.0	709.0	Deficit
Assam	220.0	2 547.15	Surplus
Bihar	860.0	332.0	Deficit
Goa	15.0	0.03	Deficit
Gujarath	440.0	191.17	Deficit
Haryana	212.0	200.73	Deficit
Himachal Pradesh	5.6	23.10	Surplus
Jammu & Kashmir	98.0	12.60	Deficit
Karnataka	340.0	164.34	Deficit
Kerala	32.0	20.26	Deficit
Mandhya Pradesh	740.0	564.0	Deficit
Maharashtra	320.0	293.0	Deficit
Orissa	860.0	186.64	Deficit
Punjab	172.0	44.0	Deficit
Rajasthan	600.0	175.0	Deficit
Tamil Nadu	1 040.0	467.73	Deficit
Uttar Pradesh	1 160.0	546.62	Deficit
West Bengal	3 800.0	8 180.0	Surplus
North-eastern States	520.0	334.078	Deficit
Others	6.0	12.0	Surplus
Total	14 460.6	15 006.40	

Source: Sinha (2000)

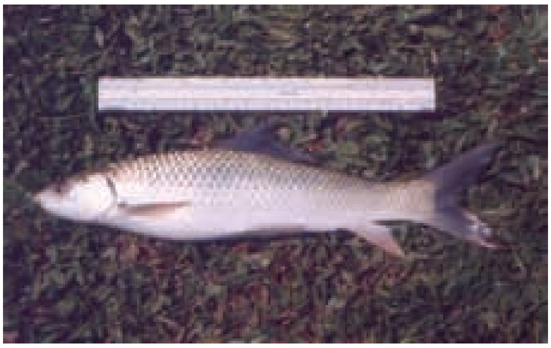
PLATE 7.11.1
Indian major carps



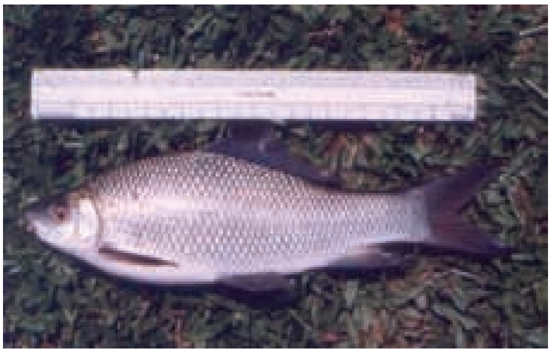
Catla catla



Labeo rohita



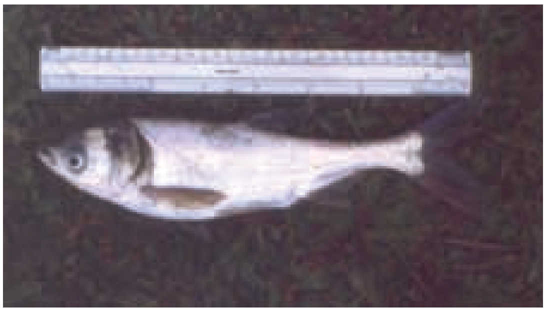
Cirrhinus mrigala



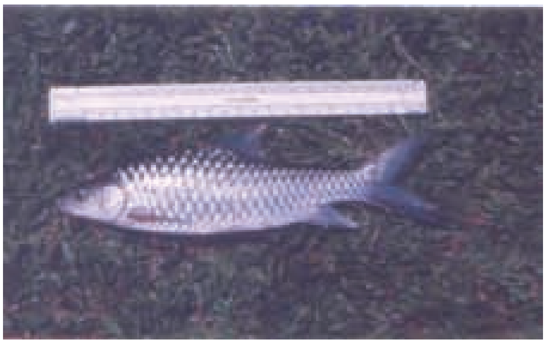
Labeo fimbriatus

PLATE 7.11.2
Exotic carps and mahseer

Common carp



Silver carp



Mahseer

Red tilapia

Over the years, the hypophysation technique has been standardized and refined, new broodstock diet developed, spawning agents (alternative to pituitary) used successfully, new breeding and hatching devices evolved and better larval rearing techniques developed. However, there still remains a big gap between seed production and requirement. At present, the lion's share of India's fish seed production comes from hatcheries. India now produces about 17 000 million fish fry which is much less than the demand.

RIVERINE FISHERY RESOURCES

The freshwater fish resources of India (Table 7.11.3) are found mainly in five major river systems, i.e. (i) the Ganga, (ii) the Brahmaputra and (iii) the Indus in the North, (iv) the Peninsular East Coast and (v) the West Coast River in the South (Figure 7.11.3) (Jhingran, 1991).

The Ganga River System

The Ganga River system has a total length of about 8 047 km and is among the largest river systems in the world. It harbors the richest freshwater fish fauna of India ranging from the cultivable Gangetic (major) carps to mahseers and other coldwater fishes of the Himalayas, the hilsa (a clupeid) catfishes and a wide array of other fishes of considerable commercial importance.

The Brahmaputra River system

The Brahmaputra River system, with a combined length of 4 023 km has a rich fauna in its upper stretches, but without much economic value. However, its middle and lower stretches have several species of carps, catfishes, the anadramous hilsa and other air breathing fish.

The Indus River system

The Indus River system, though massive as a whole, covers only a small part of northwest India, harboring the exotic rainbow and brown trouts in the upper reaches and a variety of indigenous carps and catfishes in the lower sections. The trout streams of Kashmir constitute one of the world's richest sport fishing waters attracting anglers and tourists all over the world.

FIGURE 7.11.3
Map showing different river systems of India

The East Coast River system

The East Coast River system in peninsular India is rather a composite system of rivers, the main constituents of which are the Mahanadi, the Godavari, the Krishna and the Cauvery, with a combined length of about 6 437 km. The Mahanadi has all the Indian major carps common with the Ganga system. The other rivers, besides their own indigenous fish fauna of several carp species, catfishes, murrels, prawns, etc. have had their water enriched by repeated transplantation of the Gangetic carps from the north. The transplants have

TABLE 7.11.3
Important freshwater fishery resources of the Indian river systems

River system	Fishery resources
The Ganga	Carps: *Catla catla, Labeo rohita, Cirrhinus mrigal, Labeo calbasu* Mahseers: *Tor putitora, T. mosal, T. Tor, Acrossocheilus hexagonolepis* Catfishes: *Osteobagrus aor, O. Seenghala, Silonia silondia, Wallago attu, Bagarius bagariu, Rita rita, Ompok bimaculatus Featherbacks: Notopterus notopterus, N. chitala* Clupeids: *Hilsa ilisha, Gudusia chapraSetipinna phasa Freshwater prawn: Macrobrachium malcolmsoni, M. birmanicum*
The Brahmaputra	Carps: *Catla catla, Labeo rohita, Cirrhinus mrigal* Catfishes: *Silonia silondia, Osteobagrus aor, O. Cavasius, Bagarius bagarius* Mahseers: *Tor putitora, T. progenius* Murrels: *Channa punctatus, C. marulius, C. gachua* Clupeids: *Hilsa ilisha* Other fishes: *Rhinomugil corsula, Glossogobius giuris, Colisa lalia*
The Indus	Carps: *Cyprinus carpio, Schizothorax spp., Labeo dero, Puntius conchonius* *Mahseers: Tor putitora* *Catfishes: Glyptothorax kashmirensis, G.reticulatum, Osteobagrus seenghala* *Other fishes: Botia birdi, Nemacheilus kashmirensis*
The East Coast	Carps: *Catla catla, Labeo rohita, Cirrhinus mrigal, Labeo fimbriatus, Labeo calbasu* Catfishes: *Osteobagrus aor, O. Seenghala, Silonia silondia, Wallago attu, Pangasius pangasius, Bagarius bagarius, Rita rita, Ompok bimaculatus, Notopterus notopterus* Mahseers: *Tor khudree, T. mosal, T. mussulla,* Murrels: *Channa striatus, C. marulius, C. gachua*
The West Coast	Carps: *Catla catla, Labeo rohita, Cirrhinus mrigal, Labeo fimbriatus, Labeo calbasu* Catfishes: *Rita pevimentata, Osteobagrus aor, O. Seenghala, Silonia silondia, Wallago attu, Pangasius pangasius, Bagarius bagarius, Rita rita, Ompok bimaculatus, Notopterus notopterus,* Other fishes: *Tor tor, Mastacembelus* spp.

established themselves and contributed significantly to the current fish fauna of these rivers. The tributaries of the Cauvery from the Nilgris have coldwater fishes like trout and tench.

The West Coast River system

The West Coast River system in the south drains the narrow belt of Peninsular India, west of Western Ghats and includes the basins of the Narmada and the Tapti which are rich in fauna. The other rivers that originate in the Western Ghats possess carps, catfishes, mahseers, murrels, perches, prawns, etc.

OTHER FRESHWATER RESOURCES

Reservoir fish seed resources

Information on India's reservoir fish seed resources is scanty. The reservoirs in Uttar Pradesh and Madhya Pradesh, by virtue of their being connected with the Ganga River system have natural stocks of major carps. But in view of the large volume of water impounded by them, the original stocks are being supplemented through regular stocking with major carp fingerlings. The reservoirs across other basins, however, do not have natural stocks of major carps. Hence, major carp fingerlings produced elsewhere are brought and released in these reservoirs. Several schemes were formulated for the construction of fish seed farms at reservoir sites to facilitate effective stocking operations. In most cases, where they were constructed, they did not function successfully due to poor soil quality (high porosity). The population of predatory and weed fishes dominated the catches of many reservoirs, thus reservoir stocking with desirable varieties of fish proved to be not fruitful. However, in many instances fish breed either in the reservoirs or in tributaries or streams which eventually drain into the rivers or reservoirs, leading to natural stocking of reservoirs.

Coldwater fish seed resources

From the fisheries view point, waters of temperatures falling within the tolerance limits of trouts belonging to the family Salmonidae are termed as cold. The optimum range of temperature for coldwater fish is between 10 °C to 12 °C. In India, lakes and streams located 914 m above mean sea level, where major carps do not thrive, qualify for coldwater.

Trout, salmon and char: Trout and salmon are the only exotic game fishes introduced to India. The species of trout introduced were: rainbow trout, brown trout, eastern brook trout, golden rainbow and tiger trout (a hybrid between brown trout and Salvelinus fontinalis).

The initial introduction of trouts to India was intended for European residents of the country during the later half of the nineteenth and in the beginning of the twentieth century. Details of introductions are given by Jones and Sarojini (1952) and Sehgal, Shah and Shukla (1971).

In Peninsular India, trout has been introduced in the Nilgiris and Kodai hills in Tamil Nadu and in the high ranges of the erstwhile Travancore in Kerala. In the Himalayas, trout has been introduced to Kashmir and Himachal Pradesh, to Garhwal Himalayas, Arunachal Pradesh, Nagaland, Meghalaya and to some parts of Nepal.

After introduction, trouts are known to have established only in six to eight reservoirs, in the Nilgiris (Sehgal, 1971) and in the high range of Travancore (Gopinathan, 1972).

In Kashmir, the brown trout was found to have established at Harwan and in 1980, a hatchery was built at Achhabel from where eyed-eggs were sent to other parts of the Himalayan region (Mitchell, 1918). Of the different trout species introduced, the brown and rainbow trouts acclimatized well both in streams and in the farms. Among other problems, poor hatching rate and diseases hindered the spread of trouts into the farms of Kashmir (Jhingran and Sehgal, 1978). Trouts in Kashmir streams attract anglers from all over the world; brown trout is most common and rainbow trout is available only in certain streams.

Mahseers: India is blessed with some of the world's best game fishes like the mahseers. Mahseers are regarded as a sacred fish by the Hindus. In the past, these game fish had attracted the attention of the best anglers and naturalists from several parts of the world. Ogale (2002) described the mahseers as a sport fish that provide unparalleled recreation to anglers even better than salmon. There are seven important species of mahseers belonging to the genus *Tor* in India. These are: *Tor tor*, *T. putitora*, *T. khudree*, *T. nelli*, *T. progenius*, *T. mussullah* and *T. mosal*. Over the years, their natural stocks have depleted (NCA, 1976; Ogale, 2000) due to anthropogenic activities; hence, they are now considered as threatened species. Mahseers inhabit fast-flowing streams and rivers of the hilly areas, with a temperature (optimum) range of 10 °C to 20 °C, but some species can thrive and grow well in coastal regions at temperatures ranging between 20 °C and 32 °C (Bazaz and Keshavanath, 1993; Nandeesha *et al.*, 1993; Basavaraja *et al.*, 2002).

In view of the depleting mahseer resources in India, it was concluded at a national workshop on Conservation of Mahseer Resources in India held in August 1986 that natural stocks of most species of mahseers are seriously depleted. The same was attributed to low fecundity, extreme vulnerability to predation of early larval stages and fry and environmental degradation.

Snow Trout: Snow trout (Schizothoracinae) are believed to have migrated into lakes and streams of Kashmir from Central Asiatic watersheds. Most of them are now regarded as endemic to the Kashmir valley. Presently, there are 11 valid species of Schizothorax. Vass, Raina and Sundar (1978) and Sunder, Raina and Kumar (1979) reported successful artificial propagation of schizothoracids collected from different lakes and streams.

Hilsa: The anadromous Indian shad, *Tenulosa ilisha* (Hamilton), commonly known as hilsa or river shad is, undoubtedly, one of the most commercially important fish of the country. The hilsa ascends the freshwater stretch of all the major river systems from the sea mainly for breeding, thereby forming a lucrative fisheries in both freshwater and brackishwater. However, its upstream migration has greatly been hampered by the construction of dams, weirs and barrages across the rivers. As a remedial measure, fish pass or fish lock, constructed on dams and barrages has not proved a success. Over the years, the natural stocks of hilsa have declined in major rivers, including the Ganga. Hence, there was a need to rehabilitate and save the dwindling hilsa fishery from extinction. The developmental measures such as artificial fecundation and stocking of the young ones in selected stretches of rivers were suggested.

FIGURE 7.11.4
Contribution of the three sources of fish seed to total production (1964-1965)

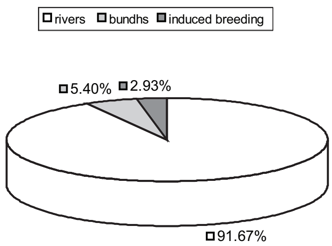


FIGURE 7.11.5
Contribution of the three sources of fish seed to total roduction (1980-1981)

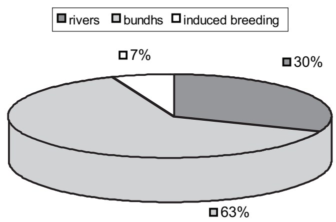
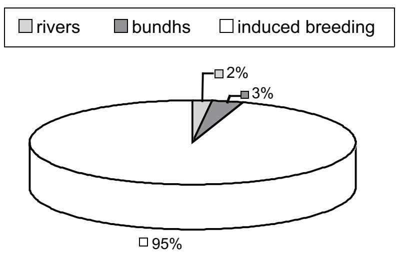


FIGURE 7.11.6
Contribution of the three sources of fish seed to total roduction (2002-2003)



SEED RESOURCES/SUPPLY

Until the late 1970s, riverine seed collection was the main source of seed of IMC for aquaculture (Figure 7.11.4), contributing to 91.67 percent of the total fish seed production during 1964–1965. Bundhs (a special type of tanks where riverine conditions are simulated during monsoon and carps bred) accounted for a major portion of fish seed from the 1960s through to the 1980s (Figure 7.11.5). With the advent of the technique of induced breeding of IMC by Chaudhuri and Alikunhi (1957) and exotic carps by Alikunhi, Sukumaran and Parameshwaran (1963a) through hypophysation, it became possible to obtain quality seed of major carps for aquaculture. This resulted in an increased reliance on induced breeding for obtaining quality fish seed. During 2002–2003, induced breeding accounted for most of the seed produced in the country (Figure 7.11.6), with bundhs and rivers contributing to nearly 5 percent.

Inspite of the intensive collection of carp spawn and fry in certain sections of rivers, a regular survey of such resources had not been made prior to 1964–1965, except for a few cases. The Central Inland Fisheries Research Institute (CIFRI) located at Barrackpore, Kolkata (formerly Calcutta), helped in locating new carp seed collection centres from 1949 through to 1957. In 1964, CIFRI initiated, in 1964, a pioneering programme on seed prompting investigations in various river systems with a view to assess the the following: (i) quality and quantity of fish seed, availability, (ii) gears used for spawn collection, (iii) methods of collection, (iv) measurement of fish seed, (v) factors responsible for fluctuation in seed availability and other aspects on an all-India basis.

The diverse geographical and climatic conditions of India are reflected in the riverine resources of the country. The most significant difference in the rivers of the north and those of peninsular India lies in the greater abundance of the IMC in the former and their poor availability in the latter which naturally has a bearing on the production of quality fish seed and its potential in the two regions. The riverine fish spawning grounds are generally located in the middle reaches of rivers. Of all the river systems, the Ganga is the richest in terms of carp seed resources

RIVERINE FISH SEED RESOURCES

Egg collection: Large-scale egg collection is possible only where locations of the breeding grounds are known and easily accessible. Eggs are collected from one or two feet deep water by disturbing the bottom and scooping them with a "*gamcha*"', a rectangular spawn collecting net. Generally, large-scale egg collection is not practised in rivers.

Collection of eggs, both from the breeding grounds and in the immediate downstream vicinity of the Ganga River system, is done by the Fisheries Department of Madhya Pradesh (Dubey and Tuli, 1961). Drifting eggs are collected by fixing a shooting net (a gear used for collecting riverine spawn) in the tributaries of the Ganga River system (Khan, 1959). Two breeding grounds of major carps are located in Bihar, which have been found to be extremely rich in major carp seed resources, with 90 percent catla and 90 percent rohu at the two centres.

In the Brahmaputra River system, the proportion of major carps collected was low and hence egg collection was uneconomical. The river system changes its current pattern very rapidly due to its torrential and flashy nature owing to steep gradients. A systematic collection of carp eggs was a trend in some tributaries of the river (Alikunhi, 1957).

The Indus River system is rather poor in seed resources. Only a small portion of the system comprising the Beas and the Sutlej and their tributaries is within India. Large-scale egg collection is not done except in the upper reaches of the system which harbor only coldwater forms. A systematic collection of fish eggs has not been reported for the other major river systems of India.

Spawn collection: Collection of spawn (larvae measuring up to 8 mm) on a commercial scale was prevalent in Bihar, West Bengal and Uttar Pradesh. Most of the spawn collection centres were located in the main Ganga, yielding quality spawn. About 75 important spawn collection centres are registered with the Uttar Pradesh Government in the Ganga, Yamuna and other tributaries (Motwani, 1964). In the lower section of the Ganga and its tributaries in West Bengal, large-scale spawn collection was carried out by private fishermen. There existed a private trade and the method of collection, distribution of collection centres, ecological conditions of the river and the trade have been described by Ganguly and Mitra (1957), Mitra (1961, 1964) and Government of India (1966). The Ganga system contributed to about 89.5 percent of the total fish seed produced in the country during 1964–1965 (Government of India, 1966). Bihar accounted for 2 010 million fry, while West Bengal contributed 1 200 million fry.

Investigations carried out by CIFRI in 1961 revealed that major carp spawn is available in the lower Brahmaputra and the spawn can profitably be exploited on a commercial scale, notably rohu spawn.

Spawn collection from the Indus River system in Punjab was unknown until 1963. However, spawn was later exploited considerably, particularly after the spawn prospecting investigations were carried out by CIFRI during 1966. Work carried out by Rajan and Kaushik (1958) and Dubey (1959) showed that spawn collection was a trend in the Narmada and Tapti river systems in Madhya Pradesh. While the collections were found to be rich in *Labeo fimbriatus,* the IMC contributed to 20-25 percent of the total spawn from the Narmada in Madhya Pradesh. Investigations carried out by CIFRI from 1959 to 1964 showed that productive centres could be located in the Gujarath State (Karamchandani *et al.*, 1967). The Narmada was the only river in India which was exploited for mahseer seed regularly during October-January every year, when lakhs of fry were collected and directly stocked in tanks (Dubey, 1959). Studies conducted by CIFRI during 1961 and 1962 monsoon season revealed, for the first time, the presence of catla and rohu spawn in the Tapti River in the Gujarath State. The occurrence of these species in the spawn suggested that they breed upstream (Karamchandani and Pisolkar, 1967). However, the spawn comprised a high percent of minor carps.

The Mahanadi, the largest riverine source of fish seed in Orissa, being the State's only major riverine source of fish seed, has been considerably exploited over the years. The river mainly harbors the hill stream fishes in the upper and middle stretches. A survey conducted by the Department of Fisheries of Orissa located a large number of spawn collection centres. However, not a single breeding ground of major carps was observed.

The Godavari and Krishna and their tributaries drain mainly in Andhra Pradesh and are sufficiently exploited for their fisheries in their deltaic region, with their upper reaches in Maharashtra being poor in commercial species. CIFRI helped in locating a centre where catla was found to be the only major carp available in the spawn (Malhotra *et al.*, 1966). *Labeo fimbriatus* was the dominant carp species. The deltaic stretches of the two river systemsare sufficiently rich in carp fishery, major carp spawn constituted about 20.3 percent (Ibrahim, 1961). Systemic survey of the spawn resources of the Krishna was not made until 1966.

The upper reaches of the Cauvery are poor in carp species. The middle and lower reaches harbor a fairly good fishery for major as well as indigenous carps, such as *Labeo kontius, Cirrhinus cirrhosa*, *Puntius dubius* and *P. carnaticus*. The IMC which were transplanted into the Cauvery and its tributaries (Raj, 1916; Thyagarajan and Chacko, 1950) have established themselves well and not only provided a lucrative fishery, but are also available as fry and fingerlings in the deltaic paddy fields of Tamil Nadu. Ganapathi and Alikunhi (1949) reported the collection of spawn and fingerlings of major carps in large numbers from the Cauvery and its tributaries.

Fry and fingerling collection: The collection of fry (larvae measuring up to 8-40 mm) and fingerlings (40-150 mm length) is normally carried out by cast and drag nets. Established fry and fingerling collection centres are very few, located in the States of Haryana, Delhi, Madhya Pradesh, Uttar Pradesh and Rajasthan. Although billions of carp fry and fingerlings are caught in the northern Bihar from July to October, they are generally not used for fish culture but consumed as food. Fry and fingerling collection as source of fish seed is prevalent in the Indus River system in the Punjab State (Plates 7.11.3 and 7.11.4).

Fry and fingerlings of major carps, along with those of medium-sized carps are collected from paddy fields in the Godavari during post-monsoon months. Chacko (1946) and Chacko and Ganapathi (1951) reported the occurrence of fry and fingerlings of major and medium carps in the Godavari and Krishna rivers.

Identification of eggs, spawn, fry and fingerlings of culturable fishes in India

In order to avoid wastage of precious rearing space, identification and segregation of different species from a mixed collection of fish seed should be accorded utmost importance. An exhaustive account on the egg and larval (spawn, fry and fingerlings) stages of carps, catfishes, murrels, mullets, cichlids, featherbacks and other fishes has been given by Jhingran (1991).

The eggs of IMC and medium carps are non-adhesive, while those of catfishes (e.g. *Notopterus* and *Mastocembelus*) are adhesive. The eggs of murrels and *Anabas* are identified by their floating nature (Jhingran, 1991). The colour of eggs is used as a reliable criterion for the identification of species.

Spawn: It is difficult to identify major carps at spawn stage as the spawn of medium and minor carps also have similarity with the former. However, a mixed collection of fish seed can be categorized as desirable and undesirable spawn. If the length of spawn is more than 5 mm when yolk sac is completely absorbed, it is considered a desirable spawn wherein the IMC account for more than 10 percent of the total spawn. The spawn is regarded as undesirable if the length is less than 5 mm when yolk sac is completely absorbed. The undesirable spawn have less than 10 percent IMC. On the other hand, it is relatively easy to identify IMC at fry stage based on the number of dorsal fin rays and morphological characters.

Fry (14-25 mm): The carp fry can be distinguished from that of catfishes and murrels by the number of dorsal fin rays as follows:

a) Major carps: number of undivided dorsal fin rays >11
b) Minor carps: number of undivided dorsal fin rays 11 or <11
c) Catfishes and murrels: pigmented (either black, brown or orange)

Keys to identify species/group

Catla:	large head; no distinct spot on caudal peduncle, opercular region brightly reddish
Rohu:	a dark spot present on caudal peduncle; a pair of barbels present; lips fringed
Mrigal:	small head and slender body; a triangular dark spot on caudal peduncle; no barbels, lips thin, not fringed
Common carp:	eyes prominent; no reddish glow on operculum; deep body; 2 pairs of barbells; no prominent spot on caudal peduncle
Silver carp:	small scales and eyes; lower jaw upturned; fins dark
Grass carp:	body elongated; head broad with short. round snout; no barbells; body dark grey above and silvery on the belly
Catfish fry:	head large; thin body; large barbells; scaleless body and movement wriggling
Murrel fry:	orange/ brownish; move in shoals near the surface of water

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Hatcheries

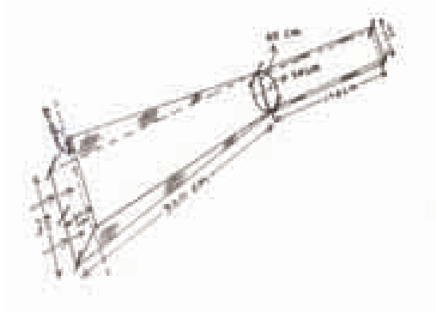
Presently, hatcheries account for the lion's share of India's fish seed production. Seed production of about 211 million fry in 1964-1965 increased to 17 000 million fry in 2003 (Figure 7.11.7). A quantum jump in fish seed production from the 1980s is attributed mainly to the introduction of the technology of the Chinese type of carp hatchery and refinement of the technology of induced breeding, coupled with usage of ready-to-use fish spawning agents like ovaprim. Despite these, India still faces shortage of quality fish seed.

Fish hatchery was earlier used as a facility for hatching of fish eggs collected from rivers and bundhs. At that time, rivers and bundhs were the main sources of carp seed. Over the years, the development and refinement of the technique of induced breeding of carps has been enlarged. Hence, more emphasis is being given to hatcheries for large-scale production of fish fry. Details on the number of Indian major carp hatcheries (both public and private sector), spawn production, conversion rate from spawn to fry, type of hatchery, spawning agent used, etc. are presented in Table 7.11.4. It is evident

PLATE 7.11.3

Gear used for riverine fish seed collection

A river course showing suitable fish spawn collection sites



A typical shooting net (Midnapore type) used to collect riverine fish spawn

A battery of shooting nets ready to be commissioned for riverine/brackishwaterfish seed collection **(Photo courtesy: Dr Utpal Bhowmick)**

PLATE 7.11.4

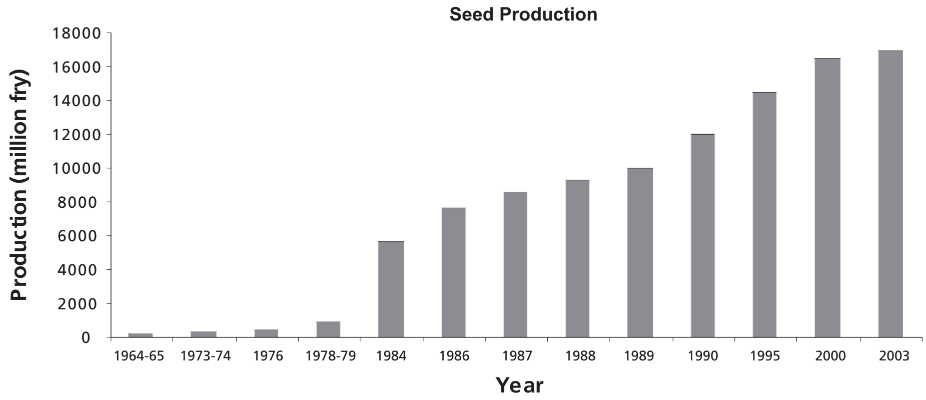
Drawings and photographs showing riverine fish seed collection activities

Collection of riverine fish seed using a *gamcha*, a rectangular mosquito netting cloth

A haul of fish fingerlings from a riverine stretch **(Photo courtesy: Dr Utpal Bhowmick)**

Fish seed being collected along the bank of a river **(Photo courtesy: Dr Utpal Bhowmick)**

FIGURE 7.11.7
India's fish seed production statistics (from 1964–1965 to 2003)



that the Chinese type of circular hatchery is the most widely used hatchery for large-scale seed production all over the country. Jar hatchery (glass or fiberglass) and double-walled hatching hapa are used for medium or small-scale operation in some parts of the country. Among the different fish spawning agents, the ready-to-use ovaprim is the most popular hormone among fish hatchery operators.

Magur, trout and mahseer hatchery details are given in Tables 7.11.5, 7.11.6 and 7.11.7, respectively. However, the seed of these fishes is not produced on a large-scale, except for mahseers.

TABLE 7.11.4
Indian major carps (indicative spawn production)

State	Number of hatcheries	Spawn production (lakhs p.a.)	Spawn to fry conversion rate (percentage)	Type of hatchery	Spawning agent used
Andhra Pradesh	20	55 000	30%	Jar/circular (Chinese type)	Pituitary extract/ ovaprim
Arunachal Pradesh	1	n.a.		Circular	n.a.
Assam				Circular	Pituitary extract/ ovaprim
Bihar	4	3 300	<25%	Circular	Pituitary extract/ ovaprim
Gujarath	12	2 200	25%	Circular	Pituitary extract/ ovaprim
Haryana	21	5 150	25%	Hapa, circular, jar	Pituitary extract/ ovaprim
Karnataka	28	6 343	20%	Circular, jar, hapa	Pituitary extract, ovaprim, HCG, ovatide
Kerala	28	21 000	20%	Jar, circular,	Pituitary extract/ ovaprim
Madhya Pradesh	72	15 800	30%	Circular,bundh	Ovaprim/ovatide
Maharastra	28	10 655	30%	Circular, hapa	Ovaprim/ovatide
Manipur	4	160	n.a.	Circular	Ovaprim, pituitary extract
Orissa	37	19 672	30%	Circular	Pituitary extract/ ovaprim,ovatide
Punjab	6	950	30%	Circular	Ovaprim,ovatide, pituitary extract
Rajasthan	19	6 550	n.a.	Circular	Ovaprim, ovatide, pituitary extract
Tamil Nadu	84	8 968	n.a.	Hapa, circular	Ovaprim, pituitary extract
Tripura	5	2 960			Ovaprim, pituitary extract
Uttar Pradesh	45	11 970	Up to 50%	Circular	Ovaprim/pituitary extract, HCG
West Bengal	30	33 600	Over 30%	Circular	Ovaprim, ovatide, pituitary extract, HCG
Total	420	342 918			

One million = 10 lakhs
n.a.: data not available; data of Assam State not included in the total;
* There are appears to be more carp hatcheries, particulars of which could not be obtained.

A modern fish seed farm now comprises breeding tanks to produce eggs, hatching tanks (hatchery-proper) to produce hatchlings, nurseries to rear spawn to fry, rearing ponds to grow fry to fingerlings and grow-out ponds to produce adult fish. A fishery establishment may have only a hatchery or nursery or rearing or stock ponds or a combination of two or three or more facilities. The magnitude of operations is highly variable, varying from just a few spawnings to commercial-scale operations.

TABLE 7.11.5
Magur (*Clarias batrachus*) hatcheries

State	Number of hatchery	Spawn production (lakhs p.a.)	Type of hatchery
Madhya Pradesh	2	1	-
Orissa	1	-	Experimental
West Bengal	1	-	Experimental
Total	4	1	-

TABLE 7.11.6
Trout hatcheries

State	Number of hatchery	Spawn production (lakhs p.a.)
Arunachal Pradesh	1	n.a.
Jammu and Kashmir	3	6
Himachal Pradesh	4	30
Tamil Nadu	1	n.a.
Uttar Pradesh	3	1.30
Total	12	37.30

Source: Fishing Chimes, 19 (10 & 11): 212-213

TABLE 7.11.7
Mahseer hatcheries

State	No. of hatcheries	Spawn production (lakhs p.a.)	Type of hatchery	Spawning agent
Maharashtra	1	5	Hatching trays	Natural (stripping)
Karnataka	1	10	Hatching trays	Ovaprim,ovatide
Uttaranchal	2	n.a.	Hatching trays	n.a.
Jammu and Kashmir	1	10	Circular	n.a.
Kerala	1	n.a	Hatching trays	Ovaprim
Tamil Nadu	1	under construction	n.a.	n.a.

p.a.: per annum
n.a.: data not available

Hatchery proper

The evolution of fish (carp) hatchery systems in India was traced by Dwivedi and Zaidi (1983). Several types of fish hatchery devices were/are in fashion in India. These range from the simplest hatching pits to the most modern eco-hatcheries. The hatching devices commonly used in India are: (i) hatching pits, (ii) Chittagong type hatchery pits, (iii) earthen pot hatchery, (iv) double-walled hatching hapa, (v) floating hapa, (vi) tub hatchery, (vii) cemented cistern hatchery, (viii) glass jar hatchery, (ix) transparent polythene jar hatchery, (x) galvanized iron jar hatchery, (xi) Shirgur's bin hatchery, (xii) hanging dip net hatchery, (xiii) circular cistern hatchery, (xiv) Chinese type of hatchery and (xv) low density polyethylene (LDPE) hatchery.

Of these, hatching hapa, glass jars and the Chinese type are widely used for the hatching of carp eggs.

Double-walled hatching hapa

The double-walled hatching hapa is one of the commonest devices to serve as an outdoor hatchery. Installable in a pond or in the margin of a river, up to 10 000 eggs can be hatched in the inner mosquito net wall of the hapa (with a of size 1.75 × 0.75 × 0.90 m). The hatchlings wriggle out through the round mesh of the inner wall and gather themselves in the outer whole cloth enclosure. Larval survival is much higher when the hatching hapa is installed in a gently or fast- flowing canal or a river because of superior exchange of water.

Glass jar hatchery

The credit of developing India's first transparent hatching device in which the developing eggs can be seen by the naked eye goes to Bhowmick (1974). In this system, the hatchings are automatically transferred to a storage hapa spawnery, situated within the hatchery building itself. The main components of Bhowmick's glass jar hatchery are: (i) an overhead tank, (2) fish breeding tank, (3) incubation and hatching jars and (4) a spawnery to hold the newly hatched spawn. The capacity of the overhead tank is 5 500 l and each of the 20/40 hatching jars is 6.35 l. The spawnery comprises of two cement tanks (1.8 × 0.9 × 0.9 m each) which can hold a nylon hapa (measuring 1.65 × 0.8 × 1.0 m), projected above the tank and hence deeper than the tank and has an overhead shower for spray. Each jar can accommodate 50 000 hardened water and swollen eggs at a time. Water flow rate is maintained at 600-800 ml/minute. Hatchery jars used to be a very successful system, nowadays hatchery jars are obtained through orders.

Chinese type hatchery

Circular breeding and hatching tanks in which water flows in a circular or centrifugal motion originated in China. Such type of hatcheries are used for hatching carp eggs and popularly known as the Chinese type of carp hatcheries. Within a small space, this system simulates some aspects of riverine environment and has proved itself to be a very successful method for breeding carps for commercial production of carp seed. In modern times, more and more hatcheries are incorporating circular breeding tanks with continuous water flow. In the system, the outlet lies in the middle of the circular tank guarded by a circular perforated structure or a sloping outlet. The principle of a hatching tank is similar to that of a breeding tank, except that the former is smaller and normally has two chambers, giving the shape of a double doughnut to the hatching tank. The outlet lies in the middle of the circular tank guarded by a straight, circular perforated pipe which regulates the water level of both chambers. One wall of the double doughnut lies at the periphery and the other at the inner end surrounding the outlet. The space between the two walls is where water flows in a circular fashion with the help of water jets/inlets placed at 45° from the bottom and where the eggs are hatched. Depending upon the system adopted, the same breeding tank can serve as a hatching as well as larval rearing tank.

The important merits of this system are that it simulates some characteristics of a riverine habitat where the fish naturally belong, with very efficient hatching (almost 100 percent), combines breeding, hatching and larval rearing and is suitable for commercial-scale operation.

The disadvantages are: (i) water requirement is high and in many hatcheries, water is usually in short supply and a large breeding tank is normally not utilized for small-scale breeding operations and (ii) concrete structures are expensive to install and once installed, subsequent modification becomes virtually impossible.

Modern hatchery proper

A hatchery proper is the most essential component of the modern fish seed farm. It is here that fish are bred, eggs hatched and hatchlings produced. Further rearing can even be done outside, but according to the latest concepts of a hatchery, fingerling rearing is done in the hatchery or fish seed farm. A modern hatchery which incorporates all the essential components and where ecological conditions are simulated is sometimes referred to as eco-hatchery. The components of a hatchery proper are : (i) ante-tank, (ii) fish breeding tanks, (iii) hatching tanks and (iv) larvae holding tank or spawnery (Plates 7.11.5 and 7.11. 6).

Modern carp eco-hatchery is the most appropriate system to produce seed of IMCs and exotic carps. It is an integrated one, with infrastructure for broodfish care, breeding tank, hatching/incubation tank, spawn and fry rearing, packing and marketing

PLATE 7.11.5

An aerial view of the Tungabhadra Fish seed farm, one of the best managed and largest fish seed farms in south India

PLATE 7.11.6

Different types of carp hatcheries

Doubled-walled hatching hapaconsisting of inner (round-meshed mosquito cloth) and outer (nylon) hapas

Outdoor fibreglass jars, provided with water supply from the bottom, used for hatching major carp eggs

Top view of a Chinese type of circular breeding tank, with an overhead shower

A view of a Chinese type of circular hatching tank, with the inner chamber covered with nylon netting

of seed, water supply system and buildings. Gupta, Rath and Ayyapan (2000) suggested guidelines for designing and managing a eco-hatchery for small-, medium- and large-scale carp seed production.

Trout hatcheries

The important trout hatcheries in India are located in the areas of: (i) Avalanche in Nilgiris (Tamil Nadu); (ii) Rajamallay in the high range of Travancore (Kerala); (iii) Achhabal, Laribal and Harwan in Kashmir; (iv) Patlikuhal, Mahili, Barot, Chirgaon and Sangala in Himachal Pradesh; (v) Kaldayani and Talwari in Uttar Pradesh; (vi) Bomdilla in Arunachal Pradesh and (vii) Shillong in Meghalaya (Jhingran, 1991).

Avalanche Hatchery. The hatchery at Avalanche, situated at an altitude of 2 280 m was the first trout hatchery to be established in the country. The hatchery has a miniature ova-house with four wooden hatching troughs each of which are provided with six glass hatching trays. It has seven stocking ponds and 20 earthen nurseries; water source is from a nearby stream. The survival from green eggs to fry is found to be 16.9-67.4 percent. The breeding season is from September to February.

Rajamallay Hatchery. Situated at an altitude of 2 295 m, the hatchery has a small ova-house containing two hatching troughs. It has four nursery and six stocking ponds. The stripping season extends from October to January. The average survival from eggs to fry of *Salmo gairdneri* was 71 percent during 1967–1970.

Hatcheries at Achhabal, Laribal and Harwan. The Achhabal hatchery is one of the oldest and biggest in Kashmir State, with water supply coming from a spring; those at Laribal and Harwan come from streams. Trout hatcheries in Kashmir comprise raceways-type stock ponds, circular ponds, a battery of nurseries and ova-houses with a series of hatching troughs and wooden trays. The stripping season of brown trout lasts from mid-November to December. The rainbow trout has a shorter stripping season lasting for about 25 days between February and March. The hatching period of brown trout eggs is 104-130 days at water temperature range between 3 °C to 7 °C as against 28-71 days of rainbow trout at 7 °C to13 °C. Application of prophylactic measures against diseases and maintenance of high dissolved oxygen level in hatching troughs resulted to improved cumulative survival from eggs to swim up fry up to 94.9 percent as against the average range of 17.1 to 37.5 percent.

Barot Hatchery. This hatchery is located at an altitude of 2 068 m in the Uhl Valley of Himachal Prudish. Hatching troughs and trays are arranged in series. The source of water is a spring. The stripping season of rainbow trout is the same as in Kashmir. The survival from green eggs to fry has been found to be 26.5 and 51.7 percent for controlled and treated hatching troughs, respectively.

Kulu Hatcheries. In the Kulu valley, there are two hatcheries, both located at an altitude of 1 462 m and fed by small channels connected to the nearby streams. The average survival from green eggs to fry stage for rainbow trout was 40.6-58.3 percent.

Hatchery Production of Mahseer Seed

To conserve mahseer and develop sport fishing, the Government of India encouraged the establishment of mahseer hatcheries. Investigations carried out by Tata Power Companies Limited (TPCL) at Lonavla, Maharashtra State, revealed the possibility of artificial propagation of mahseer (Kulkarni, 1971). Breeding techniques are now being developed for several species of *Tor* in several countries of Asia. In India, broodfish for hatchery production are derived from reservoirs, lakes and rivers during spawning season and are bred with or without hormone injection (Kulkarni, 1971; Kulkarni and Ogale, 1991; Tripathi, 1977; Ogale, 2002; Basavaraja *et al.*, 2006).

The first mahseer hatchery to be established in India was at TPCL at Lonavla in Maharashtra State and the credit goes to C. N. Kulkarni. It supplied nearly 0.8 million mahseer fingerlings (as of 1994) to different states of India and also to other countries (Ogale, 2000). In addition, approximately 0.2 million mahseer fingerlings are released annually in the reservoirs of TPCL and the mahseer population therein has increased substantially (Kulkarni and Ogale, 1991). The second mahseer hatchery was established at Harangi Fish Farm in Kodagu District of Karnataka, with a capacity of 1.0 million seed per year. Later, the National Bureau of Fish Genetic Resources (NBFGR), located at Lucknow, Uttar Pradesh, standardized the technique for large-scale production of mahseer fry in Uttaranchal State using the method adopted by TPCL. Subsequently, the Department of Fisheries of Uttaranchal established two mahseer hatchery units, one at Dehradun and the other at Bhimtal. Recently, the Jammu and Kashmir governments constructed a mahseer hatchery at Anji near Salal Hydel Project with a capacity to hatch 1.0 million eggs per year. Very recently, the Government of Kerala established one hatchery at Wayanad and the Government of Tamil Nadu has just sanctioned one mahseer hatchery which is coming up at Salaiyar Dam in Coimbatore District, under the Western Ghat Development Programme.

Artificial propagation of *Tenulosa ilisha*

Various attempts were made to artificially propagate hilsa (*T. ilisha)*, in India (Wilson, 1909; Kulkarni, 1950), but none succeeded in rearing the resultant hatchlings beyond three days. Karamchandani (1961))located the spawning ground of hilsa (about 100 km above the sea) in the freshwater zone of the River Narmada. Malhotra *et al.* (1969, 1973) successfully bred hilsa by stripping specimens collected from the Ganga River and reared the fry in freshwater pond for more than two years. Hatching of fertilized eggs was tried in different environments. Successful results were obtained when hapas, made of muslin cloth, were fixed in the river bed. The stocking density of eggs ranged between 180 000 and 240 000 per hapa. Malhotra *et al.* (1969) produced about 420 000 hatchlings which were reared in nursery ponds and attained 155 and 320.5 mm at the end of the first and second year, respectively (Malhotra *et al.*, 1973).

CIFRI made further progress in the refinement of the technique of artificial propagation *T. ilisha* and fry rearing (Anon., 1984). Live male and female specimens in good condition were collected from the river Ganga using gill net and wet stripping was done. Incubation of the developing embryos was carried out in an improvised field laboratory. Hatching period was 16-20 hrs. A total of 0.26 million hatchlings were produced and reared. Hatchlings were transported in open containers without oxygen filling at a density of 1 000 hatchlings/l. CIFRI designed a model hilsa hatchery and a circular grid hatchery for incubation, hatching and rearing of hatchlings (Anon., 2000). Each hatching jar unit can hatch 150 000 water-hardened eggs and the overall hatching rate is found to be 50-85 percent.

Hatchery establishment programme in India

During the 6th Five Year Plan (1979–80 to 1984–85), carp hatcheries of 10.25 ha with production capacities of 10.27 million fingerlings were set up under the World Bank Assistance Programme in Madhya Pradesh, Orissa, West Bengal, Bihar and Uttar Pradesh. This led to a national programme for fish seed production. Under the 6th plan, the targeted production of nearly 2 224 million fry was reached (Figure 7.11.8).

Induced breeding

During 1964–1965, the major share of India's fish seed supply was derived from riverine collection, which almost inevitably comprised a mixed lot and included uneconomic and

FIGURE 7.11.8
Fish seed production during the five-year plan period

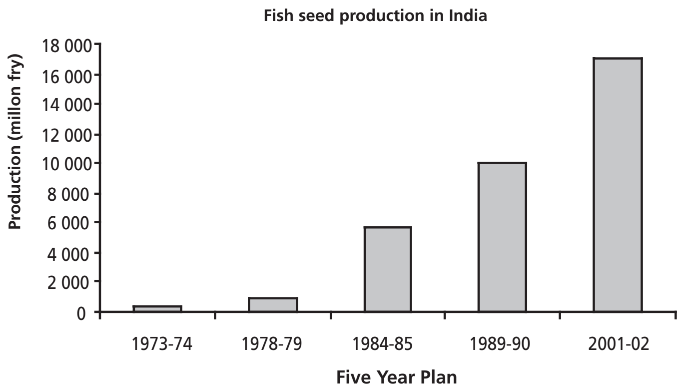


PLATE 7.11.7
An Indian major carp being injected with a spawning agent for induced breeding

even predatory forms. Moreover, the seed were available at some specific centres located in the rivers only and great difficulty was encountered in transporting them to markets. Such a process, being expensive, involved heavy mortality of seed during transit.

There was a need to develop a method for procuring pure seed of cultivable fishes and this was made possible when the technique of hypophysation was successfully applied to Indian major carps in 1957–1958 at Cuttack Substation of the CIFRI.

Trends in induced breeding of fish in India

The present day concept of induced breeding of fish can be traced back from the work of Houssay (1930) of Argentina who attempted the application of pituitary hormones for spawning of fish. However, Brazil was the first country to develop the technique of hypophysation (Von Ihering, 1935).

In India, Chaudhuri (1955) successfully induced spawning, for the first time, in an Indian major carp species using pituitary gland extract. He also bred *Pseudotropius atherinoides* by administering pituitary extract from *Cirrhinus reba*. Ramaswami and Sundararaj (1956, 1957) reported successful breeding of the catfishes, *Heteropneustes fossilis* and *Clarias batracus,* by hormone injection. In 1957, Chaudhuri and Alikunhi (1957), for the first time, succeeded in inducing breeding of IMCs, rohu and mrigal and minor carps by injecting them with carp pituitary extract. Since then, the application of this technique has spread widely and now, with modifications, forms a regular part of fish culture programmes all over the country. Induced breeding of Chinese carps was successful in 1962 by employing similar technique (Alikunhi, Sukumaran and Parameshwaran, 1963a, b). Chondar (1970, 1984) described in detail the induced breeding technique for the difficult-to-breed IMCs and Chinese carps. By judicious management of broodfish, he was able to make the specimens of several species of carps breed three times in the same season. Varghese *et al.* (1975) successfully bred carps with pituitary gland of marine catfishes, *Tachysurus thalassima* and *T. jolla.*

Induced Breeding of Indian Major Carps

The technique of hypophysation of carps has been described by several workers. Induced breeding of IMCs, which normally spawn once a year either naturally or through hypophysation during monsoon, became successful within an interval of about two months (Bhowmick *et al.*, 1977). Almost equal quantities of eggs were obtained in each of the two spawnings, thereby doubling the production of spawn.

Somashekarappa *et al.* (1990) succeeded in advancing maturity of catla by two months using a precooked diet formulated using black gram, horse gram, sunflower cake, rice bran, ground nut oil cake, broken rice and fish meal and monthly injection of the fish with HCG at 6 mg/kg body weight. Such fish could be bred once in April and again in July through hypophysation. Similarly, Gupta, Reddy and Pani (1990) successfully advanced maturity in IMCs and Chinese carps using a special feed and bred them during April-June.

Environmental factors affecting the breeding of fish

Environmental factors such as light, temperature, ecological factors, meteorological conditions and others are known to play important roles in stimulating the release of pituitary gonadotropin, thereby controlling reproduction in fish.

Light. Light is an important factor that controls reproduction in fish. Early maturation and spawning of fish as a result of enhanced photoperiodic regimes have been reported by several workers for temperate fishes. In India, *Cirrhinus reba* was found to attain early maturity when subjected to artificial day lengths longer than natural day even at a low temperature (19 °C to 20 °C) during the winter months (Verghese, 1968).

Temperature. The role of environmental temperature on sexual maturation and spawning of fish in India has been studied (Chaudhuri, 1960a; Alikunhi, Sukumaran and Parameshwaran, 1963a; Ibrahim, Bhowmick and Panikker, 1968). All observations show that there are optimum temperature ranges for induced breeding of cultivable fishes and critical temperature limits, above and below which fish will not reproduce. The IMCs are found to breed within a range of 24 °C to 31 °C (Khan, 1945; Chaudhuri, 1960a). At higher temperature fish do not spawn (Chaudhuri, 1960a).

Other factors. It is known that fresh rainwater and flooded condition in a tank are the primary factors in triggering the spawning of carps. The presence of repressive factors may be responsible for inhibiting spawning of carps in confined waters (Swingle, 1956), but when this repressive factor is sufficiently diluted by the onrush of floods in bundhs or ponds, spawning occurs. Sinha, Jhingran and Ganapathi (1974) suggested that it is the sudden drop in the electrolytic level in the environment caused by heavy monsoon rain or water current which induces gonadal hydration, resulting in natural spawning of carps.

Rainwater and weather conditions are observed to be important factors for induced breeding of fish. Successful spawning in the majority of fishes has been induced during cloudy and rainy days, especially after heavy showers (Chaudhuri, 1960a). The carps are known to breed at a fairly wide range of pH and dissolved oxygen content. The Chinese carps that have more or less similar breeding requirements and can also be bred under conditions optimum for the IMCs.

Alternative spawning agents

Studies conducted by numerous investigators on induced breeding of fishes have indicated the superiority of several ovulating agents over fish pituitary extract. Although fish pituitary extract was used extensively for fish breeding all over the world, synthetic spawning hormones are now being used widely due to their efficacy and convenience. Of all the mammalian hormones tested on fish, chorionic gonadotropin (CG) has resulted in successful spawning of fish, probably because CG behaves primarily as a luteinising hormone (LH). Synahorin (a mixture of CG and mammalian pituitary extract) in combination with pituitary gave positive results when injected to rohu (Barrackpore, 1968). Sinha (1969) reported the fractionization of pituitary extract from carps and tilapia. He obtained success in spawning of carps (Sinha, 1971). However, Bhowmick *et al.*

TABLE 7.11.8
Dosage of ready-to-inject spawning agents (Ovaprim, Ovatide, WOVA-FH, etc.)

Females of the following fish species	Dosage of spawning agents
Catla	0.4-0.5 ml/kg body weight
Rohu	0.3-0.4 ml/kg body weight
Mrigal	0.25-0.3 ml/kg body weight
Fringe-lipped carp	0.3-0.4 ml/kg body weight
Catfish	0.6-0.8 ml/kg body weight
Silver carp	0.4-0.7 ml/kg body weight
Grass carp	0.4-0.8 ml.kg body weight
Bighead carp	0.4-0.5 ml.kg body weight
Mahseers	0.6-0.7 ml/kg body weight
Males of all species of carps	0.1-0.3 ml/kg body weight
Males of catfish	0.15-0.4 ml/kg body weight

(1986) found mammalian hormones antuitrin-s, leutocyclin and LH-RH ineffective when injected singly or in combination with carp pituitary extract. CIFRI in Barrackpore undertook detailed studies on the use of LH-RH alone or in combination with progesterone and obtained breeding success which ranged between 25-49 percent in carps and 100 percent in catfish (cited by Jhingran, 1991).

Synthetic spawning agents. The stimulation of pituitary gonadotropin secretion by synthetic LH-RH has been demonstrated in a number of teleosts. Since LH-RH (natural or synthetic) alone is not very effective in inducing spawning in fish, a combination of LH-RH-a (GnRH-a) and a dopamine antagonist for induced ovulation and spawning in cultured fish is a highly effective procedure, also called the Linpe method (Peter *et al.*, 1988). Kaul and Rishi (1986) and Sahu and Biswas (1988) reported successful spawning of catla, rohu and mrigal with LH-RH analogue at 10-20 μg/kg b.w. They also obtained 100 percent ovulation with pimozide at 10 mg/kg b.w. Parameswaran, Kumariah and Singit (1988) achieved successful spawning in mrigal with LH-RH-a, buserelin acetate in combination with progesterone. Investigations of Jose, Mohan and Sebestian (1989) with LH-RH-a indicated successful breeding of mrigal and *Labeo fimbriatus*. The Linpe method rapidly gained acceptance in fish farms in China and India and has now been commercialized by Syndel Laboratories, Inc. (Vancouver, British Columbia, Canada) under the trade name ovaprim. The ovaprim spawning kit is especially formulated for use with salmonids, cyprinids and other freshwater cultured fish. It has been used successfully in a number of species in several countries and is gaining wide acceptance as the preferred method for induced ovulation and spawning of cultured freshwater fish (Plate 7.11.7). For example, in India, based on field trials (in 1988-1990) with ovaprim for induced spawning of IMCs, fringe lipped carp, silver carp, bighead carp and grass carp in various fish farms located in different agro-climatic regions, Nandeesha, Ramacharya and Varghese (1991) concluded that in economic terms, the use of ovaprim is advantageous. The spawning success, quantity of eggs obtained, the fertilization rate and hatching percentage remained consistently higher with ovaprim than carp pituitary extract (CPE) or human chorionic gonadotropin (HCG) in almost all instances. The results also indicate that nearly 40 percent more fry can be obtained by using ovaprim in place of commercial CPE. Most of the carps tested generally spawned within 10-14 hrs after injection. Ovulation and spawning has been successfully induced in India by the Linpe method in the Asian catfish, *Clarias batrachus* (Manickam and Joy, 1989) and Indian catfish, *Heteropneustes fossilis* (Manickam, 1992). Similarly, indigenous preparations such as Ovatide (M/s. Hemmopharma Ltd., Mumbai) and WOVA-FH (M/s. WOCKHARDT Ltd., Mumbai) are also being used commonly for the commercial spawning of carps and other fishes in India (Table 7.11.8). A combination of busereline (LHRH-a) and domperidone has been successfully used for the spawning of IMCs.

SEED PRODUCTION OF OTHER COMMERCIALLY IMPORTANT FRESHWATER FISHES

Exotic species

Important exotic fishes introduced into India for food, sport and vector control are listed by Jhingran (1991). They include cyprinids, salmonids, tilapia and larvicidal fishes. Of the important food fishes listed, the following are more important from the point of aquaculture: common carp, silver carp, grass carp, tilapia and gourami.

Common carp. The common carp is perhaps the world's most extensively cultured species. In India, it is widely cultivated singly or in polyculture with IMC and silver carp and grass carp. Detailed studies on the cultivable aspects of common carp have been carried out at the Pond Culture Division of CIFRI. The common carp breeds naturally in confined waters. Spawning occurs in shallow marginal weed-infested areas. It spawns throughout the year in a tropical country like India, with two peak breeding seasons, one lasting from mid-January to March and the other during July and August. However, diverse breeding techniques of this species have been described (Hora and Pillay, 1962, Alikunhi, 1966).

Silver carp and grass carp. Silver carp and grass carp occur naturally in the rivers of China and the USSR and have been introduced and cultured in many countries. Both the species were introduced into India in 1959 at the Pond Culture Division of CIFRI (Orissa). In 1963, they were bred successfully by hypophysation and their fry distributed to various states of India.

Like the IMCs, silver carp and grass carp attain gonadal maturity, but do not spawn normally in captivity in India. They, however, could be induced to breed through hypophysation (Alikunhi, Sukumaran and Parameshwaran, 1963a; Chaudhuri, Singh and Sukumaran, 1966). Complete natural spawning of both the species was also reported (Chaudhuri *et al.*, 1967).

The technique of breeding Chinese carps in India is similar to that of breeding IMCs. Although the criteria used for selecting mature broodfish of IMCs and the Chinese carps are almost same, the selection of a female grass carp is rather difficult, because the bulging nature of the abdomen which can be seen as an outcome of heavy feeding. Hence, the prospective females are starved inside breeding hapas for 6-8 hr to empty the gut, before making the final selection. The dosage of hormone given to female and male silver carp and grass carp are almost double the doses given to IMCs. Since they do not normally spawn in breeding hapa after injection, both female and male need to be stripped to facilitate artificial fertilization of eggs. The details of hypophysation of the Chinese carps in India have been presented by Jhingran (1991). The fecundity of silver carp and grass carp is 0.1-0.15 million eggs/kg body weight.

Tilapia (*Oreochromis mossambicus).* Tilapia breeds throughout the year except in tropics. The interval between two spawnings varies between 30 and 45 days and the fecundity ranges between 80 and 1 000 eggs per female. The fertilized eggs are picked by the female for buccal incubation for 10-14 days (Panikkar and Tampi, 1954). The newly hatched fry is transparent and measures 5 mm in length. No special spawning technique is followed in India as the fish breeds readily in almost all water bodies. The presence of tilapia in carp nurseries seriously affects the survival and growth of carp fry. Large-scale cultivation of *O. mossambicus* is not presently undertaken in India. However, tilapia forms an important fishery in the states of West Bengal, Kerala, Karnataka and other coastal states where it contributes significantly to commercial fish catches.

The research and development centre of Vorion Chemicals and Distilleries Limited (VCDL), Madras developed a technology for growing hybrid tilapia [red tilapia × gray tilapia (*Oreochromis* spp.)] using the distillery effluent. Male dominated hybrid fry, referred to as golden tilapia, is produced by hormonal sex reversal. The stocking density of tilapia fingerlings practised in grow-out ponds ranges from 25 000 to 120 000/ha (Rangaswamy, 1993). The yields of 50, 100-120 and 250- 400 tonnes/ha/yr under semi-intensive, intensive and super-intensive culture, respectively, are obtained in

2 crops a year. Of late, the VCDL is known to have closed down its culture operations due to practical difficulties.

Gourami (*Osphronemus goramy).* Gourami occurs naturally in the freshwaters of Southeast Asian countries. In India, gourami was first introduced in Calcutta during the first half of the nineteenth century from Java. The breeding of gourami was first reported in 1916 (Raj, 1916). It however, established itself well in India. Subsequently, it was transplanted to several states of the country. Gourami has successfully been cultured in India (Bhimachar, David and Muniappa, 1944). Gourami breeds naturally in streams and ponds during the dry season in open waters and throughout the year in confined waters. No special pond is provided for breeding. Gourami is bred and cultured in one and the same pond in which plants such as *Typha* are grown in the marginal areas where nests are built.

Tawes (*Puntius javanicus).* Tawes was introduced into India in September 1972 to determine its efficiency as weed control in fish ponds. A consignment of about 5 000 fry (10-20 mm) was procured from Indonesia and reared initially at a fish farm in West Bengal. Tawes breeds in ponds in Indonesia where riverine conditions are simulated as in dry bundhs in India. Sinha and Saha (1979) spawned the fish for the first time in Indian conditions in 1979 by administering pituitary extract. The fish bred three hrs after the second injection. A female weighing 600 g can produce about 0.1 million eggs (Sinha and Saha, 1979).

SEED PRODUCTION OF AIR-BREATHING FISHES

Murrels (*Channa* spp.), singhi (*Heteropneustes fossilis*), koi (*Anabas testudineus*) and magur (*Clarias batrachus*) thrive well in swamps and weedy marshes and can also withstand slightly brackish water.

Murrels: Murrels are known to spawn naturally in paddy fields during pre-monsoon months. All the three culturable species of murrels (*C. marulius*, *C. striatus* and *C. punctatus*) were successfully bred for production of large-scale stockable material in Karnataka and Bihar (Parameswaran and Murugesan, 1976; Banerji, 1974). Indoor rearing of murrel spawn has been successfully carried out when fed on boiled chicken egg yolk (Parameswaran and Murugesan, 1976). The murrel fry accepts zooplankton from the eighth day when it also develops air-breathing habitat (Dehadrai, 1972). Until recently fish pituitary extract was being used for induced breeding of murrels. Due to inadequate supply of pituitary glands, their high dose and the availability of alternative hormones, attempts are being made to find out a suitable spawning agent for producing murrel seed. Francis *et al.* (2000) tested carp pituitary extract, HCG, carp pituitary extract + HCG and ovaprim and obtained the best fertilization rate (93 percent) with ovaprim, in *Channa striatus*.

Magur: Magur (*Clarias batrachus*) inhabits freshwater rivers, swamps and ponds. It is a highly esteemed food fish in India, Thailand and Cambodia. Magur breeds in confined waters during monsoon months. It deposits eggs in holes made in the pond bank and about 2 000-15 000 fry are found in one hole. It can be induced to breed through hypophysation and the method employed for breeding in India is almost similar to that adopted for IMCs.

Since magur normally breeds once in a year during a very short spell, coinciding with monsoon, CIFA (Bhubaneswar) succeeded in prolonging its breeding period, i.e. prior and after the normal breeding period, by manipulating the broodstock. Such fish could be bred more than once in a season so that their seed will be available for longer periods (Sahu *et al.*, 2000). At the Freshwater Fish Farm of CIFE, Balabhadrapuram

(Andhra Pradesh), a magur hatchery has been established with a production capacity of 0.4-0.5 million fry/season (Venugopal *et al.*, 2000). They reported mean fertilization, hatching and larval survival rates of 75, 70 and 60 percent, respectively.

Singhi: Singhi (*H. fossilis*) breeds in confined waters during monsoon months. Singhi is a highly priced freshwater fish and is recommended to convalescing persons because of its protein, iron and fat content. The major constraint to its culture is the non-availability of quality seed. Singhi was induced to breed by hypophysation (Ramaswamy and Sundararaj, 1955) the optimal dose being 1½ homoplastic pituitaries from the male donors or ½ pituitary from the females (Sundararaj and Goswami, 1969). Goswami and Sundararaj (1971b) reported that a mixture of carp pituitary and HCG had a greater effect than other combinations of hormones in inducing spawning in Singhi. Fish breeds 8-10 hr after being injected with pituitary hormones. Singhi fry, during rearing stage, shows very poor survival due to non-availability of adequate quantity of choice of food and also due to cannibalism. Singhi has been successfully bred using LH RH-a + pimozide and ovaprim (Nayak and Singh, 1995, cited by Singh, 1995). Marimuthu *et al.* (2000) have reported successful spawning of this species with ovaprim. They have also demonstrated that ovatide at 0.4 ml/kg body weight is the optimum dose for effective seed production in Singhi and found to be cost-effective, compared to pituitary extract.

Koi: Koi (*A. testudineus*) breeds in swamps, marshes and paddy fields. Hypophysation is very successfully used to produce large-scale fry of koi (Banerji and Prasad, 1974). Moitra *et al.* (1979) described the spawning behaviour and larval development of koi and found 28.5±1 ºC to be a vital factor in inducing spawning of the fish. The hatchlings are small and tender and require careful rearing to achieve high survival.

Breeding of carps in bundhs

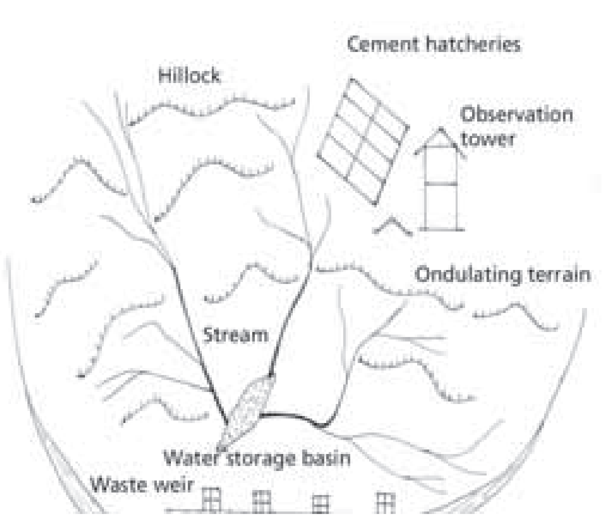
Bundhs are special-type of tanks or impoundments where riverine conditions are simulated during monsoon months for breeding carps. They may be perennial (wet bundhs) or seasonal (dry bundhs). Bundh breeding, which accounted for 5.4 percent in 1964–1965, contributed to about 63 percent in 1980. Bundh breeding is popular in Madhya Pradesh and West Bengal. Bundhs have been described in detail by Mookerjee *et al.* (1944).

Bundh breeding seems to have its origin in Bengal. Majority of bundh-type tanks, where major carps are stimulated to breed are located in the districts of Midnapore and Bankura in West Bengal and around Nowgong in the Chhattarpur District of Madhya Prudish. The first dry bundh was located in Sonar Talliya in Nowgong district of Madhya Pradesh.

The initial success achieved on dry bundh breeding of carps in Sonar Talliya by the Department of Fisheries, Government of Madhya Pradesh, in 1958 led to the construction of many more dry bundhs with improved designs. The most modern constructions are generally masonry structures with arrangements for a sluice gate in the deepest portion of bundh for complete draining and one or two waste weirs for overflow of excess water. In most cases, apart from the bundh itself, a dry bundh unit consists of storage ponds for stocking brooders, an observation tower with arrangements for storing necessary equipment and a set of cemented hatcheries (2.4 m × 1.2 m × 0.3 m) with a regular supply of water for a large number of eggs at a short time. In some cases, the embankment is a *pucca* stone masonry with a small sluice gate and a portion of the embankment itself serves as the waste weir (Dubey, 1969).

A typical wet bundh of Midnapore (West Bengal) is a perennial pond or tank, situated in the slope of a vast catchment area of undulating terrain, with proper embankments having an inlet towards the upland and an outlet towards the

FIGURE 7.11.9
A typical dry bundh (Nowgong type) used for breeding IMCs



opposite lower end. During summer, only the deeper portion of the bundh retains water where carp brooders are released for spawning. The remaining portion is dry and oftentimes used for agricultural purposes. After a heavy shower, a major portion of the bundh gets submerged with water from catchment area (catchment area: bundh, 20-100:1), coming into it in the form of streamlets.

With the onset of the southwest monsoon, the rainwater from the catchment area rushes into the bundh, creating an artificial current. The brooders, already present in the deeper area of the bundh, migrate to the shallower areas and start breeding. After the breeding is over, egg/spawn collection is done.

A typical dry bundh is a shallow, seasonal depression, having a bundh on one side and a catchment area on the other three sides. The bundh may be of varying shape and size and made of earthen wall or masonry wall. A dry bundh is smaller and shallower than a wet bundh. The bundh gets flooded in monsoon, but remains completely dry for a considerable period during a year. It consists of a sluice gate for quickly draining the water and an outlet for the excess water to flow away (Figure 9). In dry bundhs, spawning sometimes takes place in deeper areas also (Alikunhi *et al.*, 1964).

Technique of breeding major carps in a dry bundh

The mature carp brooders which are raised in perennial ponds elsewhere are introduced into the bundh at a ratio of 1:2 (Female:Male). The fish are left undisturbed for 2-3 days so that they get acclimatized to new environment. After this, 10-20 percent of the fish is given intramuscular injection of the pituitary extract or ready-to-use solution like ovaprim. Water current is created in the bundh by drawing water from a store tank. The following morning, the spent brooders are removed, eggs collected, water drained and the bundh dried for 2-3 days. The bundh is then utilized for the next breeding by releasing a fresh batch of breeders. Five to six spawning are generally conducted in each bundh during one season as opposed to only one spawning in a wet bundh. Silver carp and grass carp have been successfully bred in bundhs without stripping. Sinha *et al.* (1974) have reported natural spawning of both grass carp and silver carp in a dry bundh in Bankura District where they were able to spawn the two species without stripping. They consider dry bundhs to be one of the most reliable means of mass breeding of Chinese carps to meet the increasing demand of their seed.

Collection and hatching of eggs

After spawning, eggs are collected from bundhs, after lowering the water level, by dragging a piece of mosquito net cloth (*gamcha*) and releasing the eggs hatching either in improvised pits or double-walled hatching hapas or cement hatcheries. Each pit may contain about 0.9-2.2 million eggs, of which 2.5-25 percent hatch successfully. A double-walled hapa, fixed in the bundh itself and consisting of an outer hapa (182 cm × 91 cm × 91 cm) and an inner hapa (152 cm × 76 cm × 46 cm), accounts for a spawn survival rate of 32 to 50 percent (Alikunhi *et al.*, 1964). The provision of cement hatcheries (2.4 m x 1.2 m x 0.3 m) near the dry bundhs in Madhya Pradesh has aided in improving the survival of hatchlings to 97 percent. A cement hatchery of Madhya Pradesh has three times more capacity than a double-walled hapa and is far more economical than the latter (Dubey, 1969).

Factors responsible for breeding of fish in bundhs

No single factor can probably be attributed to spawning of major carps in bundhs and rivers. The act of spawning involves the completion of a chain of interrelated pre-conditions. Heavy monsoon flood capable of inundating vast shallow areas is believed to be a primary factor responsible for spawning. Some workers believe the availability of shallow spawning ground to be a deciding factor for spawning. The rise in the level of water, naturally or artificially, is known to bring about spawning. There is a diverse opinion about the pattern of current required for spawning. Spawning is observed in both still and flowing waters. The temperature of water for spawning is found to be between 22 °C and 33 °C. Other factors like pH, high dissolved oxygen, alkalinity, chloride and minerals do not seem to play any significant role in spawning. Soil type is not very important. Spawning is inhibited due to the presence of hormone-like secretion in captive waters. Water that has flown through a dry bed of land rich in humus has stimulatory effect on spawning. Until today, no single factor has been clearly implicated for induction of spawning of carps in bundhs and rivers.

Management of broodfish and nursery ponds

Broodfish is a prerequisite for all induced breeding programmes. Proper broodstock will lead to better breeding responses, increased fecundity, fertilization, hatching and larval survival rates and more viable fish seed. Hence, the subject of broodfish management has assumed great importance in hatchery management.

Carp broodfish pond. Carp broodstock ponds are generally large (0.2-2.5 ha), 1.5-2.5 m deep, rectangular, seasonal or drainable and earthen in nature. Water inlet and outlet should be such that they simulate riverine/fluviatile conditions, which is the natural habitat for IMCs and Chinese carps.

Source of broodfish. Since selective breeding and hybridization programmes of pedigreed fish are not carried out in fish seed farms, the source of broodfish is stock ponds from the same farm or different farms. In order to avoid inbreeding in a hatchery, it is necessary that fresh fish germplasm from natural sources or other hatcheries is introduced regularly with timed periodicities. If this is not done, inbreeding depression may set in, which has been reported to have occurred in some carp hatcheries in India (Eknath and Doyle, 1985).

Care of broodfish. The recommended stocking density of carp broodfish is 1 000-3 000 kg/ha, depending upon the species. Systematic studies on nutritional requirements of carp broodfish are limited. It is customary to feed carp broodfish with a traditional diet consisting of rice bran and oil cake (1:1 ratio) at a feeding rate of 1-2 percent of their body weight daily. In addition to the artificial feed, the grass carp is also given tender aquatic weeds/terrestrial grass. However, the breeding habits of some species like common carp demand their separation from other carp species due to their natural breeding in ponds with aquatic vegetation. As a result the common carp broodfish is segregated sex-wise and stocked in separate ponds to prevent accidental spawning in pond. However, the rest of the species can be stocked in a communal pond or stocked in separate ponds after species-wise and/or sex-wise segregation. Catla, in particular, needs to be separated from the rest of the species as it shows poor response to hormonal injection when stocked with other species. It is believed that catla broodfish need special care and diet such that deposition of mesenteric fat in the maturation phase does not hinder gonadal development of the species.

Broodstock management practice in Kannataka State

Basavaraja *et al.* (1999) have described the carp broodstock management practice followed in Karnataka State. Proper broodfish management is a pre-requisite for successful spawning. The number and quality of eggs produced is significantly affected by the conditions under which the broodstock is maintained. The quality of broodstock diet, feeding regime, the quality of broodstock and water management are the principal factors that influence the condition of the broodstock. Most seed farms raise broodstock on their own farm and maintain them in ponds at densities of 1 000-2 500 kg/ha. The earthen broodstock ponds vary in area from 0.2 to 1.0 ha, with depth ranging from 1 to 2 m. Most farms use water from perennial reservoirs. The main steps in the preparation of broodstock ponds are: (i) control of aquatic weeds, which is done manually; (ii) eradication of unwanted fish by applying mahua oilcake at 2 000-2 500 kg/ha and pond liming at 100-200 kg/ha depending on the pH of soil and water; (iii) fertilizing the pond with cattle dung, at 15 000-20 000 kg/ha/yr or poultry manure at 5 000-10 000 kg/ha/yr to enhance heterotrophic food production. In addition, 200-400 kg/ha/yr NPK mixture is applied in split doses at fortnightly or monthly intervals. The initial dose of organic manure is reduced by half if mahua oil cake is used for eradicating unwanted animals. After stocking, the pond with carps that are one-year-old or more, are fed with a conventional feed containing a mixture of groundnut oilcake and rice bran (at 1:1 or 1:2 ratio) at 1-2 percent body weight once daily. To ensure better and timely development of gonads, fish breeders use a special broodstock diet (protein: 25-30 perecent) prepared using locally available cheap feed ingredients (Table 7.11.9). This diet is nutritionally superior, advances maturation and spawning by one or two months and results in increased fecundity and better seed quality.

Management of nursery ponds

Carp culture is carried out in three phases (three-tier system) comprising nursery phase (rearing three-day-old spawn to fry), rearing phase (rearing fry to fingerling stage) and grow-out phase (rearing fingerlings to marketable size). Of the three phases, the nursery phase is most crucial and needs greatest attention of fish seed farm managers. Jhingran and Pullin (1985, 1988) have reviewed the subject of nursery and rearing pond management.

According to Alikunhi (1957), under Indian conditions, the allocation of land for different types of ponds and other purposes can be described as: a four ha farm should be divided into: (i) nursery ponds, 0.2 ha; (ii) rearing ponds, 0.8 ha and (iii) stocking ponds, 3 ha. Considering the enhanced rate of stocking and survival of spawn, fry and fingerlings (Barrackpore, 1973), the ratio of nursery to rearing to stock ponds should be 1:40:1280. The preparation of nursery, rearing and stocking ponds before releasing the stocking material is an important step for successful rearing of carp spawn to fry, fry to fingerlings and fingerlings to table-sized fish. The occurrence of large-scale mortality of stocked spawn in unprepared nurseries is a common experience of fish culturists throughout the country. About 90-95 percent mortality of carp spawn in nurseries has been reported from Orissa State (Alikunhi, Chaudhuri and Ramachandran, 1952). On the other hand, Basavaraja and Antony (1997) obtained survival as high as 100 percent in the IMC nursery. However, the average survival of carp fry in nursery ponds does not normally exceed 30 perecent (Basavaraja, 1994), which is attributed to poor nursery

TABLE 7.11.9
Feed ingredients and their contribution to broodstock diet

Ingredients	%
Rice bran	25
Groundnut oilcake	25
Fish meal	10
Maize	10
Broken rice	10
Horse gram	10
Black gram	10

Source: Basavaraja *et al.* (1999)

practices. The three-day-old spawn is ready to accept external feed and is transferred to nursery pond where predatory fishes and insects, algal blooms and poor water quality are major causes of mortality.

Control of predatory and weed fishes

Predatory fishes are harmful to carp spawn and fry. They not only compete with stocked fish for food and space, but also directly prey on them. The term "weed fish" is used to include all species of uneconomic, small-sized fish that naturally occur or are accidentally introduced in ponds along with carp spawn. Weed fishes have high fecundity and mature in summer months and even breed in captivity, in the absence of rains. According to Alikunhi *et al.* (1952), even the young weed fishes directly feed on carp hatchlings and take a heavy toll as soon as they are released in nursery pond.

The common method of removing unwanted fishes from nursery pond is by repeated drag netting. However, certain bottom-dwelling fishes like murrels, catfishes and climbing perch burrow themselves in mud and are difficult to be caught by repeated dragging. The position worsens in ponds which cannot be drained completely. In such a situation the nursery should be poisoned using fish toxicants, plant derivatives, chlorinated hydrocarbons and organo-phosphates. Of these, the chlorinated hydrocarbons are perhaps the most toxic to fish. Organophosphates are generally less toxic to fish. Plant derivatives are least toxic and are widely used.

Plant derivatives. Derris powder, with 5 percent rotenone content, is probably the most commonly used fish poison in fish ponds. At doses of 4-20 ppm, most fishes, tadpoles and bottom dwelling organisms are killed. Even zooplankton and aquatic insects are destroyed to a great extent. The toxicity of the chemical lasts up to 4-12 days. The seed powder of *Barringtonia acutangula* kills a wide variety of fish at 20 ppm, with toxic effect lasting for 48 hrs. Tea seed cake (75-100 ppm) can be used both as a piscicide and a fertilizer. It can kill fish, tadpoles and insects. Mahua oil cake (cake obtained after extracting oil from the seed of the plant, *Madhuka latifolia*) is widely used to control predatory and weed fishes in Karnataka. Mahua oil cake (toxic component: saponin, 4-6 percent) is used as a fish poison at 200-250 ppm, killing fish within eight hrs and the toxicity lasts up to 96 hrs. Later, it acts as a pond fertilizer. Bleaching powder with 30 percent chlorine content, when applied at 25-30 ppm, kills all varieties of fishes, including catfishes, murrels, weed fishes and carps. The cost of treatment at 25-30 ppm is economical as it has the advantage of ready availability at low cost.

Fertilization

Fertilization is an important step in the preparation of nursery pond. The main purpose of manuring nursery pond is to stimulate the production of zooplankton, the most preferred natural food of carp spawn and fry. After liming (200-400 kg lime per ha, depending upon soil pH), nursery ponds are treated with organic manures such as cow dung (10 000 kg/ha) or poultry manure (5 000 kg/ha) and the small quantity of inorganic fertilizers (NPK at 200-400 kg/ha). When mahua oil cake is used as a piscicide for eradicating unwanted animals the dosage of organic manure is halved.

Aquatic insects and their control

The destructive role of insects in fish nurseries has been described by Khan and Hussain (1947), Alikunhi (1957), Chaudhuri (1960a), Ganguly and Mitra (1961) and Julka (1965). Nursery ponds are invariably populated with a large number of aquatic insects either in their larval and/or adult stages. They not only prey directly on carp spawn and fry but also compete with the latter for food. Of the eleven orders of the class Insecta, the members of the Orders Coleoptera, Hemiptera and Odonata are important in nurseries.

Predatory aquatic insects multiply rapidly in a nursery pond and they move from pond to pond. To ensure better survival of carp spawn, it is important to effectively clear the pond of its insect population prior to stocking. Repeated dragging of pond with a fine-meshed net can remove most of the insects. For effective control of insects, insecticides are recommended. Since the common insecticides adversely affect the zooplankton and fish spawn, it is recommended to use selective poisons which are capable of killing only the insects, but not the spawn and fish food organisms.

Spraying diesel or kerosene on the surface of pond is a well-known and routine practice in malaria control. CIFRI's substation in Orissa developed a method for the control of predatory aquatic insects, which consists of spraying, on a non-windy day, an emulsion of oil and soap in the ratio of 56:18 kg/ha (Pakrasi, 1954). Chatterjee (1970) advocated the substitution of soap with Teepol B-300 (a detergent) in the emulsion. The recommended dose of Teepol B-300 which is readily soluble in water and easy to mix with oil, is 560 ml, emulsified with 56 kg of mustard oil. Alikunhi (1956a) recommended the use of gammexane at 0.6-1.0 ppm which kills insects within 0.5 to 11 hrs. The Department of Fisheries of Maharashtra Government prescribed an emulsion prepared by mixing light speed diesel (1 l), the emulsifier hyoxide 1011 (0.75 ml) and water (40 ml) for every 200 m^2 water surface (Shirgur and Kewalramani, 1967). Butox (a veterinary drug used to heal wounds in livestock) at 2 ml per 100 m^2 can effectively control all types of aquatic insects.

Stocking of nursery pond

Nursery pond is stocked with 3-day old spawn when adequate plankton appears in it. For maximum survival of spawn, nurseries should have a rich crop of zooplankton, preferably rotifers and cladocerans. According to Alikunhi (1957), a minimum of 1.5- 2.0 ml zooplankton in 54.5 ml water is essential for satisfactory stocking of the pond. Mitra and Mohapatra (1956) suggested that the optimum density of zooplankton in a nursery pond is 0.1-0.33 ml per spawn. Alikunhi (1956a) recommended a stocking density of 10-20 million/ha, depending upon the plankton density. Much higher stocking densities [78.13 million spawn/ha as mentioned by Hora and Pillay (1962)] are known to be adopted by fish farmers. In well manured nurseries provided with artificial feed, 1.0-2.0 million spawn has been stocked with satisfactory results at the Pond Culture Substation of the CIFRI. Sen (1974) reported stocking pawn at a high density of 10 million/ha with a survival rate as high as 66.6 perecent. Tripathi *et al.* (1979) reported stocking rohu spawn at an average rate of 10.21 million/ha with an average survival rate of 80.73 percent, leading to the production of 8 million fry in a single crop, during 11-12 days rearing. The stocking of a nursery pond is best done either in the morning or early evening.

Supplemental feeding

The stocked spawn immediately start feeding on microscopic zooplankton. The spawn feed so voraciously that within 2-3 days after stocking the density of plankton gets reduced significantly. It is known that a single specimen of live carp spawn (6.5-7.2 mm) consumes 3-34 cladocerons within an hr; the actual number depends on the size of the spawn. Alikunhi (1956a) found that during the first two days after feeding commences, the spawn do not take artificial feed but subsist mainly on natural food. After this period, both artificial and natural feeds are utilized by the larvae. The commonly used feed for IMCs and exotic carps is a mixture of rice bran and oilcake composed of groundnut, coconut, mustard, etc. The quantity of artificial feed to be given daily depends upon the weight of the stocked spawn (Alikunhi, 1957; Hora and Pillay, 1962). While the former recommended feeding rates of 200, 300 and 400 percent of body weight of the spawn during the first five days, sixth to tenth day and 11th to15th day after stocking, respectively, the latter advocated 100, 200 and 300 percent feeding rates for the corresponding periods. Artificial feed is either broadcasted on the surface of water or fed as a thick paste (dough) in the form of small balls.

Khan (1971) and Nandeesha (1995) reviewed the literature on the practice of artificial feeding in Indian freshwater aquaculture. Although a great deal of literature is available on the nutrient requirements of sub-adult and adult fish, very little information is available on the nutrient requirements of fish spawn and fry.

Rearing ponds

Spawn stocked in nursery ponds normally attain a length of 20-25 mm in 15 days with artificial feeding, giving survival rates ranging from less than 10 percent to as high as 95-100 percent. If the fry is to attain better growth and survival, it should be netted out and released in rearing ponds. The rearing ponds are pre-prepared more or less on the lines of the nursery ponds (Alikunhi, 1956a). The rearing ponds form the second phase of carp culture and are used for growing fry to fingerlings by providing more space and food so that they reach the latter size as early as possible. The rearing period may vary between 2 and 3 months.

Rearing of carp seed in pens/cages

Carps are generally grown in ponds with little water exchange. The alternatives are cage and pen systems. These can be used for rearing spawn, fry and fingerlings. Cages and pens in flowing waters can enjoy an abundant supply of oxygen, flushing of metabolic wastes of the stocked fish and nutrients from the catchment area. Grow-out of fish in cages is well known in the Indo-Pacific region, but the rearing of fish seed in pens, located in running waters, has not been widespread.

In India, rearing of major carp seed in pens located in the Bhavanisagar and the Tungabhadra reservoirs was carried out as early as 1978. Abraham (1980) reported the use of pens for rearing carp hatchlings. Swaminathan and Singit (1982), Basavaraja (1994) and Gireesha *et al.* (2003) conducted investigations on rearing carp spawn up to fingerlings in the periphery of the Tungabhadra Reservoir, located in Karnataka. Rearing of common carp fry up to fingerlings in pens installed in an irrigation tank was also demonstrated (Jayaraj, Devaraj and Chowdary, 1998).

Rearing of carp seed in pens in the Tungabhadra Reservoir

In the early 1980s, initial trials were conducted to establish pens in the periphery of the Tungabhadra Reservoir (Swaminathan and Singit, 1982). The main objective was to nurse the delicate carp spawn in pens up to fingerling stage and then stock them in the same reservoir in order to improve fish landings and boost the socio-economic status of fisherfolk. Since then, the practice of raising carp spawn up to fingerlings has become well-established.

The Tungabhadra Reservoir has a water spread area of 37 814 ha and offers vast scope for fish production. It produced 24 tonnes in 1954–1955 and 4 200 tonnes in 1981–1982 consisting mainly of catfishes, minor carps, minnows, etc. With the release of pen-reared carp fingerlings starting from 1982, the major carps, which were not formerly part of the catch, accounted for nearly 60 percent of the total catch in 1994.

Basavaraja (1994) and Gireesha *et al.* (2003) described the method of rearing carp seed in pens, located in the Tungabhadra Reservoir. An ideal site for a pen system will generally have a gentle slope with red loamy soil where water remains for a period of 2-3 months between August and November. The site should be well-protected from wind and wave action by small hill surrounding the area. A pen is normally made up of casuarina poles, 2 m high, fixed at intervals of about 1.2 m, enclosing an area of 200-5 000 m^2. Between the vertical poles, three horizontal rows of spilt bamboo stripes are tied to give support for the net materials. Close mesh (monofilament nylon fabric, 30 mesh) having a width of 1.5 m is used as the pen wall material. The bottom of the nylon fabric is inserted firmly into the mud and the vertical part securely tied to the poles and bamboo strips. Pen preparation starts 15-20 days before the dam reaches its full level. After establishment of pen, the enclosure is limed, fertilized with cattle dung and treated with soap-oil emulsion. The water in the pen is about 1.0-1.2 m deep. The pen is then stocked with 3-day old major carp larvae (4-5 million/ha), produced in the adjacent fish seed farm, fed thereafter from a boat, with a mixture of groundnut oil cake and rice bran at a ratio of 1:1. In addition, the pens are periodically manured with organic and inorganic fertilizers to sustain production of zooplankton. There is a basal application of 10 000 kg cow dung, 400 kg urea and 100 kg super phosphate per ha, followed by monthly applications at 10 percent of the initial dose.

Survival to 70-80 mm fingerlings is as high as 60 percent after three to four months. Periodic sampling is done to monitor growth and adjust the feed quantity. The fingerlings thus grown are stocked in the same reservoir to enhance major carp production. Fishing licenses are given to local residents to uplift their socio-economic status. Although the pen construction is simple, easy, less expensive and efficient for the nursery rearing of carp fry, one drawback is the shortage of area for large-scale pen operation.

FISH SEED QUALITY

India is the second largest producer of farmed fish and shellfish in the world, next only to China. The rapid growth of aquaculture in Asia in general and India in particular has been due manly to ready availability of fish seed to farmers. Even though the seed of the major cultivated species are now produced in large quantities in hatcheries, poor quality is still perceived as a major constraint to expansion of fish culture in India. Other constraints to carp culture in India have been underlined by Basavaraja (1994). Poor quality seed can have a deleterious effect on fish production and broodstock development. In contrary, quality seed will help realize better returns from aquaculture. Little, Satapornvanit and Edwards (2002) have emphasized the importance of freshwater fish seed quality in Asia and suggested criteria for selecting good quality seed for aquaculture.

In India, the availability of quality fish seed at the right time and at the right location is a prerequisite for sustainable aquaculture. Although carps, both indigenous and exotic, catfishes and murrels make up the bulk of fish raised in the country, several other species like mahseer, hilsa, trout, gourami, etc. are also important.

After the technique of hypophysation of fish was developed in India in 1957, the seed production from this source was initially restricted to the State Fisheries Departments. Bundhs as a source of carp seed has been in trend for years. A number of agencies (both government and private) are now involved in fish seed production and distribution, often as part of complex networks. In addition, seed production by farmers themselves is now widely practiced in India. However, there is still a shortage of quality fish seed.

In genetic terms, quality seed may be defined as those having better food conversion efficiency, high growth rate potential, better ability to changing environmental conditions and resist diseases (Padhi and Mandal, 1999). While the ease of production of fish seed in India has revolutionized farming, there now appears to be a major problem of poor or substandard quality seed supplied to farmers and entrepreneurs. The possible underlying causes for the gradual deterioration in yields and individual size of many species of cultured fish in Asia have been reviewed by Little, Satapornvanit and Edwards (2002). The quality and management of broodfish and hatchery practices that lead to inbreeding or contamination, in addition to poor husbandry during nursing, handling or transportation have been implicated. Prevalence of pathogens and parasites may also result in poor performance of fish seed. Attempts to upgrade stocks with wild or improved fish are currently practiced, but these (selective breeding and or hybridization programmes) have rarely been applied in aquaculture in India. For most species including carps, basic knowledge of genetic parameters is limited. Simple but reliable methods that can be used at the hatchery or farm gate to assess seed quality are lacking for freshwater fish. On the other hand, challenge/stress tests and morphological and molecular diagnostic kits are now available for testing shrimp seed quality in India.

Causes for poor seed quality

The reasons for the gradual deterioration in fish yield and individual weight of many farmed fish are not very clear. Improper production and delivery of seed to farmers or poor management of fish seed by farmers once stocked, may lead to decline in fish production.

Poor pond hygiene. Mass mortality of seed in carp nursery ponds has been frequently encountered in Karnataka (Mohan and Shankar, 1995). Mortality of seed is attributed mainly to prevalence of protozoan parasites, particularly in ponds which are not dried properly prior to stocking. Pond drying followed by liming is known to reduce mortality considerably and improve seed quality.

Presence of pests. The presence of fairly shrimp (*Streptocephalus* spp.) in carp nurseries is known to hamper its growth and survival by competing with fry for food, space and oxygen. Presence of weed fishes in nursery ponds was also known to affect production of carp seed.

Inbreeding. Since carps are highly fecund, hatchery operators tend to maintain a low effective population size (number of broodstock that contributes genetic material to the next progeny) and do not exchange broodfish between hatcheries. Poor performance of the resultant seed had been linked to inbreeding of carps in India (Eknath and Doyle, 1985). A communal or mixed spawning system for major carps in West Bengal is being practiced and is known to produce approximately 10 percent hybrids (Padhi and Mandal, 1997). This technique may lead to loss of genetic purity of important major carps. Fish farmers often complain about poor growth of fish procured from particular hatcheries (seed farms) and feel that such fish do not reach marketable size within the stipulated period. This is also attributed to inbreeding.

Poor management of brood fish and Seed. Competition among fish seed producers to meet demand sometimes leads to poor management of broodfish and fish seed which may negatively affect seed quality. Substandard quality seed are frequently observed as a result of high stocking density in nurseries. Reddy (1995) thought that most fish hatcheries in India are concerned more about the quantity rather than the quality of fish seed and produce them without following any selection norms. Consequently, seed suffer from high rates of mortality, poor growth and high susceptibility to diseases and parasites.

Transportation stress. During transportation, fish seed are subjected to confined environment, higher metabolic load, stress, strain and exhaustion. As a result, seed becomes susceptible to diseases and parasites.

Conditioning of fish seed. One type of challenge test, conditioning is nothing but acclimatizing seed to a restricted environment prior to packing and transportation. During this period, seed are stocked at a very high stocking density in a *hapa* or a pond with running water, but without provision for food so that the weak seed dies and only the healthy fry survives. Only seed that survives the `stress test' is selected for transport to a required destination. This type of conditioning of fish seed is commonly practiced in several states of India.

Mortality of hatchlings. Fish farmers in West Bengal at times encounter heavy mortality of hatchlings during incubation period (Sinha, 2000). This was reportedly due to immature bursting of egg shells and release of premature hatchlings before the anticipated period of hatching. Such hatchlings either do not survive or suffer mortality at subsequent stages. To overcome this problem, fish farmers have been using a solution which is a mixture of extract of catechu (*Acacia catechu*) and Myrobalan (*Myrobolus indica*). The plant extract enhances hatching period and prevents hatchlings from premature release due to the presence of tannin which helps toughen the egg membrane (chorion).

Diseases and parasites

Fish culture in general and carp culture in particular is gaining significant momentum in several parts of India. A large number of carp hatcheries and seed farms have cropped up in several parts of the country to cater to the increased demand for seed. High stocking density, artificial feeding, water fertilization, etc. have become common husbandry practices to optimize returns in carp nursery and rearing systems. These high density systems offer the ideal environment for disease outbreaks. Depending on the nature and severity, the disease may cause mass mortality of the affected population in a short time, produce protracted small scale mortality, reduce growth and make the larvae unsuitable for stocking. The need for adopting suitable health management measures to reduce the loss due to diseases is being increasingly felt by hatchery operators.

Common disease problems in carp hatcheries and early rearing systems

Carp hatcheries are regularly faced with disease problems. The nursery and rearing systems of carps are often very rich organically and provide an ideal environment for many pathogens. Important problems in hatcheries and early rearing systems are caused by some of the following pathogens (Mohan, 1998):

- Protozoan parasites like *Ichthyophthirius multifilis* (white spot disease), *Trichodina* complex and ectodermal ciliates like *Epistylis* and *Vorticella*. All these ectoparasites can cause mass mortality of younger stages of carp very quickly and the situation becomes worst in waters with low oxygen and high organic matter.
- Diseases caused by myxosporidians are a serious threat to the fish seed farms. These sporozoan spores present in the pond soil are normally ingested by the developing fry. Once inside the target tissue, the sporozoans can cause massive destruction of their target tissue and produce large scale mortality.
- Worm parasites like *Dactylogyrus* (gill fluke) and *Gyrodactylus* (skin fluke) with their well-developed attachment haptor and feeding apparatus can cause mortality in early developmental stages of carps.
- Opportunistic secondary bacteria (*Aeromonas*) and fungi (*Saprolegnia*) can become serious problem in fish larvae which are heavily parasitized.
- In carp rearing ponds, major problems are because of larger ectoparasites, secondary invaders, systemic bacterial pathogens and viruses. Ectoparasites like *Dactylogyrus* and *Argulus* (fish lice) and endoparasites like sporozoans are very important. Bacterial problems like surface ulcerative conditions and acute systemic diseases are common in carp rearing systems. Oftentimes, mortalities seen in carp culture systems are a result of ectoparasitic and systemic bacterial diseases. External fungal problems are normally associated with fish which are poorly handled. The possibility of viral diseases causing mortalities in carp nurseries cannot be ruled out.

Bacterial and fungal diseases in carp rearing systems

Bacteria can cause diseases either as secondary invaders or as primary pathogens. Bacterial diseases in larvae can be broadly classified as surface ulcerative, acute systemic and chronic granulomatous type. Surface ulcerative type of diseases are characterized by haemorrhagic surface ulcers and are normally caused by *Aeromonas, Pseudomanas, Vibrios, Flexibacteria, Myxobacteria*, etc. Surface ulcerative disease conditions at times develop to acute systemic disease. These are characterized by the presence and proliferation of bacteria in internal organs like kidney, heart, spleen, blood and other visceral organs. These diseases produce significant necrotic changes in all the affected organs and can cause mortality in a short time scale. Bacterial haemorrhagic septicemia caused by numerous serotypes of *Aeromonas hydrophila* is a major problem.

Reports of viral diseases in freshwater carp rearing systems of India are very few. This may be due to the lack of facilities and personnel for viral disease investigations.

Fish seed reared under controlled condition are particularly stressed making them prone to parasitic and nonparasitic infection. Prophylactic measures are taken for the diseases encountered. The affected fish are normally treated with solution of either $KMnO_4$ (3-5 ppm) or common salt (3-4 percent) or $CuSO_4$ (2-3 ppm) for all common bacterial and fungal diseases and with gammaxane for fish lice infection.

Mohan and Shankar (1995) reported mass mortality of 12-15 day old catla fry in a fish farm in Karnataka. The fry stocked in nursery ponds were found to have dark coloration, lethargic, swimming in circle, settling at the bottom and dying in large numbers. The entire stock of more than one million fry died within 3-5 days of appearance of the first clinical signs. Histological tissues sections of gills and kidney positively confirmed massive infestation by the myxosporidian *Myxobolus* spp. Fresh examination of gill smears made from several moribund fry consistently showed the presence of large numbers of *Myxobolus* spp. spores (Mohan and Shankar, 1995). As

TABLE 7.11.10
Treatment chart for common disease conditions of carp larval rearing systems

Disease agent	Chemical	Method	Concentration/time
1. Ectoparasitic protozoans			
a. *Ichthyophthirius* spp.	Formalin	Short bath	60-100 ppm for 30 min
b. *Trichodina* spp.	Formalin	Long bath	20-30 ppm
c. *Epistylis & Vorticella* spp.	Formalin	Dip	200-300 ppm for 1 min
d. Ichthyobodos spp.	Formalin	Dip	20-30 ppm for 30 min
2. Monogenetic worms			
a. *Dactylogyrus* spp.	Organophosporus pesticides	Dip	10 ppm for < 1 min
b. *Gyrodactylus* spp.	Nuvan, Dipterex	Long bath	0.5 ppm for 24 hrs
3. Crustaceans			
a. *Lernaea*	Nuvan, Dipterex	Long bath	0.5 ppm for 24 hrs
b. *Argulus*	Nuvan, Dipterex	Long bath	0.5 ppm for 24 hrs
4. Endoparasites			
a. Sporozoans	Nuvan, Dipterex	Long bath	0.5 ppm for 24 hrs
b. Cercaria and metacercaria of digenetic trematodes	Nuvan, Dipterex	Long bath	0.5 ppm for 24 hrs
5. External Mycosis *Saprolegnia*	Malachite green Formalin	Dip Bath Bath Dip	60 ppm for < 1 min 1-2 ppm for 1 hr 50-75 ppm for 30 min 100-200 ppm for 1-3 min
6. Surface bacterial diseases	Proflavine Oxytetracycline & Furnace	Bath Short bath	20 ppm 1-5 ppm
7. Systemic bacterial diseases	Furazolidone Oxonilic acid Chloramphenicol	In feed In feed In feed	50 mg /kg fish/day 10 mg/kg fish/day 50 mg/kg fish/day

Source: Mohan (1998)

there was no known effective systemic therapy for histozoic sporozoans in fish, it is vital to prevent the infestation in nurseries by resorting to drying and liming of the pond. Mohan *et al.* (1999) observed acute and chronic mortalities of common carp seed due to invasion of metacercaria of a digenetic trematode (*Centrocestes* spp.). Histopathological examination indicated that the metacercaria can be highly pathogenic when they encyst in the integument and gills.

Four separate cases of mortalities due to the dinoflagellate, *Piscinoodium* spp. in fry of common carp, mahseer (*Tor khudree*) and tilapia reportedly occurred in rearing tanks of a fish farm in Mangalore (Ramesh *et al.*, 2000). Mortalities coincided with decreasing temperatures in the months of September and October. Clinical signs consisted of rust or dust coloured appearance of the skin, lethargic swimming near the surface, gasping accompanied with conspicuous daily mortalities. In three cases, where the size of juvenile was small, mortalities reached 100 percent. They attributed the observed mortality to massive gill and skin pathology induced by the attachment and feeding of the parasite.

Gas diseases. Heavy mortality of catla (10-12 in size) due to gas disease was observed in a municipal pond of Madras during 1947 (Chacko and Job, 1948). The symptoms of the diseases were presence of gas bubbles in gill filaments, heart and blood vessels and also in the gut. The air bladder was highly distended. The gas disease also referred to as gas embolism which occurs due to super saturation of water with either oxygen or nitrogen and is generally encountered in fish nurseries.

The crustacean parasites (*Lernaea* and *Argulus*) infestations are often encountered in carp broodfish, with catla being the most susceptible species (Basavaraja, 1994). The remedial measures taken by fish breeders are: (i) manual removal of the parasites and (ii) subsequent treatment of fish with a solution of $KMnO_4$ (5 ppm) for 5-10 min.

FISH SEED MARKETING

Fish seed syndicate

Until the 1980s, Fish Seed Syndicate, Calcutta was the major supplier of fish seed to different states. Seed dispatches made by the Syndicate between 1959–1960 and 1981–1982 indicated that Maharashtra and Madhya Pradesh were consistent buyers (Singh and Gupta, 1984). Maharashtra's purchase of fish seed increased from 43 lakhs in 1959–1960 to 402 lakhs in 1981–1982, while Madhya Pradesh's purchases of fish seed increased from 82 lakhs to 301 lakhs. The other states also procured seed from the Syndicate, but not regularly. The percentage expenditure on fish seed varied across the states and was the highest (18.9 percent) in Karnataka and the lowest (3.4 perecent) in Assam. While some farmers preferred seed supplied by Department of Fisheries, FFDAs and Corporations, other farmers preferred seed supplied by the private sector (Sreenivasa Rao, 1984). No state has attempted to integrate seed production and marketing. There exists a lot of variation in the price of carp seed between private and public sectors and even within private farms or public farms. The productivity and profits of private farms have been found to be better than that of public seed farms. Transportation of fish seed from site to market is one of the most important activities in fish seed marketing. Besides head load, other means of transportation include bicycle, tricycle, slings, jeep, tempo, etc.

Seed selling rate

Seed selling rate of fry and fingerlings not only varies with size and species, but also from region to region and from state to state. For example, the selling rate of carp seed adopted by Department of Fisheries, Karnataka (Table 7.11.11) is different from that of Tamil Nadu. In Karnataka, like in other states, the price of fingerlings is highest. While the price of fry is next highest, the selling rate of spawn is least.

In Tamil Nadu, the selling rate of fingerlings of catla, rohu, mrigal and common carp is Rs 480, 300, 300 and 270, respectively. Among the carps, the silver carp and grass carp command the maximum price in Karnataka, whereas catla fingerlings fetch the highest price in Tamil Nadu. Other charges, if any, are shown separately. Although it is not possible to have a uniform rate for the entire country due to vastness, it should be possible to have a uniform rate at state level.

Data on fish seed production is highly variable. Another gap in fish seed data is the absence of grading system of fish seed, i.e. spawn, fry and fingerlings. The sizes are not standardized. Various agencies classify them differently and size grades recommended by different agencies are listed by Katiha (1999) (Table 7.11.12). The general classification of carp seed is presented in Table 7.11.13. It neither provides information regarding source nor species composition.

TABLE 7.11.11
The selling rate of carp seed adopted in Karnataka

Sl. no.	Description	Price (Rs) per 1000
1. Catla		
	a. Spawn	22
	b. Fry	78
	c. Fingerlings	258
2. Rohu		
	a. Spawn	18
	b. Fry	59
	c. Fingerlings	240
3. Mrigal		
	a.Spawn	15
	b. Fry	53
	c. Fingerlings	210
4. Common carp		
	a. Spawn	10
	b. Fry	35
	c. Fingerlings	210
5. Grass carp		
	a. Spawn	40
	b. Fry	125
	c. Fingerlings	400
6. Silver carp		
	a. Spawn	40
	b. Fry	125
	c. Fingerlings	400
7. Other charges		
	a. Plastic bags	4
	b. Oxygen filling per bag	2
	c. Packing charges	4

US$ 1 = INR 45 (July, 2007)

Source: Department of Fisheries, Government of Karnataka

TABLE 7.11.12
Fish seed grades according to different sources

	Source	Grade (mm)			
		Spawn	Fry	Fingerlings	Advanced fingerlings
1	Fish Seed Committee	0-8	8-40	40-150	-
2	National Committee on Agriculture	0-8	8-25	120-150	-
3	Fish Seed Syndicate	-	Up to 25	31-150	-
4	Private Trade in West Bengal	0-8	8-40	41-100	100-230
5	Indian Institute of Management, Ahmedabad	0-10	10-25	45-50	120-155

Source: Katiha (1999)

Like in many other states, in Uttar Pradesh, the Department of Fisheries is the main agency involved in managing fish seed farms and seed procurement. The World Bank provided loan for development of fisheries and as a part of loan agreement, the Fisheries Corporation was started during 1979–1980 with the primary objective of fish seed production and its marketing on a commercial scale. A survey conducted by Indian Institute of Management (IIM), Ahmedabad, which is solely responsible for collection of data on fish seed production and marketing in India, showed that the public rearing farms were running at huge losses in Uttar Pradesh (Sreenivasa Rao, 1984). Private rearing farms were both efficient and profitable. Similar situation exists in many other states including Karnataka (Krishna Rao, 2005).

TABLE 7.11.13
Classification of fish seed

Sl. no.	Name of fish seed	Size (mm)	Uses
1.	Spawn/hatchling/larva	5-10	For stocking nurseries and suitable for economic transport over long distance or long periods
2.	Early fry	15-25	For stocking rearing ponds or other small shallow ponds and transport (as above)
3.	Fry	26-40	For stocking small culture ponds and small transport
4.	Advanced fry	41-60	For stocking small ponds in semi-intensive systems
5.	Early fingerlings	61-80	For stocking medium sized shallow ponds
6.	Fingerlings	81-100	For stocking medium sized deeper ponds in semi-intensive systems, ponds and pens
7.	Advanced fingerlings	101-125	For stocking large ponds and tanks, pens and cages in semi-intensive systems
8.	Juveniles	126-150	For stocking large ponds, reservoirs and tanks, pens and cages, running waters, intensive systems
9.	Yearlings	151-200	For stocking reservoirs with major catfish population

Source: Internet (www.India-agronet.com)

Transportation of fish seed and broodfish

Transportation of fish seed

Transportation of fish seed is gaining increased importance due to the ever increasing global trade in live fish. Successful transportation of fish seed from the site of production to the place of culture is an important factor which influences the viability of aquaculture. Traditional methods of transporting fish seed in *hundies* (earthen or aluminium pots) results in heavy mortality of fish seed during transport. The main reasons for the mortality of seed during transportation are: (i) lack of oxygen, (ii) accumulation of metabolites like ammonia, CO_2, faeces, etc., (iii) hyperactivity, strain and exhaustion, (iv) diseases and parasites and (v) physical injury.

Now, with the innovative changes brought about in the system, complemented by the technological breakthrough achieved in aquaculture, fish seed and broodfish transportation has become fairly dependable and safe, although there is still ample scope for further refinement. In general, the methods for seed transport can broadly be classified into two systems: (i) open system, where seed transported with or without aeration/oxygenation/water circulation and (ii) closed system, where seed are transported in sealed air-tight containers with oxygen/aeration.

Open system

Until the late 1940s, fish seed were mainly transported using traditional methods. Under this method, prior to transportation, fry and fingerlings were conditioned to empty their digestive tract and move in a restricted area during transport (Figure 7.11.9). Alikunhi (1957) thought that the fry can possibly stand the strain of long distance transport better if they are fed on animalcules like cladocerans during conditioning and transport. The most common method of conditioning is to store fry in a cloth hapa in ponds or in a still part of the river. Saha and Chowdhury (1956) suggested that the depth of water where a conditioning enclosure is to be installed should be 30-35 cm. The period of conditioning depends on the size and health of the spawn, fry and fingerlings. Jagannadhan (1947) indicated that catla fry need 48-72 hr of conditioning, while Alikunhi (1957) suggested that about 6 hr of conditioning is required before fry should be packed for transportation. During conditioning and transportation, fry and fingerlings should not be handled with bare hands to prevent the removal of slime and scales covering the body that will render them susceptible to fungal and bacterial infection (Jagannathan, 1947). After the fish seed have been properly conditioned, they are ready to be transported (Hora and Pillay, 1962). Saha and Chowdhary (1956) described the traditional method of transporting fry and fingerlings in *hundies*, practiced in Bengal. A traditional *hundi* is an earthen vessel, but later aluminium *hundies* were introduced. Though the *hundies* are of variable sizes, they are generally of two types, the smaller one has 22 cm mouth diameter and 23 l capacity carried as a head load and the other larger one has 23 cm diameter and 32 l capacity used for transport by rail or bicycle or as slings. The *hundies* are filled with water from the same source as the fry and they are stocked at 50 000 in the smaller and 75 000 in the larger ones. About 58 g of fine silt is sprinkled over the water surface in the *hundi.* During transport, the *hundies* are shaken periodically. Basu (1951) reported that addition of silt not only coagulated the suspended organic pollutants but also kept down the zone and extent of pollution. Saha and Chowdhury (1956) observed that addition of silt, removal of sediments by mopping them up with a rough cloth rope and partial exchange of water permitted transport up to a duration of 30 hrs. Saha, Sen and Mazumdar (1956) demonstrated that pulverized earth, activated charcoal and Amberlit tend to absorb carbon dioxide and ammonia from the medium, consequently increasing the survival of fry.

Improved open metal containers have increasingly come into use and are known to have an edge over earthen *hundies*. These are round vessels with a wide mouth, which can be closed with perforated pressed-in lids, the larger type being 53 cm diameter at the base, 20 cm at the mouth and 38 cm high. Transport of carp seed in aluminium pots mounted on bicycle or tricycle is a common sight in Kolkata (Plate 7.11.9). Another container traditionally used for the transport of fish fry and fingerlings is galvanized round tin carriers with a flat bottom of about 40-50 l capacity. The inner lid is perforated and dish-like and it serves as well for aeration by cascading down the water splashed into it during transportation.

PLATE 7.11.8

Photographs showing fish seed transport activities

Measurement for packing and transport

Head load

As slings

Cycle rickshaw

PLATE 7.11.9
Photographs showing fish seed trade activities at Kolkata

A woman involved in fish seed collection and tempoarry storage

A fish seed market at Niati, Kolkata

Carp fingerlings being weighted at a Kolkata fish seed market

Catfish being sold at a Kolkata market

In other parts of the country, the open method of transportation of fish seed is getting out of use mainly because it involves constant vigil and frequent renewal of water on long journeys. And also it is not economical to transport bigger fingerlings and adults in small packing units. For this purpose, truck-mounted open tank with facilities for mechanical aeration and/or water circulation were initially used quite successfully (Hora and Pillay, 1962; Patro, 1968).

Closed system

In the closed system, the source of oxygen is not air, but oxygen which is supplied with a cylinder, into an enclosed space above the water. In the early 1950s, CIFRI (Barrackpore) introduced the 18 l kerosene tins with air-tight screw-capped lids, provided with tubes for draining in oxygen from a cylinder and letting out displaced water. About 900-1 000 fry (1-2 cm long) could be conveniently transported by air for over 20 hours.

The Maharashtra State Department of Fisheries gets the credit for introducing polythene bags for the successful transportation of major carp fry. The fry (20-25 mm) were transported in polythene bags (840 mm × 610 mm; thickness 0.0622 cm) inflated with oxygen, kept in kerosene oil tins (18 l), from Calcutta to Bombay. Ranade and Kewalramani (1956) found that such bags approximately double the quantity of fry transportable compared to that being shipped through the *hundies.* Singh (1977) proved that rohu fingerlings need greater quantity of oxygen for transport during the same period than mrigal; the oxygen required for 50 fingerlings of rohu (109-126 mm) for transport during a 12 h period is 1 680 ml against only 475 ml for mrigal (98-100 mm) at 31 °C to 32 °C.

In Karnataka State, carp seed are commonly transported by road in 18 l capacity high-density polythene bag containing one third water and two thirds pure oxygen, sealed and packed in rectangular metal boxes (Basavaraja, 1994). The number of seed to be packed in each bag depends upon the size (from 2 000 -10 000, 600-700 and 150-200 for spawn (<8 mm), fry (8-40 mm) and fingerlings (40-150 mm), respectively. In Karnataka and Andhra Pradesh, fish farmers have, over the years, developed a method for transporting fish fry and fingerlings in large (1 000 l) plastic tanks, with continuous oxygenation during the journey hrs.

Transport of yearlings and brood fish

It is impossible to transport bigger fingerlings/yearlings and brood fish in small packing containers. For the transport of yearlings and broodfish, trucks mounted with open tanks which facilitates mechanical aeration and/or circulation were initially used quite successfully (Hora and Pillay, 1962; Mammen, 1962; Patro, 1968). Open canvas containers (1 m × 1 m × 1.25 m) are used in Punjab and Madhya Pradesh for transporting major carp breeders. In addition, galvanized iron drums of 180 l capacity are also used.

In India, two successful models of closed system carrying live-fish were designed. One is based on Mammen (1962), which is called ‘splashless tank’. The later model of the ‘splashless tank’ is a ‘petrol tank’ design with 1 150 l capacity and an autoclave-type lid. It has a built-in aeration system for supplying compressed air, which works on a belt driven by the engine of the transporting vehicle. An oxygen cylinder is carried only as a stand-by for emergency. The inner surface of the tank is lined with U-foam which prevents physical injury to live fish during transport. Live fish with a total weight of about 250 kg or 90 000 carp fingerlings can be transported at a time in the "splashless tank". The load ratio of fish to water in this type of carrier is about 1 kg of fish per 4.5 l water.

Patro (1968) designed another live fish carrier which consists of a laboratory gas supply design type. It has an outer chamber of 120 cm diameter open from top and a slightly smaller one closed from top; the latter, during transport, fits inside the former. The top of the inner chamber is provided with an air vent and an oxygen valve. The outer chamber serves as a storage tank and is initially filled with water along with fish to be transported. The inner chamber, which is slipped from the upper open end of the water serves as an oxygen holding chamber at its top and is lined throughout with U-foam to prevent fish from sustaining injury during transport. This double-barrel type carrier can transport live fish with a total weight of 100 kg at a time.

Use of anaesthetics in live fish transport

Sedation would reduce the metabolic activity and decrease oxygen consumption by fish. It also reduces the excretion of ammonia, carbon dioxide and other toxic wastes. It controls the excitability of the fish, thereby reducing the chances of injury and the time required for handling them. However, care should be taken in selecting the sedative and also its dosage. Sedation should be such that it should not totally suppress the escape reaction of fish and it should be possible to revive the sedated fish quickly. Sodium amytol at 21 to 28 mg/l water, MS 222 at 50 ppm, urethane, thiouracil, quinaldine and hydroxyl quinaldine at 100, 10, 5-10 and 1 ppm, respectively, and quinaldine at 5 ppm are successfully used for the transport of fish seed, fingerlings and broodfish.

Use of antiseptics and antibiotics

The accidental introduction of infectious diseases and parasites along with fish consignments is a possibility that must be guarded against. This calls for prophylactic measures like the use of antiseptics and antibiotics in the transport medium or short-term bath prior to transport. The recommended chemicals and their dosages are given in Table 7.11.14.

TABLE 7.11.14
Recommended chemicals and their dosages for use in the transport medium

Chemical	Dosage (mg/l)
Acriflavine	10 ppm
Methylene blue	2 ppm
$CuSO_4$	5 ppm
$KMnO_4$	3 ppm
Chloromycetin	8-10 ppm
NaCl	3 percent
Formalin	15 ppm

FINANCING FISH SEED PRODUCTION

Though fish farming and fish seed production have been found to be a profitable business venture, financing for this sector has not been formalized. Funding agencies and banks are not fully convinced about the potentials of fish seed production. Recently, the National Bank for Agriculture and Rural Development (NABARD) is known to have modified its policy of direct funding and has come forward to provide financial services through primary societies at the village level. Although commercialized banks provided loans for fish seed production, not many farmers can avail of loans due to risks involved in it. Pathak (1990) discussed the commercial success of fish hatchery projects funded by International Development Association (IDA) and NABARD. IDA supported the construction of 27 modern fish hatcheries. Of these, NABARD sanctioned 18 fish hatcheries in the corporate sector and 9 in the private sector. In addition, NABARD also supported several carp seed production programmes in many states. In addition to the modern mega-hatcheries, several mini-hatcheries involving credit outlay approximately Rs 6 million was supported in the private sector in some states. Most of these hatcheries have become operational and are producing seed of commercially important fishes.

FISH SEED INDUSTRY

There appears to be no centralized freshwater fish seed trade in India. However, West Bengal plays a significant role in freshwater fish seed trade and ranks first in freshwater fish seed production as well as fish production (Sinha, 2000). The carp seed industry in West Bengal is dependent on riverine seed collection, bundh breeding and induced breeding. Rahman (1946) provided information about fish fry trade in Bengal. Ganguly and Mitra (1957) reported on the distribution of fry collection centres, methods of collection and fry trade for the river Bhagirathi (West Bengal). While Mitra (1961) described the fish trade in Dhulian area, Mitra (1964) also reported the nature of the fish trade in the Hooghly area.

Ghosh (1984) highlighted the carp seed trade at Kakdwip, giving information on trade centres, mode of arrival of fish seed, methods of purchase and sale and socio-economic condition of the traders. Trade starts from the middle of June with the onset of southwest monsoon and continues until the end of September. In order to carry out the trade, traders pay a rent of Rs 70-75/season to the landlord for construction of a hut. In addition, each hut owner pays electricity charges of Rs.15/ point/season. They build the huts at their own cost. A number of huts, locally known as a *chala* (size 6 m × 2.4 m) are constructed. There is a rectangular earthen pit in each hut which is locally known as *chowka* or *Jawa*, which is divided into two distinct halves by a wooden partition to keep the fry and fingerlings separate to avoid overcrowding and also for easy disposal. Ordinary g*amcha* is used to collect the seed from the pit during sale or transfer. Seed are transported by road or rail.

The traders purchase and sell the fingerlings by weight and the fry by volume, i.e. by *kunke* or *kunka*. Fingerlings are purchased at Rs 30-35/kg and sold at Rs 40-45/per kg. Each *kunka* is purchased at Rs100-110 and sold at Rs 120-140 per 10 000-12 000 fry depending upon their size. The price, however, varies from season to season. In both categories, i.e. fry and fingerlings, mrigal was found in highest number, followed by catla. Most traders belong to poor fishermen community and solely depend on fish trade. Some engage themselves in other trades during off season. However, they are unable to run the trade on a large-scale due to paucity of funds. Both joint and or single ownership is/are also noticed among the traders.

FISH SEED TRADE AT KOLKATA

Jhingran (1991) described fish seed trade practised at Calcutta during the 1970s and 1980s. The spawn collectors, during spawning season, form themselves into groups, each called *savar*, consisting of about 15 to 25 persons in West Bengal and about 20 to 45 in Bihar. Each *savar* has a leader who is usually a man native to the area of collection. There are about 100 *savar* in West Bengal, usually refugees from Rajasthan in Bangladesh settled in Murshidabad district of West Bengal, who regularly migrate to Bihar in boats every season, working first on the river Koki and its tributaries where the spawn appear by the middle of May and then operating on the main Ganga by about mid-June. Some fishermen from Midnapore district of West Bengal migrate to Orissa and collect spawn from the rivers Brahmani, Baitarani and Subarnekha. There are about 6 000 spawn catchers working privately in Orissa.

In the beginning of the season, Calcutta spawn merchants advance necessary funds to a group leader for the purchase of nets, boats, provisions, etc. *in lieu* of his commitment to bring the catches of his party to the merchants making such advances. Profits are shared usually at the end of the season. Carp spawn collected in Bihar, West Bengal and Orissa are mostly brought to special spawn markets in Howrah and Sealdah in West Bengal for public sale.

The stocking material, i.e. spawn, fry and fingerlings referred to earlier, has a special terminology in fish seed trade in India. In Bengal fish trade circles, eggs are known as *dim*, early hatchings or larvae with yolk sac called *dimpona*, older fry up to 4 cm long are called *dhanipona* (fine *dhanipona* as *phuldhanni*), fingerlings (4 to 10 cm long) as *chara*, young fish (10 to 23 cm long) as *chala* and larger fish (more than 23 cm long) as *nala*. Spawns are sold by *kunka* (27 000 spawn per *kunka*) or *bati*. None of these measures is, however, standard. The *bati* used in the Howrah market has a fluid capacity of 135 ml and contains 40 500 to 81 000 spawn, measuring from 4.5 to 9 mm in length, while the Sealdah *bati* is little larger with a fluid capacity of 170 ml containing 51 000 to 1 02 000 spawn of the same size ranges as the above. The catch in the early season fetches a higher price as it is believed to be from young spawners and, therefore, perhaps more viable. The price fluctuations in the Calcutta markets during the 1964 season ranged from Rs 72 to Rs 1 000 per *kunka*. On the arrival of spawn in the market from various collection centres, merchants transfer them immediately into wide-mouthed earthen containers called *gamlas*. Spawn are poured from gamlas into the hollow through a piece of coarse cloth so that they may be measured by *kunka* or *batis* (Government of India ,1966).

In recent years, carp seed of specific purity produced in hatcheries as well as bundh-type tanks, in which partial induced breeding has been applied are replacing riverine seed for obvious reasons, specific purity being the main consideration.

DEVELOPMENTS IN FRESHWATER FISH SEED PRODUCTION IN ANDHRA PRADESH

Construction of 102 fish ponds covering an area of 2 050 ha by the Government of Andhra Pradesh for the benefit of fishermen and success achieved initially by a few farmers in 1972–74, encouraged other farmers in Krishna and Godavari districts to take up carp culture on large-scale (Jhingran, 1991). Freshwater fish culture developed at a rapid pace in the 1980s as a significant commercial enterprise in the rural areas of Andhra Pradesh. Semi-intensive carp culture, practiced by agriculturists-turned fish farmers in more than 30 000 ha of newly-dug out, earthen ponds, significantly increased India's fish production. Initially, the fish seed requirements were met by the local government fish seed farms and imports from West Bengal. However, since 1976 many enterprising fish farmers have also ventured into carp breeding on their own, on a commercial scale by successfully adopting induced breeding and hatchery technologies (Jhingran, 1991). At present, the private hatchery operators even supply fish seed to neighboring states, including Karnataka. Data on the number of private hatcheries, capacity, price of seed, etc. are not available since they hesitate to reveal details, fearing income tax consequences. As a result, Andhra Pradesh has almost become self-sufficient in freshwater fish seed production. Looking at the success of Andhra Pradesh fish farmers, many other states are increasingly taking up freshwater fish seed production and fish farming.

Fish seed trade in Karnataka

The present annual production of fish seed in Karnataka State of about 235 million fry, limited to IMCs and common carp, is far short of demand and is not even sufficient to meet the requirement of 400 million fry for stocking ponds and tanks, let alone reservoirs (Krishna Rao *et al*., 2005). In addition, about 30-40 million fingerlings are imported from West Bengal and neighboring Andhra Pradesh. The Andhra Pradesh fish merchants collect the requirement of the farmers in advance and supply fingerlings on credit at lower cost than the government rates. The seed of exotic carps (grass carp and silver carp) are almost wholly imported from West Bengal. There is no trade of seed of other varieties like catfishes and murrels.

Air-breathing fish seed trade

There has been no organized trade of air-breathing fish seed as yet in the country. However, due to the concerted efforts of CIFRI, State Fisheries Departments and State Agricultural Universities, some sort of organized method of collection and marketing of seed, particularly in West Bengal, Bihar, Assam, Andhra Pradesh, Tripura, Karnataka, Uttar Pradesh, Kerala and Manipur is prevalent (Dehadrai, 1981). Presently, limited demand for air-breathing fish seed, particularly *Clarias* spp., are met from natural resources and hatcheries. Presently, some sort of trade exists for *Clarias* spp. at Kolkata.

Risks and uncertainties

The following risks and uncertainties were identified in this review:

- changes in climatic conditions such as untimely rainfall, drought, floods, etc. are common in certain parts of the country and these can adversely affect fish seed production;
- multiple ownership and multipurpose utilization of resources wherein aquaculture is given least priority in some states;
- conflicts between water users;
- mismanagement of seed farms particularly those owned by Department of Fisheries/FFDAs/Corporations. Oftentimes, farms are underutilized due to lack of technically qualified staff or officers/managers tend to indulge in undesirable activities like corruption, nepotism, etc.;
- predation of fish seed by birds (mainly cormorants, kingfisher, herons) and otters;
- poaching of broodfish by the staff or outsiders.

Impacts of exotic fish on native fish

In India, the introduction of exotic fish has had mixed reaction. Some species like trout filled a vacant niche with no competition from any native species. Others like grass carp, silver carp and common carp, have helped in boosting freshwater aquaculture production, but in some cases have negatively impacted native fish (Das, 1997).

The introduction of silver carp in the Govindasagar Reservoir (Himachal Pradesh) resulted in a sharp decline of the dominant native species catla due to overlapping feeding habits and habitat. Similarly in Kalyani Reservoir (Madhya Pradesh), the catla population has declined due to competition with silver carp. The introduction of common carp in different lakes of Kashmir and Manipur has led to a sharp decline in *Schizothorax* spp. The presence of tilapia in Amaravathi and Vaigai reservoirs and Powai and Jaisawand lakes has eliminated almost all other species, including the major carps and the indigenous catfishes, due to its prolific breeding and omnivorous feeding habits. The mosquito fish (*Gambusia affinis*) has practically eliminated all other indigenous species in Ooty Lake in Tamil Nadu, damaging the economy of the lake area (Das, 1997). Hybridization between introduced and native species has changed the composition of fish fauna of inland waters of India. Natural hybrids of common carp are available in the rivers of Ganga and Yamuna. Hybrids of IMCs and Chinese carps are known to occur in some reservoirs and lakes of India (Abidi and Lakra, 2005).

Impacts of the introduction of *Clarias gariepinus* in India

The exotic African catfish, *Clarias gariepinus,* is reported to have had a clandestine entry into India from Bangladesh, first into West Bengal and later spread to other parts of the country. It is known to be found in the rivers of Ganga, Yamuna, Sutlej, Godavari and several other rivers of India (Sugunan, 2000). Its highly cannibalistic nature prompted the Government of India to ban its culture in the country. Despite the ban, it has been gaining popularity among the farmers of Punjab, Uttar Pradesh, West Bengal, Andhra Pradesh, Orissa, Bihar, Karnataka, Assam and other states as an economically viable alternative species to Indian major carps. The African catfish accounted for nearly 16 percent of the total catch from the river Yamuna in a single day, with weights ranging between 1 and 2 kg (Sugunan, 2000). Clandestine fry production goes on in West Bengal and other northeastern states of the country. Many farmers sell the African catfish deliberately as the native *C. batrachus*.

SUPPORT SERVICES

The development of technique of induced breeding of fish is probably the most outstanding achievement in the field of Indian fisheries research. Subsequently, several developments took place in Indian freshwater aquaculture. They are: (i) commencement of an All-India Co-ordinated Research Project on Composite Fish Culture and Fish Seed Production, in 1971, by CIFRI, (ii) the commencement, in 1975, of rural aquaculture project by the CIFRI with the aid of International Development Research Centre (IDRC) of Canada in West Bengal and Orissa and (iii) the initiative taken by the West Bengal Government on the application and extension of CIFRI-developed technology to rural carp polyculture. Simultaneously, the National Demonstration Scheme and the Operational Research Project, involving, among others, demonstration and integration of aquaculture with livestock rearing were initiated (Sinha, 1978). The highlights of the Operational Research Project were the conduct of various training programmes on composite fish culture, induced breeding of IMCs and exotic carps, including maintenance of broodfish, spawn and fry rearing, in the project area. Besides the training programmes, demonstrations on different aspects of scientific fish farming and pond management were organized.

Next in the line of development of freshwater aquaculture was the establishment of FFDAs by the Ministry of Agriculture of the Government of India. This is regarded as the most important step in the removal of the field constraints in the spread of freshwater aquaculture as a rural small-scale industry. Subsequently, the entire inland culture fishery resources of the country are vested with Gram Panchayats or other local bodies, or the government and the water bodies are contracted on annual lease. FFDAs, started in 1975, were found to be a suitable organizational framework as well as nucleus of growth. Hence, the National Council of Applied Economics and the World Bank recommended further expansion of the programme. Presently, more than 450 FFDAs are in operation covering most of the states in the country. The FFDA meets the basic needs of fish farmers in respect to: (i) technical support, (ii) extension support and (iii) financial support.

The Government of India has been encouraging education, training, research and extension activities to enhance fish seed production in the country. Similarly, at the state level, various programmes are being undertaken to boost fish seed production. In Haryana, an outlay of Rs 1.41 million was earmarked for the year 1999–2000 for education, training and extension to provide needed training, refresher courses and to disseminate information on fish seed production and fish culture technology to fish farmers. It was proposed to provide short-term training to 800 fish farmers, organize 34 demonstrations and 80 film shows and exhibitions, besides giving publicity material.

SEED CERTIFICATION

India has an aquatic animal export and import business. Some legislation relating to the import and export of live aquatic animals does exist in India, but it is not complete. Some sort of health certification and quarantine procedure does exist in India and the aquatic animal health quarantine has been described by Punyabrata Das (1997). The NBFGR, located at Lucknow, Uttar Pradesh, has been recognized as the focal agency for formulating legislation on aquatic animal health certification and quarantine. However, there is no definite fish seed certification in India.

While a world-wide market exists for Indian ornamental fish, marketing of major carp seed is possibly restricted to south and southeast Asia. Until the early 1990s, the major centre for carp seed production was West Bengal from where uncertified seed were distributed to the rest of the country. Later on, other states started producing fish seed. In 1993–1994, West Bengal produced 7 540 million fry, accounting for nearly 75 percent of the country's fish seed production (Das, 1997). In addition, there are private seed producers whose contribution to the total fish seed production is significant.

The decision-making procedure for importing and exporting aquatic animals rests with the Union Ministry of Agriculture, Government of India, New Delhi. Presently, no detailed legislation for aquatic animal quarantine or health certification exists in India.

LEGAL AND POLICY FRAMEWORKS

In the past, regulations, based on empirical knowledge, were imposed to cater to maximum sustainable yield. These regulations assumed the forms of protective legislations on mesh size limit, legal sizes, closed season, declaration of sanctuaries, limit on catches, restriction of efforts, prohibition of use of destructive methods of fishing, etc; the basis for the above regulations is the belief that every fish should be given a chance to breed at least once.

The Indian Fisheries Act came into being in 1897 (Government of India, 1956), relevant provisions are reproduced below:

1. If any person uses any dynamite or other explosive substance in any water with intent to catch or destroy any of fish that may be therein, he shall be punishable with imprisonment for a term which extend to two months or with fine which may extend to two hundred rupees.
2. Closed season, i.e. restriction on fishing during certain periods, is followed in Bihar, Madras, Jammu and Kashmir, Madhya Pradesh, Mysore, etc. In all large reservoirs, fishing is closed from June-July to end of September so that fishes are not disturbed during their breeding migrations.
3. In 1956, the Punjab State Government prohibited catching of rohu, mrigal, mahseer and catla smaller than 25.4 cm long. In Delhi, the capture and sale of these species below 20.4 cm in length has been prohibited since 1948. The State of Uttar Pradesh has prohibited, since 1954, the capture and sale of fry and fingerlings of major carps, 5.1-25.4 cm in length from July 15 to September 30

and of breeders from June 15 to July 31 in the prohibited areas, except under a license issued by the proper authority. In Madhya Pradesh, a size limit of 22.9 cm was imposed in 1953, for the capture of rohu, mahseer, mrigal and catla.

4. Certain areas have been declared as protected waters or sanctuaries and closed for fishing.
5. Other systems such as restrictions on the sale of legal sizes of fishes and issuing of licenses of fishing have been followed in various states of India.
6. While the Indian Fisheries Act and the Legislations framed by different State Governments exist, the machinery for the enforcement of the regulations in most cases is so inadequate that the objects of formulating these are hardly fulfilled.

Despite legal prohibition, the capture and destruction of broodfish and juveniles in large quantities are commonly practiced all over the country and are largely responsible for the impoverishment of the freshwater fisheries. Legislations based on empirical knowledge are of doubtful utility. The Indian Fisheries Act is under revision.

Presently, it appears that there are no legal policy parameters in force for regulating fish seed production in the country. However, the Assam State Government has recently introduced certain policy parameters (Anon., 2004). Among them, the notable ones are:

1. All hatchery owners must be registered with the Department of Fisheries.
2. Mixed spawning of carps by hatchery or hapa breeders is illegal and is an offence.
3. The Department of Fisheries (DOF) is to exercise necessary initiative to collect data on fish seed production.
4. The officials of DOF are to take necessary action to form a network of seed producers in their respective areas.
5. The farmers may be educated to grow only pure strains of cultivable varieties of carps as recommended by DOF.
6. The research and extension wings of DOF may be strengthened with competent persons and necessary research conducted on different aspects of fish seed production.
7. Fish seed markets may have to be established in each district through a network of seed producers for the benefit of both producers and buyers. Seed may be certified by the competent authority before being sold.
8. The DOF may instruct all seed producers to use a standard method (perforated steel *bati*) to count fish spawn, fry and fingerlings.
9. Entrepreneurs in the private sector may be encouraged to establish feed plants to produce pelleted feed for broodfish and larvae to improve their quality.
10. Non-functional hatcheries may be leased out to technically qualified persons to operate them profitably.
11. Utmost care must be taken while releasing hatchery produced carp seed in natural water bodies like *bheels*, as most hatcheries are engaged in mixed spawning.

ECONOMICS OF FRESHWATER SEED PRODUCTION

Carp seed production

Freshwater fish culture in ponds and tanks is traditionally carried out in India. Improved technology of fish culture should eventually lead to the maximization of fish production and profit. Right quality of seed supply is one of the most important factors influencing yield. However, the gap between the actual supply of fish seed and demand is increasing over the years. Large-scale production of fish seed through eco-hatcheries and nurseries is one of the most important technologies covered under institutional financing schemes by NABARD and other financial institutions.

Induced breeding of carps

Induced breeding is a major tool for spawn production of IMC and Chinese carps. A brief account of the technology together with its operational economics is given by Tripathi (1991). To produce 10 million spawn comprising 1.5, 2.5, 2.0, 2.5 and 1.5 million spawn of catla, rohu, mrigal and grass carp, respectively, during a single monsoon season, about 120 sets of broodfish is required, with a total weight of about 1 616 kg. Assuming 60 percent breeding response for IMCs and 40 percent for Chinese carps and 80 percent fertilization rate and 70 percent hatching rate, it could be possible to produce 10 million carp spawn in a breeding season. Based on this, a net profit of 130 percent on operational costs is easily possible.

Fish seed production using the Chinese type of circular carp hatchery

During one breeding season, lasting 120 days in a monsoon season, about 30 batches of spawn could be produced, each batch of 4 days duration. About 10 million carp eggs could be hatched in one batch (spawning pool measuring 8 m diameter and hatching pool of 3.6 m diameter), with 95 perecent hatching success, resulting in the production of 285 million spawn (6 mm length). At the sale price of Rs 10/1 000, a total income of Rs 2.85 million could be derived during one season. After deducting 50 percent towards recurring and nonrecurring costs, nearly Rs 1.4 million could be realized in one season, assuming that uninterrupted operations are carried out. However, if only 15 batches of eggs are taken, the net profits would be about Rs 0.7 million per breeding season per circular hatchery.

Dry bundh operation

An increase in the number of bundhs in West Bengal, Madhya Pradesh, Rajasthan, Gujarath and other States of the country, indicated that spawn production through dry bundhs is an economically viable system. The cost of production in a bundh set up in 1962–1963 worked out to be Rs 635 per million spawn which was considered quite satisfactory for an old type of dry bundh. When 4 crops of spawn are taken from one bundh in a season, it is estimated that the cost of spawn production per million in Madhya Pradesh turns out to be Rs. 75, Rs 80 and Rs 70 for rivers, wet bundh and dry bundh, respectively. In 1980, an account of the economics of as many as 18 dry bundhs revealed the cost of production to be Rs 200-450 per million spawn. The cost of production of spawn in bundhs of Midnapore and Bankura District of West Bengal is much cheaper than that of riverine spawn. A study conducted by CIFE (Mumbai) demonstrated a profit of Rs 2 256 (one breeding) and Rs 10 000 (4-5 breeding) could be obtained from a bundh area of 426.55 m^2 in one season. A fish farmer of Madhya Pradesh has been running a 0.16 ha dry bundh since 1991–1992 and produces 7.0 million spawn and 1.0-1.2 million fingerlings every year and earns about Rs 0.1 million (Dubey, 2000). Besides spawn production, a dry bundh can be used to grow fry or fingerling stage more economically.

Carp spawn collection

The economic viability of a riverine spawn collection site was studied by Ghosh (1981). Production costs based on a unit of eight fishermen operating 15 nets in two months during a monsoon season showed annual depreciated of capital costs at Rs 1 200 (18 percent), labour costs Rs 4 000 (60 percent), services, interest on capital borrowings and loan refund each of Rs 500 (7.5 percent), giving a total of Rs 6 700 per unit. The profitability of spawn collection at centres located by CIFRI, has an average of 317 lakhs, ranging from 102 to 543 lakhs at eleven centres. Depending on production levels, the cost of production at site ranges from Rs 22.3 per lakh for a production level of 300 lakhs to Rs 134 per lakh for 50 lakhs of production. At a selling price of Rs 250 per lakh of spawn, the projected profits range from 51 percent to 377 percent for productions ranging from 50 lakhs to 300 lakhs in a season.

LIMITATIONS/ PROBLEMS/ CONSTRAINTS

A number of limitations/problems/constraints have been identified in this review. These are:

- Among the major bottlenecks faced in dry bundh breeding, the most vital one is poor spawning due to high mortality during hatching in earthen pits or hapas. It is particularly so with small farmers who cannot afford to adopt improved hatching devices. The bundhs can not be constructed everywhere.
- Inadequacy of quality broodfish for spawning in bundhs. In most cases, the broodfish ponds are located at some distance. Transport of broodfish from such locations to bundhs is cumbersome and adds to the cost of seed production.
- Fungal and bacterial infection of spent broodfish is commonly encountered in bundhs. This is important specially in the context of repeat spawning of broodfish as practiced by farmers of West Bengal.
- The prevention, diagnosis and treatment of diseases of fish seed and broodfish have not received the required attention.
- Lack of of nursery area and low survival in nurseries have led to the shortage of quality seed.
- Fish seed collected from rivers normally contains a high percentage of uneconomic species like predatory and weed fishes. Valuable nursery space is wasted by rearing such spawn to fry stage since it is not possible to segregate seed at spawn stage. The riverine seed also suffer high mortality during transport from collection site to rearing centres. The riverine seed collection is highly undependable due to uncertainty of monsoon.
- Wide gap between supply and demand for quality fish seed has affected freshwater fish production in several states.
- Indiscriminate destruction of broodfish, carps in particular, during their spawning migration or assembly at breeding grounds in rivers is a common event.
- Large-scale mortality of eggs and spawn sometimes occur especially when stranded at breeding grounds.
- Pollution (mainly industrial and agricultural) of rivers has adversely affected fish seed resources

STAKEHOLDERS

Producers/farmers

In general, there exists a large extension gap which limits the dissemination of technologies to the rural community. Records from past several years reveal that due to the lack of technical support and basic infrastructure, fish breeding and seed rearing are rarely undertaken by farmers in the villages. Radheysham (2002) reported a case study on carp seed production as a commercial activity taken up in phases (over a period of 11 years, in Orissa) by farmers through a needs-based and problem-solving approach. Although technological packages were available to the farmers by researchers, farmers played a key role in planning, formulating and implementing the technologies.

Carp breeding was initiated using common carp in 1987. In the following years, induced breeding of catla, rohu and mrigal was introduced. The successful experience in the profitable carp breeding sustained the interest of the farmers so that they breed fish every year and this led to a rising trend in spawn production from 0.35 million in 1987 to 21.3 million in 1997. A total of 1 118.6 kg of female broodfish could be utilized producing 70.9 million spawn in 11 years. Fry and fingerling production technologies were demonstrated in the rural area. In 11 years, the production of 15.94 million fry and 1.88 million fingerlings made the neighboring villages self-sufficient in carp seed production.

The estimated net income from spawn production was Rs 207 246 (US$4 820) and the return on expenditure was 274 percent, whereas from seed rearing the net income

PLATE 7.11.10
Photographs showing sterile common carp and hatchery production

Sterile common carp hatchery in operation (Photo courtesy: Dr. G. P. S. Rao)

Sterile common carp hatchery in operation (Photo courtesy: Dr. G. P. S. Rao)

was Rs 606 550 (US$14 106) and the average return on expenditure was 131 percent. This technology was found to be viable, sustainable and employment generating. This success motivated other farmers to undertake seed production and carp farming (Radheysham, 2002).

New varieties/strains/innovations

The sterile common carp (*Chakri*)

The common carp, *Cyprinus carpio* (Linn.) is one of the widely cultured fishes in the world. In India, it is commonly cultured, either singly or in combination with the IMCs catla, rohu and mrigal and also with the Chinese carps, grass carp and silver carp. It grows almost at par with the fastest growing IMC, the catla. However, sometimes, due to its prolific breeding habit, it offsets the stocking density of the culture pond, resulting in a production of undersized fish of very low market value.

A technology has been developed at the University of Agricultural Sciences, Bangalore by Dr. G. P. Satyanarayana Rao and his team to induce sterility in common carp to overcome the problem of uncontrolled reproduction in the culture ponds. This sterile common carp (Plate 10) has been thoroughly screened for various parameters to determine its usefulness as a good candidate for augmenting fish production in the country.

The advantages of this sterile common carp, as compared to normal common carp, are: (i) fast growth, 47 percent faster, (ii) yields more meat per unit weight of fish, (iii) better conversion efficiency and (iv) better resistance to the most common bacterial pathogen, *A. hydrophila*.

This technology along with a special feed for the production of sterile common carp seed has been released for commercial culture by the University of Agricultural Sciences (Bangalore) in 2002. The University has also issued a license to M/s. Tetragon Chemie P. Ltd., Bangalore, on a non-exclusive basis, to commercialize the special feed.

Large-scale demonstrations on the culture of sterile common carp has helped the industry establish two hatcheries in 2003, one at KVT, Bhuj, Gujarat State and the other at Baballi, Shimoga District, Karnataka with an annual production capacity of 3.5 and 1.5 million fingerlings, respectively. Additional two hatcheries are in the pipeline. All these will ensure proper supply of sterile common carp seed to the farmers.

Encouraged by the progress made in this new field of biotechnology to augment fish production, a workshop was organized in June 2005, involving all the farmers, scientists and the officials of the Department of Fisheries, connected with the sterile common carp culture programme, to take stock of the situation and to review the strategy for popularizing its culture.

Genetically superior rohu (*Jayanti*)

The Norwegian Agency for Development Cooperation (NORAD) has funded an institutional cooperation project on Genetic improvement of the Indian major carp, rohu (*Labeo rohita*) for growth through selective breeding. The project is being operated, since 1992, at Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, Orissa. The project was started with a broader gene base, i.e. fingerlings sampled from five rivers, the Ganga, the Gomati, the Brahmaputra, the Yamuna and the Sutlej. To these, the CIFA (Bhubaneswar) farm stock was added as the sixth stock. After three generations of selective breeding, rohu has shown an average gain of growth of 17 percent per generation (Jana *et al.*, 2002). Field testing experiments in different agro-climatic areas, such as Punjab, West Bengal and Andhra Pradesh also showed a similar trend of genetic gain. The genetically improved variety of rohu has been named *Jayanti* by the Indian Council of Agricultural Research (ICAR) in New Delhi and the commercial production of *Jayanti* seed is now being attempted for distribution to farmers.

Government institutions, extension services

Government institutions: Under the new Central Sector Scheme, i.e. National Fish Seed Programme, 25 commercial fish seed farms (hatcheries) were established in selected states of India, namelyAndhra Pradesh, Haryana, Uttar Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Tripura, besides river valley projects (Singh and Sampath, 1983). These fish seed farms have a 10 ha water spread area, located near an indoor hatchery system with a capacity produce 10 million quality seed per annum per hatchery. Apart from this large-scale commercial fish seed production programme, Fish Farmers Development Agencies (FFDAs), functioning under the on-going Development of Aquaculture Programme in the states, have also been provided with small fish seed farms with sizes ranging from 2 to 5 ha.

The construction of these fish seed farms/commercial hatcheries under these two programmes necessitated a uniform design according to state/local conditions. The hatchery/fish seed farm complex would include an indoor hatchery unit, earthen ponds, water gates, central channel, tube wells, administrative building, staff quarters, store rooms, perimeter fencing, internal roads, etc. Each hatchery is set up to provide facilities to produce hatchlings by induced breeding, nursing and rearing them to fry stage (approximately 9 and 18 ponds for 5 and 10 ha hatchery, respectively). About 25 percent of this area is used for broodfish maintenance and the broodfish should be replaced to the extent of one-third each year to keep a healthy broodstock for undertaking breeding operations. It is envisaged to produce 5 and 10 million fingerlings of 5 cm size from each 5 and 10 ha hatchery, respectively. These commercial scale fish seed farms have been set up to overcome shortcomings/limitations of small-scale hatcheries. The budget estimated for a 10 ha commercial fish seed farm under the National Fish Seed Programme was Rs. 3.9 million (applicable to the year 1983). While 70 percent of the total cost is borne by the federal government, 30 percent of the cost is met by the concerned state government. With regards to fish seed farms under FFDAs, the federal and state's share is 1:1.

Extension services: In order to transfer technologies developed by research institutions, universities, colleges, KVKs (Krishi Vignana Kenddra), etc. to end users/entrepreneurs, extension education units have been established in several central and state governments. The government sponsored programmes like KVKs, NCDC (National Cooperative Development Corporation), FFDAs, etc. which also provided extension services on fish seed production; state level Fisheries Departments, Fisheries Development Corporations, Cooperative Societies, etc. supported fisheries extension activities.

A detailed account of the packages of practices related to induced breeding, hatching, nursery and rearing pond management and cost and return of induced breeding, nursery and rearing pond management of major carps, developed at CIFRI, has been given by Das and Sinha (1985). Technology developed on these aspects has been described earlier in this report. The State of West Bengal is the pioneer in carp seed production in India. It has contributed to nearly 75 percent of the total fish seed production of the country (Sinha, 2000). This has been possible through the intensive training and demonstrations efforts of CIFRI, Directorate of Fisheries and NGOs, resulting in the establishment of a large number of glass jar and eco-hatcheries through out the state. The state produces about 45 percent surplus seed to cater to the needs of other states.

Subsidies. Subsidies are given mainly to boost fish seed production in the private sector. The Government of India offers subsidy to FFDAs at Rs 20 for every 1 000 fry transported and gives subsidy at 20 percent with a ceiling of Rs 40 000 per ha for fish seed rearing, but not to individuals. On the other hand, it provides subsidy of 10 percent with a ceiling of Rs 80 000 and Rs 1.2 lakhs to entrepreneurs in the Plains and Hilly areas, respectively. The government also offers subsidy for setting up a fish hatchery with a capacity of 10 million fry at Rs 8 lakhs and Rs 12 lakhs in the Plains and Hill States/Districts/Northeastern region, respectively.

In order to promote fish seed production and rearing, state governments offer subsidies. In Karnataka, in order to promote fish seed production in the private sector a subsidy of Rs one lakh for the construction of one ha pond for fish seed production and Rs 0.75 lakh for the construction of one ha pond for fish seed rearing, is provided by the Department of Fisheries. Also, the FFDA gives financial assistance of about Rs 8.0 lakhs per hatchery with a 10 million fry capacity. In Himachal Pradesh, a subsidy at 25 percent with a ceiling of Rs 12 500 for each set of aerators/pumps, is given. In Orissa, the government gives Rs 1.6 lakhs to a self-employed person for producing fish seed through hatchery.

Researchers

The ICAR (Indian Council of Agricultural Research) under the Ministry of Agriculture, Government of India is the nodal agency for all research and training pertaining to agricultural sciences, including fisheries. Under ICAR's direct supervision, there are different fisheries institutions, such as CIFRI (Kolkata), CIFA (Orissa), CIFE (Mumbai), NBFGR (Uttar Pradesh) and the National Research Centre for Coldwater Fisheries (NRCCF, Uttaranchal). Of these, CIFRI and CIFA are more actively engaged in research in freshwater fish seed production. Besides these institutes, a number of Fisheries Colleges which are part of the State Agricultural Universities are involved in research pertaining to fish seed production. Presently, there are 13 Fisheries Colleges, all of which have been established under the Agricultural Universities. Almost all the Colleges are engaged in teaching, research and extension in aquaculture (fish seed production). Seed production is carried out using hapas or jar hatchery or circular tanks of Chinese origin. Many traditional universities, NGOs, etc. are also involved in producing and rearing fish seed.

Donors (funding agencies)

The Norwegian Agency for Development Cooperation (NORAD), Norway has funded an institutional cooperation project on Genetic improvement of the Indian major carp, rohu (*Labeo rohita*) for growth through selective breeding. The project is being operated, since 1992, at Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, Orissa.

The Department for International Development (DFID) of the United Kingdom has funded a similar mega project for the genetic improvement of another Indian major carp, catla (*Catla catla*). This research project is being operated at the University of Agricultural Sciences, Bangalore, but has now been transferred to newly started Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, Karnataka. Initial results indicate that inter-hatchery crosses of catla produced better growth than intra-hatchery crosses.

FUTURE PROSPECTS AND RECOMMENDATIONS

Based on this review, the following future prospects and recommendations are provided:

1. A live gene bank for producing and supplying pure seed of IMCs and exotic carps may be established since the quality of carp seed produced in several hatcheries are reportedly not satisfactory due to continuous inbreeding.
2. Fish hatchery operators should be trained on better broodfish management, hatchery management and nursery management to produce quality fish seed.
3. Government or financial institutions should sponsor setting up of field laboratories for assessing and monitoring fish seed quality.
4. More emphasis should be laid on multiple spawning of carps so as to ensure the availability of seed over a longer duration in a year.
5. Greater support (technical as well as financial) from government agencies is needed for sustainable fish seed production.
6. Apart from the routine production of carp seed, emphasis needs to be given also to produce seed of valuable species like catfish and murrels, which command a good price in several parts of the country.
7. Mixed spawning should be prevented to protect the genetic purity of our precious carps gene pools.
8. Attempts should be made for efficient marketing and distribution of fish seed from surplus states to maximum deficit states.
9. The Government of India should explore the possibility of having a uniform fish seed grading system and pricing for the entire country.

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7.12 Freshwater fish seed resources in Indonesia

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ABSTRACT

The status of freshwater fish seed resources in Indonesia is described in this paper. The most commonly cultured species are common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*), catfish (*Clarias* sp., *Pangasius* sp.) and gouramy (*Osphronemus gouramy*). The main freshwater producing regions are Java (23 percent) and Sumatra (67 percent) of the total production at 482 683 tonnes in 2003. Freshwater cultured fish seed are mostly supplied from hatcheries and only some species are supplied from the wild. There are about 20 species of freshwater fish that have been successfully bred in captivity. Despite the progress, development of the freshwater seed sector is very slow compared to marine fish and shrimp hatchery business. This may be market-related as freshwater fish are particularly intended for the local market and only a small percentage (i.e. tilapia and catfish) is aimed for the export market. Other reasons include the decreasing quality of seed, inbreeding issues which caused slow growth and exporter requirements (e.g. fish size, number of fish, off-flavour, etc.). Another obstacle to the development of the freshwater aquaculture sector is the non-availability of credit for small-scale farmers. Nevertheless, the fish seed requirement to realize the targeted freshwater aquaculture production of the top five freshwater species (common carp, tilapia, walking catfish, gouramy and Siamese catfish) shows the great opportunity and prospect for the freshwater fish seed industry.

INTRODUCTION

Freshwater aquaculture in Indonesia started with the stocking of common carp in backyard ponds in West Java and subsequently expanded to other parts of Java, Sumatra and Sulawesi islands in the early twentieth century. However, it was only in the late 1970s when a remarkable increase in production from freshwater aquaculture was observed as a result of the introduction of new farming technologies, which contributed to the availability of hatchery-produced seed and the development of compound feeds.

During the period from 1999 to 2003, total aquaculture production increased from 882 989 tonnes in 1999 to 1.22 million tonnes in 2003 with an incremental growth of 8.5 percent/yr. In the same period, total freshwater aquaculture production increased from 304 579 to 482 683 tonnes. In 2003, freshwater fish aquaculture production contributed 39.43 percent to the total aquaculture production. Production increased due to technology innovation, expansion of aquaculture areas and availability of suitable quality and quantity of fish seed.

The most commonly cultured species are common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*), catfish (*Clarias* sp., *Pangasius* sp.) and gouramy (*Osphronemus gouramy*). Common carp is the most dominant species, with production comprising about 46 percent of the total freshwater aquaculture output. Production of common carp in ponds, cages and paddy fields doubled from 139 370 tonnes in 1999 to 220 330 tonnes in 2003. The rapid growth of common carp was the result of floating cage in the reservoirs. The second important species, Nile tilapia, which was first introduced in Indonesia in 1969, is becoming an important species as the aquaculture export commodity, with its production doubling from 31 424 tonnes in 1999 into 71 789 tonnes in 2003 comprising one third of the total aquaculture production. The next dominant species are catfishes. There are some species of catfishes such as *Clarias batrachus*, *C. garipienus*, *Pangasius suchi, P. jambal*, with production of 70 826 tonnes comprising 32 percent of the total aquaculture output. Another species is gouramy, with a production of 22 722 tonnes.

The main freshwater producing regions are Java (23 percent) and Sumatra (67 percent) of the total production at 482 683 tonnes in 2003. Common carp, Nile tilapia, catfishes and gouramy are common species cultured in Java. People in Sumatra are not familiar with gouramy; Kalimantan and Sulawesi are not familiar with C*larias* sp. and gouramy.

Freshwater aquaculture is carried out in fish ponds or fish cages and pens in lake and reservoirs as well as in paddy fields using monoculture or polyculture and integrated with animal husbandry or crop farming.

The culture of ornamental fish has also been expanding, triggered by the huge export demand and strong government support. This industry, comprised of a wide range of producers from small backyard operators to large-scale commercial producers, earn over US$20 million from the export of 30-40 million fish annually. With the outbreak of koi herpes virus (KHV) disease afecting carp farming, many common carp hatchery, nursery, and grow out farmers/operator have shifted to the production of ornamental fish species for the export market.

SEED SUPPLY

Freshwater cultured fish seed are mostly supplied from hatcheries and only some species are supplied from the wild. There are about 20 species of freshwater fish that have been successfully breeding in captive area. These include common carp, Nile tilapia, catfish, gouramy, giant freshwater prawn, grass carp, Java barb (*Puntius gonionotus*), Nile carp (*Osteochillus hasselti*), freshwater pompret (*Colosoma* sp.), catfish (*Macrones* sp.), Sultan fish (*Leptobarbus hoeveni*), silver carp, bullfrog (*Rana catesbiana)*, *Cherax* sp. and some ornamental fish such as guppy, koi, botia, arowana, angelfish and goldfish. Seed dependent on wild source include marble goby (*Oxyeleotris marmoratus*), featherback (*Notopterus chitala*), snakehead, climbing perch (*Anabas testudeneus*) and soft shell turtle (*Trionyx sp.*).

SEED PRODUCTION FACILITIES AND TECHNOLOGY

Government

In the field of freshwater aquaculture, there are four Technical Implementing Units (TIU) under the responsibility of the Directorate General of Aquaculture (DGA) and there are 398 hatchery units owned by local governments (provincial and district levels).

Technical implementing units (TIU)

TIU has the main task of developing and implementing hatchery technology, aquaculture technology, environment and fish health management. The applied technology developed by TIU are disseminated to provincial freshwater hatcheries and district freshwater hatcheries located in their areas of responsibility. Freshwater TIUs also function as broodstock centers for freshwater fish. The present status of freshwater aquaculture TIUs are presented in Table 7.12.1.

Provincial freshwater fish hatcheries

There are 30 freshwater fish hatchery units under the management of the provincial government. Each provincial government has at least one freshwater fish hatchery unit. Seed production ranged from 1 to 5 million fry/yr depending on facilities, human resources and management. Table 7.12.2 shows the names and capacities of provincial freshwater fish hatcheries.

TABLE 7.12.1
The present status of aquaculture technical implementing units (TIU) in Indonesia

No.	Name of TIU	Commodities	Region
1	Freshwater Aquaculture Development Center, Sukabumi	Nile tilapia, giant freshwater prawn, gouramy, common carp, catfish, ornamental fish	Java, Bali, Nusa Tenggara, Sulawesi, Papua
2	Freshwater Aquaculture Development Center, Jambi	Siamese catfish, Jambal catfish, Malaysian carp, Baung catfish, klemak, botia	Sumatra and Kalimantan
3	Regional Freshwater Aquaculture Development Center, Mandiangin	Walking catfish, Baung catfish, sand goby, Nile tilapia, catfish	Kalimantan, Java, Bali, West Nusa Tenggara, East Nusa Tenggara
4	Regional Freshwater Aquaculture Development Center, Tatelu	Nile tilapia, common carp and gouramy	Sulawesi, Maluku, Papua

TABLE 7.12.2
Production capacities of provincial freshwater fish hatcheries in Indonesia

No	Province	Name of the hatchery	Production capacity (fingerlings)
1	Nangroe Aceh Darussalam	Toweran	1 680 000
2	Sumatera Utara	Kerasaan	960 000
3	Sumatera Barat	Sicincin	888 000
4	Riau	Sei Tibun	216 500
5	Jambi	Kerinci	3 480 000
6	Bengkulu	Marga Sakti	1 485 588
7	Sumatera Selatan	Air Satan	4 200 000
8	Bangka Belitung	Pemali	138 455
9	Lampung	Purbolinggo	3 000 000
10	Dki Jakarta	Ciganjur	5 400 000
11	Banten	Curug Barang	1 200 000
12	Jawa Barat	Wanayasa	2 520 000
13	Jawa Tengah	Janti	4 500 000
14	Di. Yogyakarta	Cangkringan	4 548 000
15	Jawa Timur	Umbulan	3 600 000
16	Bali	Sangeh	2 880 000
17	Nusa Tenggara Barat	Aikmel	3 600 000
18	Nusa Tenggara Timur	Noekele	789 000
19	Kalimantan Barat	Anjungan	2 508 000
20	Kalimantan Tengah	Talohen	107 660
21	Kalimantan Selatan	Karang Intan	3 000 000
22	Kalimantan Timur	Sabulu	5 400 000
23	Sulawesi Utara	Tateli	4 800 000
24	Gorontolo	Paguyaman	269 000
25	Sulawesi Tengah	Kalawara	1 200 000
26	Sulawesi Tenggara	Punggaluku	2 760 000
27	Sulawesi Selatan	Lajoa	2 400 000
28	Maluku	Waiheru	1 440 000
29	Maluku Utara	Jailolo	-
30	Papua	Masni	4 560 000
	Total		**70 524 000**

District freshwater fish hatcheries

There are 416 freshwater fish hatchery units under the responsibility of the district government. Production ranged between 500 000 to 1 million seed/yr. Table 7.12.3 shows information on district freshwater fish hatcheries in Indonesia.

Private sector

Freshwater fish hatcheries owned by the private sector are mostly dominated by small-scale fish farmers and there are only few hatcheries owned by commercial private companies.

Small-scale fish hatcheries

There are about 26 365 small-scale hatcheries owned by an individual or a farmer group. Most of the individual farmer hatchery operators are small-scale, use traditional technology transferred from generation to generation. Species most commonly used are common carp, tilapia, giant gouramy and Java barb. Production ranged between 30 000 to 3 million seed/yr mainly depending on facilities and financial resources.

Farmer groups with about 25-60 members have more complete hatchery facilities and to some extent apply new technology. They produce more than one species and production is higher at about 16- 45 million seed/yr.

Commercial hatcheries

So far, there are six hatcheries operating at commercial level. Production varies depending upon available facilities which may consist of a laboratory, larval rearing

TABLE 7.12.3
Production capacities at the district freshwater fish hatcheries in Indonesia

No	Province	Number	Production capacity (fingerlings)
1	Nangroe Aceh Darussalam	8	5 040 000
2	Sumatera Utara	31	27 048 000
3	Sumatera Barat	14	10 296 000
4	R iau	4	6 156 000
5	Jambi	8	4 884 000
6	Bengkulu	15	7 872 000
7	Sumatera Selatan	13	17 916 000
8	Bangka Belitung	-	138 455
9	Lampung	10	10 068 000
10	Dki Jakarta	3	11 040 000
11	Banten	4	1 920 000
12	Jawa Barat	24	6 720 000
13	Jawa Tengah	61	50 736 000
14	Di. Yogyakarta	17	18 384 000
15	Jawa Timur	38	39 732 000
16	Bali	20	11 316 000
17	Nusa Tenggara Barat	12	13 656 000
18	Nusa Tenggara Timur	35	11 916 000
19	Kalimantan Barat	8	4 380 000
20	Kalimantan Tengah	-	107 660
21	Kalimantan Selatan	2	5 700 000
22	Kalimantan Timur	5	2 400 000
23	Sulawesi Utara	7	6 120 000
24	Gorontolo	-	269 000
25	Sulawesi Tengah	11	18 260 000
26	Sulawesi Tenggara	7	16 368 000
27	Sulawesi Selatan	29	37 608 000
28	Maluku	-	60 519
29	Maluku Utara	-	0
30	Papua	30	16 152 000
	Total	**416**	**361 688 000**

TABLE 7.12.4
List of commercial private hatcheries

No	Name	Location	Species	Seed production/ year
1	PT. Surya Dharma Hatchery	Sleman, Yogyakarta	giant freshwater Prawn	50 000 000
2	PT. Aquafarm Nusantara	Klaten, Cental Java	Nile tilapia	4 500 000
3	PT. Toba Tilapia	Deli Serdang, North Sumatra	Nile tilapia	8 000 000
4	PT. Nalendra Sinta Mina Usaha	Subang, West Java	Nile tilapia	12 000 000
5	PT. Central Panganpertiwi	Subang, West Java	common carp catfish Nile tilapia	18 693 394 60 000 000 6 822 366
6	PT. Central Penganpertiwi	Situbondo, East Java	Nile Tilapia catfish	12 000 000 7 000 000

tanks, breeding tanks and other physical infrastructure. Some of them have Seed Production Certificate from the DGA indicating that the seed they produce are of good quality. Table 7.12.4 shows information on commercial freshwater fish hatcheries in Indonesia.

SEED MANAGEMENT

Broodstock management

Small-scale fish hatcheries usually have limited number of broodstock. Regeneration of broodstock is seldom and depends on available budget. Obviously, over-aged broodstock are commonly used. Seed quality is oftentimes neglected and they are caught in a system where middlemen purchase seed paid on an installment basis or delayed payment. Commercial hatcheries, on the other hand, have good procedures for maintaining their broodstock. Regeneration of the broodstock is carried out through improved technology and by following “genetic rules” in the production of good quality breeder based on a national standard developed by the DGA and the National Standard Agency (NSA). Although they do not have research facilities and research staff, they keep in touch with national experts from universities or government research agencies. Feeds are provided daily, either indirectly using fertilizer or commercial pellet. Application of organic fertilization, mainly chicken manure using a rate between 500 g/m^2 up to 1 000 g/m^2 and inorganic fertilizers such as urea and TSP at a rate of 150-200 kg/ha are the normal practice. Commercial pellets are applied at a dosage of 2-5 percent body weight daily. Broodstock ponds are usually divided for male and female and to some extent for species separation. Small-scale hatcheries normally mix different species in one pond; males and females are separated. In contrast, commercial operations use only one species. Water is kept flowing gravitationally into broodstock ponds. Table 7.12.5 shows an example of standard procedures to produce Majalayan

TABLE 7.12.5
Standard procedure in the Majalayan common carp broodstock at stagnant water and running water ponds

Process	Larval rearing I (stagnant water pond)	Larval rearing II-IV (stagnant water pond)	Grow-out I (stagnant water pond)	Grow-out II (running water pond)	Grow-out III (running water pond)
Product (g/fish)	1-2	5-10	200	1 000	2 000
Selected number (percentage best selected)	100	50	50	30	25
Stocking density (fish/m^2) (kg/m^3)	50 -	10 -	2 -	- 5	- 5
Time period (weeks)	2	10	12	16-20	40

common carp broodstock using stagnant water pond and running water pond, a common practice at freshwater hatcheries.

Larval management

Most farmer hatcheries implement the natural spawning method using earthen pond or concrete tank. There are four stages commonly practiced by farmers to produce larvae up to fingerling size: (1) Larval rearing I to produce 20-day old larvae, (2) Larval rearing II to produce 40-day old larvae, (3) Larval rearing III to produce 70-day old fingerlings and (4) Larval rearing IV to produce 90-day old fingerlings. All larvae and fingerlings can be produced in earthen ponds, bricked ponds, or paddy fields. In some areas, they can be produced in cage nets. During larval rearing, water depth of pond is maintained at 50-70 cm depending on the size of fish. Water is kept flowing during larval rearing at 0.4 to 0.7 l/sec in a larval rearing area of 500 m^2. Turbidity is maintained at a reading of 25 cm. Larval rearing in paddy field is slightly different in the sense that water depth at the flat area is maintained up to 20 cm. Table 7.12.5 shows the standard procedure for common carp larval rearing while Table 7.12.6 shows the standard procedure for larval rearing in paddy field.

Feed management

Fish hatcheries feed their young larvae usually with crushed boiled eggs which are spread out evenly in the larval jar or hapas. During larval rearing, no feeds are provided except as part of organic fertilization. In some commercial hatcheries which produce male tilapia, crumbled feeds containing methyl testosterone used to feed first stage of larva are given. After the larvae digestion system is completed, larvae are then fed indirectly with live feeds such us phytoplankton, zooplankton (*Daphnia* sp., *Moina* sp.) through application of fertilizer. For economic species such as Borneo catfish and ornamental fish, *Artemia* nauplii or high formulated diet feeds are added. Under normal conditions, feeding with commercial pellet containing 24-30 percent protein is given twice a day. However, in areas having difficulties in finding commercial pellets, rice bran has become alternative feeds for young fish.

SEED QUALITY

It is difficult to get good quality seed, even from commercial hatcheries. This is due to available broodstock of the fish. The situation was exacerbated due to the outbreak of KHV which seriously affected the industry of common carp in the provinces of West Java and East Java. With regards to tilapia, the problem is getting good quality broodstock. Although some strains were imported from neighboring countries such as the Philippines, Malaysia, Singapore, Thailand and Japan, currently the produced seed

TABLE 7.12.6

Standard procedure for the production of fingerling size of Majalayan common carp at each stage of larval to fingerling rearing

No.	Standard	20-day old	40-day old	70-day old	90-days old
1	Organic fertilizer (g/m^2)	500	200	200	150
2	Agricultural Lime (g/m^2)	50	50	50	50
3	Seed				
	Size to stock (cm)	0.6-0.7	1-3	3-5	5-8
	Stocking density (fish/m^2)	100	50	25	20
4	Feed				
	Dosage (% of biomass)	20	10	5	4
	Feeding frequency (times/day)	2	3	3	3
5	Harvest				
	Rearing period (days)	15	20	30	20
	Survival Rate (%)	60	70	80	80
	Production size (cm)	1-3	3-5	5-8	8-12

have already been mixed. Efforts to get good quality seed and broodstock has been implemented through the Tilapia Broodstock Center established since 2003 where the National Freshwater Aquaculture Center was appointed as center coordinator. The NSA sets up the seed quality criteria, broodstock quality criteria and production procedures. Many stakeholders are involved in determining the criteria for seed and broodstock quality and decisions are taken as a consensus through a combination of

TABLE 7.12.7
Standard procedure for the production for fingerling size of Majalayan common carp in paddy field

No	Standard	40-day old	70-day old	90-day old
1.	**Culture method**	In between rice crop	Integrated with rice	Integrated with rice
2.	**Seed**			
	Size to stock (cm)	1-3	3-5	5-8
	Stocking density (fish/m²)	3-5	2-3	1-2
3.	**Feed**			
	Dosage (% Biomass)	10	5	3
	Feeding frequency (times/day)	2	2	2
4.	**Harvest**			
	Rearing period (days)	20	30	20
	Survival rate (%)	50	70	70
	Production size (cm)	3-5	5-8	8-12

practical experience, scientific basis and economic considerations. Currently, there are eight freshwater fish species for which such criteria has been set by the NSA. These include common carp (Sinyonya and Majalaya), Nile tilapia, Siamese catfish, walking catfish, gouramy, giant freshwater prawn and bullfrog.

Tables 7.12.8 and 7.12.9 show some examples of criteria, published in 1999, for common carp seed and broodstock.

TABLE 7.12.8
Quantitative criteria for seed of common carp, Majalayan strain

Criteria	Larvae (0-4 days old)	Kebul (5-20 days old)	Putihan (21-40 days old)	Belo (41-70 days old)	Sangkal (71-90 days old)
Maximum age (days)	4	20	40	70	90
Minimum total length (cm)	0.6	1	3	5	8
Minimum weight (g)	-	0.2	3	6	10
Minimum uniformity in size (%)	80	80	80	80	80
Minimum uniformity in color (%)	95	95	95	95	95

TABLE 7.12.9
Quantitative criteria for reproductive character of the Majalayan carp

Criteria	Male	Female
Age at early maturation stage (months)	8	18
Standard length (cm)	22	35
Weight at early maturation stage (g/fish)	500	2 500
Fecundity (eggs/kg)	-	85 000 – 125 000
Egg diameter (mm)	-	
Dry egg	0.9-1.1	

Note: Qualitatively criteria for the Majalayan broodstock is indicated by the ratio of standard length to body height 2.30:1.00, ratio of standard length to head length 3.57:1.00; total number of scale on lateral line: 26-33; dorsal spine: D.3.15-17; pectoral spine: P.1.12-17; ventral spine: V.1.6-8, anal spine: A.3.4-6 and caudal spine C.12-16

SEED MARKETING

Traditional fish seed marketing uses direct purchasing. This practice dominates in the rural area or through several layers of middlemen (e.g. private traders, collectors or market agents). Local collectors play an important role in marketing from production site to market. There are two kinds of collectors: (a) village-based collectors have usually lived in the villages since childhood and work as local agents and (ii) regional collectors are those who collect seed from the village-based collectors. These collectors usually provide loans, small-scale credit or at times advance their own money to ensure that farmers sell the seed to them.

In Java, live fish markets are available which facilitates the sales of farmer-produced seed. Sukabumi, Majalengka, Tasikmalaya districts in West Java, Magelang District in Central Java and Lamongan in East Java are the places for selling live fish through the live fish market. Live fish markets not only function as venue for marketing activities, they also, to some extent, serve as a venue for monitoring seed quality as well as price level.

SEED INDUSTRY

The freshwater fish seed industry in Indonesia is dominated by small-scale farmer-operated hatcheries whose contribution to the seed supply is about 80 percent of the national seed demand.

Generally, the seed business follows the fish seed culture size categorization, i.e. 1-3 cm; 3-5 cm; 5-8 cm and 8-12 cm. However, hatcheries sometimes sell different stages of fish, e.g. eggs for gouramy, 3-4 day old larvae for common carp and Nile tilapia and nauplii and post-larvae for the giant freshwater prawn.

A major limiting factor in the seed industry is the lack of high quality broodstock caused by in-breeding process.

SUPPORT SERVICES

Technology

The Research Institute for Freshwater Fish (RIFF) located in Sukamandi, West Java and Palembang, South Sumatra undertakes research and technology development on freshwater aquaculture. The technology developed by research institutes are transferred to the TIUs of the DGA and state hatcheries or directly disseminated to fish farmers.

TIUs and state hatcheries have the roles to develop applied technologies which are ready to be applied by the fish farmer.

Recently, institutional cooperation on technology development has been carried out between the Freshwater Aquaculture Development Center (FADC) in Sukabumi and the Fish Culture Research Institute (or HAKI) of Hungary on genetic improvement of common carp. Researchers from FADC Sukabumi had been invited to visit HAKI to learn techniques for producing good quality seed of common carp. This collaboration was supported by FAO.

Meanwhile, FADC Jambi is continuing collaborative work with the Japanese International Cooperation Agency (JICA) on extension programs for fish farmers from Jambi and Riau provinces.

Training and extension

Training is one activity for transferring technology through support from government or in collaboration with regional or international organizations such as JICA or the Network of Aquaculture Centres in Asia-Pacific (NACA). Training varies depending on the target group and whether the program is a Training for Trainers (TOT) and/or a training for farmers. TOT is usually for government officers or extension workers with the responsibility to distribute information to the farmers. The policy on extension was previously mandated to the central government. In line with Legislation No. 22/1999 revised into Legislation Law No. 32/2004, responsibilities for extension services to farmers and fishers has been given to local government, particularly the district government. The central government is still involved in extension work through government research institutes, the TIU and fisheries service offices which are mandated to disseminate the technologies that they have developed.

Financial

So far, there is no special credit scheme for aquaculture/hatchery business provided by banks, although financial schemes are provided to coastal aquaculture business by many state banks (e.g. Bank Mandiri, Bank Bukopin). Nevertheless, financial support is limited to a small amount. To support the need for a working capital by small-scale farmers, the DGA established an empowerment program for fish farmers where a revolving fund program has been established for use by farmers. This program is for demonstration purposes only and available only in certain areas of the country.

Networking

Networking among fish farmers either at individual or intra-group level is very weak. Transfer of information and knowledge between and among farmers is very limited. Annual meeting of stakeholders of freshwater hatcheries is organized by the DGA.

SEED CERTIFICATION

Since 1998, a certification system was established focused on management of hatcheries. However, certification for good quality seed has not been implemented yet. The DGA issues a "Certificate for Hatchery" after an assessment by an assessor, representing the DGA and the TIU, acting as an Independent Body for Quality System Certification, has been completed. Assessment is conducted concerning some aspects of management, production process, social, environment, food safety and traceability.

LEGAL AND POLICY FRAMEWORKS

The Ministry of Marine Affairs and Fisheries (MMAF), the responsible authority for the development of the aquaculture sector in Indonesia, has issued a number of specific rules and regulations to be used as legal and policy frameworks for seed development. These include the following:

Ministerial Decree of Agriculture Ministry No. 26/Kpts/OT.210/1/98 on Guidance of Indonesian Fish Seeding Development. This decree covers regulations concerning the supply and distribution of fish seed for local demand which should conform with 7 parameters (i.e. type, size, amount, price, quality, time and place) and other aspects related to sustainability of seed production business, rural-based culture industry, standardization and certification of the hatchery unit, control of the exploitation and sustainability of fish resources especially of germplasm, observation on and supervision of hatchery and seed production activities.

Ministerial Decree of Agriculture Ministry No. 214/KPTS/UM/V/1973 on Export Prohibition of Some Fish Species from Indonesian Territory. This decree is related to the supervision and maintainance of sustainability of fisheries resources, in line with preventing the negative effect of fishery development by giving priority to the demands for domestic seed and prohibition of the exportation of certain species from the Indonesian territory.

Ministerial Decree of Agriculture Ministry No. 700/KPTS/IK.120/11/1989 on Exportation of Penaeid Shrimp from Indonesian Territory. Live penaeid shrimp can be exported from the Indonesian territory except broodstock and pre-broodstock sizes, since shrimp hatcheries still depended on wild broodstock as implementation of the broodstock production technology has not yet been successful.

Ministerial Decree of Agriculture Ministry No. 810/KPTS/IK.210/7/1999 on Examination, Assessment and Releasing of Fish Type and Variety. This regulation is issued to guarantee the availability of fish/shrimp seed in high quantity and good quality which are required for establishing superior varieties. To determine the characteristics of these varieties, assessment and examination are carried out by an Expert Team as required by law.

Ministerial Decree of Marine Affairs and Fisheries Ministry No. 07/2004. Ministerial Decree of Agriculture Ministry No. 1041.1/Kpts/IK.120/1999 on Providing and Distribution of Fish Seed. Under this decree, supervision concerning the production and distribution of fish seed and/or broodstock obtained from nature, hatcheries, or imported from abroad and through genetic improvement should be done in order to guarantee the availability of fish seed both in quantity and quality.

Ministerial Decree of Agriculture Ministry No. 1042.1/Kpts/IK.210/10/1999 on Certification of Hatchery Unit and Monitoring of Fish Seed. This decree regulates the procedures involved to certify good quality seed. The process requires assessing the capability of hatchery units with respect to facility, human resources and production system, as well as procedures in place to comply with the certification requirements (e.g. technical standards for breeding to guarantee quality seed production).

ECONOMICS

Freshwater fish production makes a very important contribution (59 percent) to protein diet from aquaculture, since most of the freshwater fish production are targeted for local consumption. Only Nile tilapia has been exported in fillet form.

To support freshwater fish production, there are at least 26 365 fish farmer households directly involved in freshwater fish seed industry.

STAKEHOLDERS

The different stakeholder groups involved in Indonesian freshwater fish seed production sector are listed and briefly described below.

Producers/farmers. Fish seed producers in Indonesia consist of farmers involved in freshwater fish hatchery operations consisting of about 26 365 households. They breed the broodstock supplied by government and private companies or those which came from the wild to produce fish seed.

Local institutions. There are 33 provincial fisheries service offices and 414 district fisheries service offices. The main task of these institutions are to build a strong extension system for fish farmers. The provincial and district government hatcheries have the main task of producing broodstock and disseminating the seeding technology.

Small hatcheries. Small hatcheries who supply most of local freshwater seed demand consist of fish farmer-operated hatcheries on an individual as well as group business basis. The main objective of the business is to produce seed.

Large hatcheries. Large hatcheries owned by private companies usually have their own breeding program for maintaining their broodstock and seed quality.

Associations. Two associations relevant to Indonesia's freshwater fish seed sector are: (i) Indonesia Seed Society (ISS) and (ii) Indonesia Aquaculture Society (IAS). The ISS is an independent organization oriented to agricultural development (including aquaculture), especially seeding and germination and that which promote the implementation of good agribusiness practices and environment-friendly concepts. ISS provides a place for networking and cooperation in order to strengthen the national seeding system. In partnership with the government responsible for developing the fisheries sector, ISS will make serious efforts towards attaining competitiveness and production of high quality seed and enhancing the distribution system. The IAS is a professional organization oriented towards aquaculture development and the promotion of the implementation of good aquaculture practices and environment-friendly concepts. The IAS has wide membership from the aquaculture business, research, government, university and academic sectors.

Government institutions. The main national institution who is responsible for Indonesia's freshwater fish seed is the Directorate of Seed Development under DGA. The TIUs, under the DGA, were established to support the implementation of technical duties in the field as well as to serve broodstock centers.

Researchers. Researchers mostly work at research institutes and at universities and other academic institutions. Research institutes in the field of freshwater aquaculture are presented in Table 7.12.10.

Universities and other academic institutions which have fisheries faculty/department are listed in Table 7.12.11.

Donors. There is no specific international agency directly supporting the development of the freshwater fish seed industry. The Southeast Asian Fisheries Development Center (SEAFDEC) has been involved in the development of the giant freshwater prawn, particularly in seed development. SEAFDEC has been working, since the last three years, with FADC Sukabumi to strengthen research collaboration on *Macrobrachium* seedling. Another international organization interested in freshwater seedling technology was JICA, through a project which ended in mid-2005. During project implementation, JICA gave more attention to development of common carp, marble goby, pangasius and tilapia. JICA is continuing the project for another 3 years with FADC Jambi with specific focus on extension.

Other relevant information. Development of the freshwater seed sector is very slow compared to other hatchery business, e.g. marine fish and shrimp. This may be market-related as freshwater fish are particularly intended for the local market and only a small percentage (i.e. tilapia and catfish) is aimed for the export market. Other reasons include the decreasing quality of seed, inbreeding issues which caused slow growth and exporter requirements (e.g. fish size, number of fish, off-flavour, etc.).

Another obstacle to the development of the freshwater aquaculture sector is the non-availability of credit for small-scale farmers. Banks are reluctant to provide loan to small-scale farmers since they require collateral (e.g. land certification) from farmers. Only middle- and large-scale farmers have those documents.

TABLE 7.12.10
Research institutes in the field of freshwater aquaculture

No.	Name	Location
1	Research Institute on Freshwater Aquaculture Sukamandi	Jl. Raya 2, Sukamandi, Subang.
2	Research Institute on Freshwater Aquaculture Palembang	Jl. Beringin 308, Mariana PO. Box 1125, Palembang
3	Research Installation on Freshwater Aquaculture Bogor	Jl. Raya Sempur, Bogor
4	Research Installation on Freshwater Aquaculture Pasar Minggu	Jl. Ragunan PO. Box 20, Ps. Minggu, Jakarta Selatan
5	Research Installation on Freshwater Aquaculture Jatiluhur	Jl. Jatiluhur PO. Box 01 Purwakarta
6	Research Installation on Freshwater Aquaculture Depok	Jl. Perikanan PO. Box 16 Depok
7	Dempond Research Installation Cibalagung	Jl. Banteng Suroso No. 26, Cibalagung, Bogor
9	Dempond Research Installation Cijeruk	Desa Cipulus, Cijeruk, Bogor

TABLE 7.12.11

Universities and other academic institutions with fisheries faculty/department

No.	University	Location
1	Abulyatama University-Faculty of Fisheries	Jl. Biang Bintang Km. 8.5 Banda Aceh - Nanggroe Aceh Darussalam
2	HKBP Nommensen University, Department of Fisheries	Jl. Dr. Soetomo No. 4A Medan 20234 - SUMUT
3	Dharmawangsa University, Faculty of Fisheries	Jl. Yos Sudarso No. 224 Medan - SUMUT
4	Riau University - Faculty of Fisheries	Jl. Bangkinan Km. 12.5 Pekanbaru - RIAU
5	Islam Riau University, Department of Fisheries	Jl. Prof. Muh. Yamin No. 69 Pekanbaru
		Jl. Kaharuddin Nasution No. 113 Perhentian Maryopan Pekanbaru 28284 - RIAU
6	Bung Hatta University, Faculty of Fisheries	Jl. Sumatera Ulak Karang, Padang 25133 - SUMBAR
7	Muhammadiyah University, Departement of Fisheries - Faculty of Fisheries	Jl. Jend. A. Yani No.13 Ulu Darat, Palembang
8	Batang Hari University, Department of Fisheries	Jl. Letkol. Slamet Riyadi - JAMBI
9	Prof. Dr. Hazairin University,Departement of Fisheries	Jl. Jend. A. Yani No. 01 Bengkulu
10	Fisheries High School (STP) Jakarta	Jl. AUP, Pasar Minggu PO.BOX 7239/7326 JKPSm 12520
11	Satya Negara Indonesia University - Faculty of Fisheries	Jl. Makmur/Arteri, Kebayoran Lama Utara. JKT 12440
12	Bogor Institute (IPB) Faculty of Fiheries	Jl. Rasamala No. 01 Darmaga, Bogor 16680 - JABAR
13	University of Djuanda, Department of Fisheries	Jl. Tol Ciawi, Bogor - JABAR
14	Padjajaran University, Department of Fisheries	Jl. Raya Jatinangor Km. 21 Bandung 45363 - JABAR
15	Gadjah Mada University, Department of Fisheries	Sekip Unit I Yogyakarta 55821
16	Siliwangi University, Department of Fisheries	Kotas Pos 65 Tasikmalaya - JABAR
17	Yogyakarta Fisheries Academy	Jl. Kenari No.65 Muja-muju - Yogyakarta
18	Diponegoro University, Faculty of Fisheries	Jl. Hayam Wuruk No. 4A Semarang - JATENG
19	Fisheries Academy Karya Husada	Jl. Kyai Saleh No.3 Semarang - JATENG
20	Fisheries Academy Kalinyamat	Jl. HMS. No. 1 krian Jepara - JATENG
21	Panca Sakti University, Faculty of Fisheries	Jl Pancasila No. 02 Tegal - JATENG
22	Pekalongan University, Faculty of Fisheries	Jl. Garuda No. 49A Pekalongan
		Jl. Majapahit No. 16 Pekalongan - JATENG
23	Fisheries Academy PGRI Tuban	Jl. Manunggal No. 61 Tuban - JATIM
24	Fisheries Academy Qomaruddin	Jl. Raya Bungah Gresik - JATIM
25	Muhammadiyah University, Faculty of Fisheries	Jl. KH. Kholil No. 73 Gresik - JATIM
26	Hang Tuah University, Faculty of Fisheries	Jl. Arif Rahman Hakim No. 150 Sukolilo Surabaya 60111 - JATIM
27	Dr. Soetomo University- Department of Fisheries	Jl. Semolowaru Surabaya - JATIM
28	Al Falah University, Faculty of Fisheries	Jl. Taman Mayangkara Surabaya - JATIM
29	Jenggala University, Department of Fisheries	Jl. Sasakandang Sidoarjo 61200 - JATIM
30	Sidoarjo Fisheries Academy	Jl. Raya Sedati Km. 8 Sidoarjo 61200 - JATIM
31	University of Brawijaya, Faculty of Fisheries	Jl. MT. Haryono No. 161 Malang 65100 - JATIM
32	Muhammadiyah University, Department of Fisheries	Jl. Tlogomas Km. 08 Malang 65144 - JATIM
33	High School of Fisheries Science (STIP)	Jl. Cengger Ayam I No. 05 Malang 65100 - JATIM
34	University of 17 August 1945, Departement of Fisheries	Jl. Adi Sucipto No. 26 Banyuwangi 68450 - JATIM
35	Airlangga University, Department of Fisheries	Jl. Airlangga No. 4-5 Surabaya - JATIM
36	University of Marwadewa, Department of Fisheries	Jl. Terompong No. 36 Tanjung Bungkak - Denpasar
37	45 Mataram University, Faculty of Fisheries	Jl. A. A. Gede Ngurah Cakranegara, Mataram - NTB
38	University of Nusa Cendana, Department of Fisheries	Jl. Jenderal Soeharto No. 72 Kupang - NTT
39	Veteran University of Ahmad Yani, Department of Fisheries	Jl. A. Yani Km. 32 Loktabat, Banjar Baru 70712 - KALSEL
40	University of Muhammadiyah, Faculty of Fisheries	Jl. KH. Ahmad Dahlan, Walikota Baru Kupang - NTT
41	University of Lambung Mangkurat, Faculty of Fisheries	Jl. A. Yani Km. 36 Banjar Baru 70714 - KALSEL
42	University of Muhammadiyah, Department of Fisheries	Jl. A. Yani No. 111 Pontianak - KALBAR
43	University of Palangkaraya, Faculty of Fisheries	Jl. Yos Sudarso, Tanjung Nyaho Palangkaraya 73114
44	Mulawarman University, Faculty of Fisheries	Jl. Pasir Balengkong PO. BOX 40 Samarinda - KALTIM
45	University of Muslim Indonesia, Faculty of Fisheries	Jl. Urip Sumiharjo Km. 5 Makassar - SULSEL
46	University of Hasanuddin, Faculty of Fisheries	Jl. Perintis Kemerdekaan Km. 10 Makassar - SULSEL
47	45 University of Makassar, Department of Fisheries	Jl. Urip Sumiharjo Km. 4 Makassar - SULSEL
48	Cokroaminoto University, Faculty of Fisheries	Jl. Perintis Kemerdekaan Km. 11 Makassar - SULSEL
49	Politani Negri Pangkep	Mandalle - SULSEL
50	University of Al-Khairaat Palu, Faculty of Fisheries	Jl. Sis Al Jufri No. 44 Kamonji Palu - SULTENG
51	University of Dayanu Ikhsanudin, Faculty of Fisheries	Jl. Yos Sudarso, Bau Bau Buton - SULTRA
52	University of Haluoleo, Department of Fisheries - Faculty of Fisheries	Jl. Malaka, Kampus Baru UNHALU Aduonohu Kendari - SULTRA
53	Sam Ratulangi University, Faculty of Fisheries	Kampus UNSRAT Bahu, Manado 95115 - SULUT
54	University of Pattimura, Faculty of Fisheries	Jl. MR. CHR. SUPLANIT, Poka. Ambon 97100 - MALUKU
55	Khairun University, Faculty of Fisheries	Jl. Bandara Babullah, Akehuda Ternate 97700 - MALUKU UTARA
56	University of Borneo, Faculty of Fisheries	Jl. Jenderal Soedirman No. 85 Kampung Baru Tarakan - KALTIM

FUTURE PROSPECTS AND RECOMMENDATIONS

Exportation of freshwater fish mainly Nile tilapia for 2009 is targeted at 36 000 tonnes (estimated value of US$144 million) while other species are targeted for local consumption. The target production for 2009 of the main species of freshwater fish and the required supply of seed are presented in Table 7.12.12.

The fish seed requirement to realize the targeted freshwater aquaculture production shows the great opportunity and prospect for the freshwater fish seed industry.

TABLE 7.12.12

Targeted production of the main species of freshwater fish and the required supply of seed for 2009

No.	Species	Production (tonnes)	Seed (million)
1	Common carp	446 000	1 742.5
2	Nile tilapia	195 000	760.5
3	Walking catfish	175 000	622.2
4	Gouramy	45 000	150.0
5	Siamese catfish	36 500	121.7
	Total	717 500	3 396.9

7.13 Freshwater fish seed resources in Mexico

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ABSTRACT

Aquaculture officially began in Mexico in the early 1970s, as an alternative to produce low cost food fish for rural communities. Tilapia, common and Chinese carps were introduced, reproduced in government fish hatcheries and fingerlings distributed to newly trained farmers for growing to small ponds throughout the country. Gradual private investment and the introduction and mastering of culture technologies for high value species, gave way to a new, growing and competitive industry, which yielded almost 80 000 tonnes in 2004.

Freshwater aquaculture production is mostly comprised of tilapia, which contributes more than 35 percent, common carp (11 percent), rainbow trout (1.7 percent) and channel catfish (1.15 percent) of the total national aquaculture production, the balance of production coming from marine species.

There are 165 registered hatcheries in the country, both public and private, whose total output is approximately 200 million fingerlings of the above species per year. Additionally, imports of eggs and fry from the United States of America, Canada and Europe, amount to between 17 and 20 million annually. Furthermore, the rapid expansion of the industry (25 percent per annum during the last 5 years), has stimulated the establishment of a growing number of hatcheries.

Breeding and hatchery techniques have been adapted from standard procedures developed and employed worldwide. In the case of tilapia, seed is produced in hatcheries that are vertically integrated and attached to medium- or large-sized ponds or cage farms. Breeders are stocked in earthen or concrete ponds or in cages (1-1.5 males per 2-3 females). In cages, artificial spawning floors are provided. Fry are transferred to sex reversal ponds and fed with hormonized feed to produce all-male cohorts.

Carp seed are produced chiefly by government hatcheries. Pituitary extracts are injected to breeders to induce spawning and are then maintained in 0.1-0.2 ha ponds. Fry are raised in earthen fertilized ponds until they reach 5-8 g and then distributed to growers.

Rainbow trout hatcheries are all part of vertically-integrated farms. Manual stripping of breeders and artificial dry insemination are employed. In addition, some farmers regularly import eyed-eggs to maintain genetic diversity. Weaned trout are reared within the farm to market size.

A few native species, such as *Cichlasoma urophthalmus*, are also bred in captivity employing natural methods (i.e. earthen ponds stocked with mature adults at a ration of 1 male:2-3 females and left to spawn naturally) and their seed regionally distributed to growers.

Pricing of fish seed in Mexico, especially of carps and tilapias, is generally biased given that government hatcheries sell these at subsidized prices, thus distorting the market. Mid- to large-sized farms produce their own seed. With the rapid growth of this sector, support services to the industry are also increasing. Genetic research and technical training are provided through government programmes. However, there are no genetic banks or genetic follow-up programmes. Farmer networks are not well consolidated, thus seed producers tend to work individually.

As far as seed quality is concerned, currently there are no official standards in the country. It is the buyers´ level of satisfaction in terms of seed performance (i.e. survival rate, growth rate, disease resistance, etc.) that determine acceptance or rejection of seed. Zoosanitary certification of seed is mandatory if eggs, fry or fingerlings are to be moved both within the country and internationally. Genetic improvement is only a part of research programmes, and links between scientists and farmers are still very weak.

INTRODUCTION

The information presented in this document is based principally on statistics published by the Federal Government which have been compiled and circulated to the fisheries sub-delegations in each of the states comprising the Republic of Mexico. Another source of information was the content of the statistical yearbook of fisheries, most recently published in 2003. The National Fisheries Map was prepared by the National Fisheries Institute (INP, Instituto Nacional de las Pesca) through the General Directorate of Aquaculture Research (Dirrecion General de Investigacion en Acuicultura) in coordination with the National Commission on Fisheries and Aquaculture (CONAPESCA, Comisión Nacional de Pesca y Acuicultura). Other institutions are devolved agencies of the Secretariat of Agriculture, Farming, Rural development, and Fisheries and Food (SAGARDP, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación). Other sources include: (i) information which the state committees on aquatic animal health has compiled after visits to the producers; these committees are part of a tripartite structure of joint responsibility between producers and state and federal government, (ii) articles and presentations published in conferences, symposia, or events related to aquaculture and (iii) information from state governments.

In Mexico, aquaculture started as an activity which complemented social support to rural communities aimed at increasing the consumption of animal protein and improve the nutritional well-being of the population (Juarez-Palacios, 1987).

From its beginnings, there have been two development trends in aquaculture which reflect the different stages of aquaculture development in the country, namely: (i) promotional aquaculture and (ii) commercial aquaculture. Promotional aquaculture is applied in small bodies of water and production units, principally for domestic consumption using species such as tilapia and carp, as well as aquacultural fisheries activities such as systematic sowing, in medium- and large- sized reservoirs, of seed produced in state or federal-owned aquaculture centers and management of fish spawn where it occurs in the wild. The species most commonly seeded are carp, tilapia, catfish and bass (the latter for sport fishing). Commercial aquaculture, on the other hand, carried out in controlled systems using species such as trout and catfish, and later with tilapia, had the objective of obtaining high production levels, in order to become a viable commercial prospect, which inevitably demands greater investment (Ramírez and Sánchez, 1998).

Within the encouragement of aquacultural activity, some native species, such as silverside (*Chirostoma stor*) are primarily destined for re-stocking and to support rural communities.

The species currently farmed in Mexico, their final use and the infrastructure of the production systems are presented in Table 7.13.1.

TABLE 7.13.1
Cultured freshwater fish in Mexico

Species	Common name	Use	Production system	Infrastructure
Cyprinus carpio specularis	common carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Cyprinus carpio communis	mirror carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Cyprinus carpio rubrofuscus	pot-bellied carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Carassius auratus	goldfish	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Ctenopharyngodon idella	grass carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Hypophthalmichthys molitrix	silver carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Ariistichthys nobilis	bighead carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Mylopharyngodon piceus	black carp	re-stocking, human consumption, aquarium	semi-intensive, extensive	natural and concrete ponds, cages
Atractosteus spatula	alligator gar	human consumption, sport fishing	extensive	natural ponds
Micropterus salmoides	largemouth bass, Patzcuaro trout	human consumption, sport fishing, handicrafts, biological control	Intensive semi-intensive, extensive	rustic reservoirs, natural and concrete ponds
Atractosteus tropicus	tropical gar	re-stocking, human consumption, sport fishing, handicrafts,	extensive	rustic reservoirs, natural and concrete ponds
Chirostoma estor	pike silverside	re-stocking, human consumption	extensive, controlled	natural and concrete ponds, plastic and galvanized tanks
Chirostoma humboldtianum	pescado blanco	re-stocking, human consumption	extensive, controlled	natural and concrete ponds, plastic and galvanized tanks
Chirostoma promelas	blacknose silverside	re-stocking, human consumption		
Chirostoma lucius	longjaw silverside	re-stocking, human consumption		
Chirostoma sphyraena	bigmouth silverside	re-stocking, human consumption		
Oreochromis aureus	blue tilapia	re-stocking, human consumption	intensive, semi-intensive, extensive	rustic reservoirs, natural and concrete ponds, cages
Oreochromis niloticus	Nile tilapia	re-stocking, human consumption	intensive, semi-intensive, extensive	rustic reservoirs, natural and concrete ponds, cages
Oreochromis mossambicus	Mozambique tilapia	re-stocking, human consumption	intensive, semi-intensive, extensive	rustic reservoirs, natural and concrete ponds, cages
Oreochromis urolepis homorum	Wami tilapia	re-stocking, human consumption	ntensive, semi-intensive, extensive	
Oncorhynchus mykiss	rainbow trout	re-stocking, human consumption, sport fishing	intensive, semi-intensive	natural and concrete ponds, cages, and fast-flowing channels
Ictalurus punctatus	channel catfish	re-stocking, human consumption	intensive, semi-intensive	natural and concrete ponds, cages, and fast-flowing channels

Source: INP SAGARPA (2003)

TABLE 7.13.2
Volume and Value of fish production though aquaculture, by principal species for 2003 (tonnes, value in pesos and dollars)

Species	Volume*	Value	
		1 000 pesos	US$
Total	**204 012**	**4 423 255**	**419 265 877**
Catfish	2 464	47 558	4 507 867
Carp	22 059	172,355	16 336 967
Silver side fish	812	5 416	513 365
Prawn	43	3 059	289 953
Bass	818	19 458	1 844 360
Tilapia	58 660	608 080	57 637 915
Trout	3 734	126 543	11 994 597
Others	5 428	711 974	67 485 687

Source: Annual Statistics of Fisheries (SAGARPA, 2003)

TABLE 7.13.3
Volume of aquaculture production of cultured live fish by principal species in 2003 (in tonnes)

Species	Total	Aquaculture	
		Controlled systems	Aquaculture fisheries
Total	207 776	74 039	133 737
catfish	2 516	497	2 020
carp	22 189	405	21 784
silverside fish	812	0.50	812
prawn	43	3	40
bass	848	3	845
tilapia	61 516	964	60 551
trout	3 734	3 483	251
others	5 466	4 562	904

Source: SAGARPA, 2003

The most recent statistics for aquaculture production in Mexico, from 2003 (Anuario Estadístico de Pesca, 2003) can be found in Table 7.13.2 and Table 7.13.3.

The growth of the population of Mexico has led also to a rise in the numbers living in extreme poverty, exacerbated by poor diet with low levels of nutrition. Aquaculture has the potential to provide an alternative diet through production of products with good quality protein that will help diminish malnutrition in this vulnerable sector of society.

Mexican statistics reveal that the annual average per capita consumption of fish, between 1992 and 2002, was 12.47 kg (SAGARPA, 2002) which falls below the minimum annual requirement of 20 kg.

Although rural aquaculture programmes do exist in zones of lesser economic development and high levels of poverty, a limiting factor on their expansion is the lack of interest in the sector, the lack of tradition of eating fish, as well as the lack of information on the benefits of eating fish. It is thus essential to have more solid and continuous programs of expansion for aquaculture.

SEED SUPPLY AND RESOURCES

Seed are produced from state and federal as well as private hatcheries. Seed of the following species are produced: trout, carp, tilapia, catfish, bass, silver carp.

In order to help the population living in poverty, the production of 39 hatcheries operated and supervised by CONAPESCA had been sent to 608 municipalities, of which 51 percent are highly marginalized. This has benefitted 126 000 families through improvement in the quality of their nutrition and income generation through fish sales (SAGARPA, 2004).

The national program of support to rural aquaculture promoted the development of aquaculture in marginalized areas through the supply of fingerling, technical assistance and delivery of resources for the renovation or construction of infrastructure, acquisition of equipment and provision of contracts for specialized technical assistance. As a result of this program, 11 541 families in the most marginalized regions of the country benefited in 2001. Ponds are stocked with 13 million fry for the production of carp, catfish, and tilapia. In 2003, beneficiaries of the program included 4 129 producers located in 239 communities in 110 municipalities in the country (SAGARPA. 2004).

SEED PRODUCTION AND TECHNOLOGY

Table 7.13.4 shows the production technologies of different species in different states.

TABLE 7.13.4
List of federal government, state government, private and commercial hatcheries

Trout

State	Hatchery	Technology used	Fry production
Baja California	Private	Artificial spawn	No data home consumption
Chihuahua	hatchery de Guachochi[1]	Artificial spawn	636 350 520 000*
	hatchery de Madera[1]	Artificial spawn	Not in production at present
Mexico	hatchery “El Zarco”[1]	Artificial spawn	Not in production at present
	hatchery Calimaya[2]	Artificial spawn	Not in production at present
	58 private produccers[4]	Artificial spawn	2 000 000
	Private importers[3]	Eyed eggs importation from USA and Australia	7 000 000 eyed eggs dead are not considered
Hidalgo	La trucha de “El Zembo”[4]	Hatchery. Egg incubation, imported form USA	450 000
	Worker´s Cooperative “La trucha de San Diego”[4]	Hatchery. Egg incubation, imported form USA	75 000
	Worker´s Cooperative acuícola “Apulco”[4]	Hatchery. Egg incubation, imported form USA	64 000
	S.P.P. de San Miguel Regla	Artificial spawn	No data
Michoacán	hatchery Pucuato[2]	Artificial spawn	170 606
Puebla	hatchery Apulco[1]	Artificial spawn	2 000 000 750 000*
	hatchery “La Rosita”[2]	Artificial spawn	1 000 000 750 000*
	Private hatchery Xoulin[3]	Artificial spawn	No data home consumption
	Commercial sector	Artificial spawn	450 000*
	Private sector	Artificial spawn	300 000*
Veracruz	hatchery Matzinga[1]	Artificial spawn	Not in production at present

Total production of the trout fry reported from federal government hatcheries in 2004 were 1 025 156 CONAPESCA.

* No official data, from aquatic health aquaculture committee, state government, universities and general publication, etc.

Carp

State	Hatcheries	Technology used	Fry production
Aguascalientes	Hatchery Pabellón de Hidalgo[1]	Artificial spawn and induced	1 211 500
Chiapas	Hatchery San Cristóbal[1]	Artificial spawn and induced	336 156 1 650 000*
Chihuahua	Hatchery La Boquilla[1]	Artificial spawn and induced	326 000 287 150*
Coahuila	Hachery La Rosa[1]	Artificial spawn and induced	6 821884 5 700 000*
Durango	Hatchery Valle de Guadiana[1]	Artificial spawn and induced	2 824 450 4 000 000*
Guanajuato	Hatchery Jaral de Berrio[1]	Artificial spawn and induced Artificial spawn and induced	3 356 500
	Hacthery Martín Magaña[3]		No data
Hidalgo	Hatchery Tezontepec de Aldama[1]	Artificial spawn and induced	31 403 531
	Integral farm of Poli- culture Tezontepec[2]	Artificial spawing and induced	6 082 000
Jalisco	Hatchery Tizapan El Alto[1]	Artificial spawn and induced	335 950
	Hactchery Las Pintas[1]	Artificial spawn and induced	No data
Michoacán	Hacthery Pátzcuaro[1]	Artificial spawn and induced	45 850 1 075 000*
	Hatchery Zacapu[1]	Artificial spawn and induced	2 104 389 1 500 000*
Estado de México	Hatchery Tiacaque[2]	Artificial spawn and induced	14 000 000
	Hatchery La Paz[2]	Artificial spawn and induced	711 000
Puebla	Hacthery "La Rosita[2]	Artificial spawn and induced	1 000 000
Querétaro	Hatchery Calamanda[1]	Artificial spawn and induced	161 250 750 000*
	Hatchery Conca[2]	Artificial spawn and induced	348 000*
San Luis Potosí	Hatchery El Peaje[1]	Artificial spawn and induced	509 000
Sonora	Hatchery Cajeme[1]	Artificial spawn and induced	No data
Tamaulipas	Hatchery Tancol[1]	Artificial spawn and induced	No production at present
Tlaxcala	Hatchery Atlangatepec[1]	Artificial spawn and induced	750 000

Total carp fry production reported from federal government hatcheries CONAPESCA 2004, were 52 578 139

* Unofficial data, from the aquatic animal health committees, state government, universities, scientific publication, etc.

Tilapia

State	Hatchery	Technology used	Fry production
Aguascalientes	Hatchery Pabellón de Hidalgo[1]	Natural spawn	5 716 000
Baja California	Private	Natural spawn	Home consumption
Campeche	State	Natural spawn	800 000 fingerling/month*
Chihuahua	Hatchery "La Boquilla"[1]	Natural spawn	187 950 217 900*
Coahuila	Hachery "La Rosa"[1]	Natural spawn	370 919 660 000*
Colima	Hatchery "El Saucito"[1]	Natural spawn	434 449
	Hatchery "Jala"[1]	Natural spawn	2 314 717
	ha Potrero Grande[1]	Natural spawn	10 000
Chiapas	Hatchery Benito Juárez[1]	Natural spawn	1 140 700
	Hatchery El Pataste[1]	Natural spawn	262 000
	Hatchery San Cristóbal[1]	Natural spawn	No data
Chihuahua	Hatchery La Boquilla[1]	Natural spawn	187 950
	Hatchery Guachochi[1]	Natural spawn	No data
Durango	Hatchery Valle de Guadiana[1]	Natural spawn	289 833
Estado de México	Hatchery La Paz[2]	Natural spawn	2 250 000
Guanajuato	Hatchery Jaral de Berrio[1]	Natural spawn	264 166
Guerrero	Hatchery Aguas Blancas[1]	Natural spawn	437 900
Hidalgo	Hatchery "Acuicultores de Tollan[4]	Natural spawn	1 500 000 fry 40 percent for state consumption. To cover the full demand, suppliers are from Morelos, Oaxaca and Michoacán states.
	Hatchery Tezontepec de Aldama[1]	Natural spawn	This year begins the fry production. No data for planned production
Jalisco	Hatchery Las Pintas[1]	Natural spawn	No data 1 800 000*
Michoacán	Hatchery Pátzcuaro[1]	Natural spawn	No production
Morelos	Hatchery El Rodeo[1]	Natural spawn	1 640 660
	Hatchery Zacatepec[1]	Natural spawn	957 668
Nayarit	Hatchery San Cayetano[1]	Natural spawn	373 350
Oaxaca	Hatchery Temascal[1]	Natural spawn	3 905 050
Querétaro	Hatchery Calamanda[1]	Natural spawn	162 250 1 324 000*
Quintana Roo	Private		300 000 fingerling/month*
Sinaloa	Hatchery Chametla[1]	Natural spawn	5 938 400
	Hatchery El Varejonal[1]	Natural spawn	10 387 000
Sonora	Hatchery Cajeme[1]	Natural spawn	No data
	Worker´s cooperative La Laguna del Río[4]	Fingerling importation	Fingerling importation 950 000
Tabasco	Hatchery Puerto Ceiba[1]	Natural spawn	1 520 866
Tamaulipas	Hatchery Tancol[1]	Natural spawn	265 200 349 400*
Veracruz	Hatchery La Tortuga[1]	Natural spawn	1 049 500
	Hatchery Los Amates[1]	Natural spawn	262 090
	Hatchery Sontecomapan[1]	Natural spawn	1 816 402
	Hatchery Tebanca[1]	Natural spawn	72 894
Zacatecas	Hatchery Julián Adame[1]	Natural spawn	811 000

Total tilapia fry production reported from federal government hatcheries CONAPESCA 2004, were 43 813 964.

* Unofficial data, from the aquatic animal health committees, state government, universities, and scientific publication.

Bass

State	Hatcheries	Technology used	Fry production
Aguascalientes	Hatchery Pabellón de Hidalgo[1]	Natural spawn and induced	254 400
Coahuila	Hatchery La Rosa[1]	Natural spawn and induced	52 376 47 000*
Chihuahua	Hatchery La Boquilla[1]	Natural spawn and induced	No data
Durango	Hatchery Valle de Guadiana[1]	Natural spawn and induced	96 123 100 000*
Estado de México	Hatchery La Paz[2]	Natural spawn and induced	23 000
Michoacán	Hatchery Pátzcuaro[1]	Natural spawn and induced	Not in production
Sinaloa	Hatchery El Varejonal[1]	Natural spawn and induced	No data
Sonora	Hatchery Cajeme[1]	Natural spawn and induced	No data
Tamaulipas	Hatchery Tancol[1]	Natural spawn and induced	23 230

Total bass fry production reported from federal government hatcheries CONAPESCA 2004, were 426 129.

* Unofficial data, from the aquatic animal health committees, state government, universities and scientific publication.

Catfish

State	Hatcheries	Technology used	Fry production
Coahuila	Hatchery La Rosa[1]	Natural spawn and hormone induced	268 271 181 000*
Chihuahua	Hatchery La Boquilla[1]	Natural spawn and hormone induced	845 500 675 000*
Durango	Hatchery Valle de Guadiana[1]	Natural spawn and hormone induced	No data
Guanajuato	Worker´s cooperative Granja El Geranio[4]	Natural spawn and hormone induced	No data
Michoacán	Hatchery Huingo[2]	Natural spawn and hormone induced	No data
Sonora	Hatchery Cajeme[1]	Natural spawn and hormone induced	No data
San Luis Potosí	No data	Dato no disponible	No data
Tamaulipas	Private Criadores Acuícola de Tamaulipas S.A de C.V[3]	Fingerling importation	150 000
	Acuamex[3]	Natural spawn and hormone induced	No data

Total catfish fry production reported from federal government hatcheries CONAPESCA 2004, were 1 113 771.

* Unofficial data, from the aquatic animal health committees, state government, universities and scientific publication.

Native silverside fish

State	Hatcheries	Technology used	Fry production
Jalisco	Hatchery Tizapán El Alto[1]	Natural spawn	4 000
Michoacán	INERENA[2]	Natural spawn	No data
	CRIP Pátzcuaro[1]	Natural spawn	65 000

Catán

State	Hatcheries	Technology used	Fry production
Tamaulipas	Hatchery Tancol	Natural spawn	79 900 35 000*

* Unofficial data, from the aquatic animal health committees, state government, universities and scientific publication

SEED MANAGEMENT

This section provides a brief description of seed management protocols for each species.

Trout. There is no management of broodstock. In general, they are not provided with food specific to their requirements. Young are fed according to size; the selection of food according to size is often deficient. There is no sanitary management program in rearing farms. In intensive farms, there are programmes for sanitary management which include preventative measures such disinfection of equipment.

Carp. At breeding time, the organisms are given vitamins in commercial preparations, supplemented by alfalfa. Hypophysis extracts are used to induce spawning. There is no programme for genetic management. There are preventative programmes and sanitary management in seed production centers which are federal or state-run.

Tilapia. There are no sanitary management schemes in commercial farms. Seed are separated in ponds and given hormone-supplemented feed for approximately one month.

Catfish. No available information.

Native silverside fish. There is no programme on genetic modification. Feed for larvae include cultivated algae, rotifers.

Bass. No information available.

SEED QUALITY

Federal and state hatcheries have qualified personnel who could apply preventative treatment, health management and hygiene programs in hatcheries during fry production. Frequently used chemicals include sodium chloride, formalin, malachite green and methylene blue. Other preventative actions include restricted access, smooth walls, treatment of water discharge and foot baths.

Since genetic programmes are still being developed, few options exist for assuring quality of fry in terms of growth rates, uniformity of size, survival, etc. Trout normally has 20 percent mortality of eggs produced.

SEED MARKETING

Fry sales generally occur in hatchery facilities. There is no specific way to distribute fry; there are intermediaries who buy and sell fry to farms which are distantly located from hatcheries. These intermediaries usually act individually. On the other hand, rural fish farmers go to hatcheries to purchase or receive (in case of donations) fry. These facilities are financed by the federal and state governments to support rural aquaculture. There is no information about financing support for farmers for fry

TABLE 7.13.5

Price of fry depend on size and the structure of production facility

Type of Facility	Trout		Carp		Tilapia	
	Cost per thousand or unit (Mexican pesos)	Size	Cost per thousand or unit (Mexican pesos)	Size	Cost per thousand or unit (Mexican pesos)	Size
Private	600.00	6 cm			$ 0.15	inch
Private	1 000.00	4 - 5 cm.				
Private	0.70	I in				
Hatchery State government	400.00	4 cm	donation			
Hatchery Federal government	0.11 0.27 0.21	trout to centimeter trout inch eyed eggs unit	$ 110.00	4 cm	$ 0.16 0.31 $ 110.00 $ 165.00	inch inch 4 cm 4 cm
Social sector					$ 0.30	inch
Social sector					$ 0.15	inch

Type of Facility	Catfish		Bass	
	Cost per thousand or unit (Mexican pesos)	Size	Cost per thousand or unit (Mexican pesos)	Size
Hatchery Federal government	$ 0.31	Inch	$ 1.28	inch

PLATE 7.13.1
Tilapia aquaculture systems in México


Tilapia


Tilapia fry


Cage production system


Confinement production system


Semi-intensive production system


Intensive production system

PHOTOS COURTESY OF TABASCO STATE HEALTH COMMITTEE (CESAT)

production or importation of eyed-eggs for hatcheries. The market is generally stable and not much fluctuation in prices. Price of fry depend on size and the structure of production facility as shown in the table below:

SEED INDUSTRY

Trout. In the trout hatchery industry, there are small-scale producers producing between 3 000 to 30 000 seed; medium-scale producers producing between 30 000 to 100 000 seed and large-scale producers whose production is between 100 000 to one million seed; the latter are represented by federal and state and some private

PLATE 7.13.2
Practical training courses provided by state and federal agencies to rural fish producers in Mexico

hatcheries. One of the main problems during the production of trout fry is the lack of eggs during summer due water temperature; all eggs supplied during this season are imported. A mechanism adapted by the trout industry, at present, is to import eyed-eggs incubated in hatcheries and set on sale as fry to the market. National egg production is not stimulated although a great demand for fry exists in the market. In order to be profitable, fry production must be on a grand scale. Prices are more or less stable. Sale of fry to distant farms are made by intermediaries, but these are rather uncommon. Seed are provided to the rural sector through government-supported programs to the aquaculture industry or through federal and state government donations. There is no data available about the participation of women in this activity.

Carp. The different carp species are practically produced in its totality by the state and federal hatcheries, which can be considered as large-scale producers. The production of fry, as commented earlier, in most cases is made through donation of seed for stocking in dams or to maintain the subsistence of aquaculture or for home consumption. The price that federal government, at the moment, has fixed for the fry is with a very high subsidy and price is rather symbolic. In economic terms, a farmer does not face any financial issues such as low price, seasonality, weather conditions, distance between suppliers and markets, etc., since fry is mainly government-produced.

Tilapia. Production of tilapia occurs in medium- and large-scale, the latter in private farms or in the federal and state governmental facilities. Meanwhile, medium-scale farming occurs in the social sector. The hormone-treated fry used for monosex production is attracting more interest and demand from producers as is as the red variety because of its pleasing aspects. It appears that climate has no favourable or unfavourable effect on the production of fry throughout the year. The sale mechanism is the same as for those of trout, where farmers come to hatchery facilities to buy fry directly. It is possible that there are some intermediaries, but at present there is no information about the existence of unions or associations. The price of fry depends on the source (i.e. government, social, or private). Acquisition of fry for rural aquaculture or simply for subsistence, in many states in the country, is through government donation or through different support programs already established for farms in the rural sector. There are no official statistics on fry production in private hatcheries. However, numbers have been increasing in the states of Jalisco, Colima and San Luis Potosí. It is probable that fry production from social and government facilities could be related to home consumption. Many private companies have imported broodstock from Colombia. The participation of women in this area is not recorded or registered in any document.

Catfish. With regard to catfish production, there is little information, probably because broodstock decreased during the last decade. The size of fry production by government centers is medium-scale and there is no data or information from private producers who, probably, produce only for home consumption. The authorized price for selling fry is based on those authorized by federal governmental hatcheries. According to information given by the state aquaculture health committee, catfish fry comes from San Luis Potosí and Tamaulipas and the price is only the one authorized by the federal government. There is no information about the existence of intermediaries or network distribution. Apparently there are no weather condition problems affecting fry production, due to the fact that the country has an ideal climate for its reproduction. Five percent natural mortality is the normal occurrence for catfish fry. At present catfish culture is mainly located in the northeast and central plateau of the country. There is no information about the acquisition of the fry by the social and rural sectors. A recent problem has been the high mortality due to a viral pathogen.

The fry of other species such as native silverside fish, catán and pejelagarto, are not commercialized, they are generally donated to the rural communities and farmers. These centers of production are federal, state or university stations of investigation. Its production is still in an early stage since oftentimes there is no complete knowledge on techniques for reproduction, methods of feeding and handling in culture conditions of the species, in some stages of their life cycle like reproduction and feeding.

SUPPORT SERVICES

State governments have programmes on aquaculture development, technical advice and capacity building. State government hatcheries provide fry to rural aquaculture with 100 percent subsidy. At the federal level, three government agencies under SAGARPA are responsible for rural and social aquaculture. Each one is briefly described below:

CONAPESCA. This institute teaches courses and provides technical support. In the 1980s, it published an important manual aimed at social producers. The manual included all aspects of culture of trout, catfish, carp and tilapia. At present, the manual is being re-introduced including sections on good production practices and food quality. However, there is less information available for freshwater fish species compared to shrimp, for example.

SENASICA. This agency provides national services concerning health, agriculture and cattle food quality, The new General Law of Sustainable Aquaculture and Fisheries (2007) has given it the responsibility for national aquatic animal health services. Recently SENASICA has shaped the state aquaculture health committee as an auxiliary body. This committee has a tripartite structure, where federal and state governments and producers contribute equal amount of money for the committee's activities. Their own personnel are contracted including producers or other related professionals to fulfill farm level health management programs. At the moment, there are 19 aquaculture health committees in the 19 states of Mexico. The work program of the committee includes the following: (i) development of technical and administrative structure of the committee in accordance with the state necessities to support the aquaculture industry; (ii) assessment of the health and sanitary status of farms; (iii) development of sanitary and health programs for fry production and distribution and (iv) promotion of good production and management practices in farms. With these objectives, farms are visited and samples collected. Technical support on main fish pathogens, treatments and good production practices are provided. Training courses (practical and theoretical) are also given on subject areas such as risks and diseases in tilapia farming, pathology and nutrition of carps, good aquaculture production practices in trout. Pamphlets and manuals about regulations are also produced.

INAPESCA (formerly INP). This institute has the responsibility for coordinating and guiding the scientific and technological research in the field of aquaculture and fisheries as well as the transfer of innovation and technology to the fisheries and aquaculture sector at the national level. This is achieved by the Regional Centers for Fisheries Research (Centros Regionales de Investigacion Pesquera) working and addressing the problematic situations in fisheries and aquatic farms. They serve as advisers to the aquaculture production cycle by evaluating the farm situation and implementing research and transfer technology programmes in different areas such as health management, infectious and parasitic disease diagnosis, nutrition, reproduction and genetics. The work is carried out jointly with CONAPESCA, SENASICA, the state aquaculture health committees, research institutions and universities.

SEED CERTIFICATION

At present, the most significant effort concerning seed certification is in trout fry, mainly through the state aquaculture health committees, in coordination with the state and federal governments. The work carried out in species like catfish, carp or tilapia is going more slowly, with little action concerning those species, since the market value is lower than trout. A regulatory framework for this activity was released in July 2007 and will be the responsibility of SENASICA. The previous inspection of trout fry before mobilization, has given us knowledge about the health status of the fry population which became one of the basis for setting the criteria to recognize the health status of zones. This can allow the designation of zones free of pathogens, in the case of trout, for instance, the infectious pancreatic necrosis virus (IPNV).

LEGAL AND POLICY FRAMEWORKS

Legal Framework for Aquaculture

The legislation is based on the Mexican Constitution, the General Law of Sustainable Aquaculture and Fishery (Ley General de Pesca y Acuacultura Sustentable, July 2007)) and its regulation, the General Law of the Ecological Balance and all those rules that legislate the aquatic field and exploitation of the natural resources.

General Law of Sustainable Aquaculture and Fishery Regulation

The new General Law of Sustainable Aquaculture and Fishery is still under review and has not yet been published, therefore the description in this document refers to the previous law, where the third paragraph, Chapter 1, makes reference to the general layout of aquaculture (Articles 101 to 105). Chapter 2 refers to commercial aquaculture, specified in Articles 107 and 108 the requirements for this kind of concessions in waters with federal jurisdiction. Chapter 3 refers to the development of aquaculture (Articles 114-119), where the requirements for this kind of concession are specified. In Chapter 4 (Articles 120-124) didactic aquaculture is mentioned including the requirements for its authorization. The introduction of live species in water bodies of federal jurisdiction is covered in Chapter 5 (Articles 125-127) which outlines the detailed information required. Chapter 6 (Articles 128-136) refers to aquatic animal health management. This section layout the aquatic animal health certification requirements, for importation of live aquatic species (animals or plants) to the national territory. This certificate must be issued by the competent authority of the country of origin. In this section, quarantine specifications of the imported species and the actions to be carried out at the final destination are also described. In order to be able to move the species from the quarantine, an aquatic animal health certificate has to be obtained from the Ministry (General Law of Sustainable Aquaculture and Fishery's Regulation, 2007).

However, todate there is no specific legal framework to support and regulate the production of fresh water fish species fry. The importation of trout eyed-eggs or fingerlings are regulated under the Official Mexican Norm NOM-010-PESC-1993, which establishes the sanitary requirements for the import of live aquatic organisms in any stage of development, destined for aquarium exhibition or aquaculture activity in the national territory. NOM-011- PESC-1993 regulates the application of quarantine in order to avoid the introduction of diseases from imported aquatic organisms.

ECONOMICS

There is no available data on profitability, supply, demand, prices, factors that determine the price of the seed, or the economic contribution of the activity from producers, since the economic studies are not available in fry production. The existing data refers to the value of fish meat production.

Seasonality production of trout fry is the most important issue, because there is no year-round production, therefore the importation of summer eggs is a profitable business since in Mexico we do not have the technology to apply delayed spawning (photoperiod) method in order to get summer eggs. Therefore there is a high risk of introducing imported diseases. A research project is addressing photoperiod technology with the aim of having egg production throughout the year and minimizing the risk of disease introduction through importation.

An analysis of the economy of fry production should be considered, since state and federal hatcheries frequently donate fry to the rural communities, or the price is highly subsidized. This situation could be one of the reasons why the rural or private sector of fry production have not grown and may not be a profitable option, since the larger farms generally produce their own fry.

INFORMATION OR KNOWLEDGE GAPS

There is a lack of specific regulation for different genus or species, supporting and establishing health and production norms, including all stages of development, from egg, fry, fingerlings until commercial size, as well as for health management and good aquaculture production practices. There is a lack of diagnostic laboratory services for monitoring the health status of the reared fry, as well as farm status certification programs through a sampling plan, in order to achieve a certified broodstock population which will ensure the production of healthy fry. Genetic research projects with the target of improving seed quality are also lacking.

STAKEHOLDERS

Local institutions are represented by the State Aquaculture Health Committees, as well as the state and federal government, who offer services for field work and technical assistance. There appears to be no association of producers of freshwater fish. This scheme only exists in Mexico in the shrimp production sector, where the National Association of Producers of Larvae of Shrimp, ANAPLAC, represents the shrimp hatchery interest and points of view.

Listed below are some of the stakeholders in the freshwater fish seed sector in the country.

Small hatcheries. Concerned with development of local market. Some social centers of production of fry exist that sell fry locally.

Large hatcheries. Concerned with the development of new varieties/strains or innovations. They do not exist at the moment. In trout the aquaculture production center 'El Zarco' operated by the federal government, has the project to turn the center into a center of excellence for the production of quality fry with specific genetic programs for survival size, appearance and resistance to diseases and at the same time to establish technology for egg production during summer.

Associations. Concerned with representing the interests of the industry. No existing associations of freshwater fish fry; however, associations of producers of trout, catfish and tilapia exist.

Government institutions. Concerned with offering legal and political frameworks to the industry involved in seed production and seed marketing as well as offering extension services. As previously mentioned, the main institutions are SAGARPA, CONAPESCA, SENASICA, INAPESCA and DGIA.

Researchers. Universities and research institutions concerned with information, knowledge and technology generation. A great number of academic and research institutions exist in Mexico, carrying out projects relative to species of fish of freshwater culture, in the areas of genetics, nutrition, diagnosis of the infectious agents, summer egg production, standardization of diagnosis techniques, etc. These institutions acquire resources through the National Council of Science and Technology (CONACYT), as

TABLE 7.13.6

Institutions that carry out aquaculture research projects

Level	Universities or research centers
University	Instituto Politécnico Nacional Escuela de Biología
	Instituto Tecnológico de Monterrey
	Instituto Tecnológico del Mar No. 1 de Veracruz
	Instituto Tecnológico del Mar No. 6 de Nayarit
	Universidad Autónoma de Aguascalientes
	Universidad Autónoma de Baja California (UABC)
	Universidad Autónoma de Baja california Sur
	Universidad Autónoma de Campeche (UAC)
	Universidad Autónoma de Jalisco
	Universidad Autónoma de Nuevo León (UANL)
	Universidad Autónoma de Yucatán
	Universidad Autónoma Metropolitana (UAM-Xochimilco y UAM –Iztapalapa
	Universidad de Occidente (UDO)
	Universidad de Sonora (UNISON)
	Universidad Juárez Autónoma de Tabasco (UJAT)
	Universidad Nacional Autónoma de México (UNAM) Facultad de estudios superiores FES – Unidad Iztacala
Research centers	Centro de Investigación en Alimentación y Desarrollo (CIAD) CIAD Mazatlán y hermosillo
	Centro de Ciencias de Sinaloa (CCS)
	Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
	Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)
	Centro de Investigación y estudios avanzados del Instituto Politécnico Nacional CINVESTAV – Unidad Mérida
National Fisheries Institute Regional Centers of Fishing Research(CRIP)	CRIP – Unidad Pátzcuaro
	CRIP – Unidad Veracruz
	Dirección General de investigación en acuacultura

well as cooperation with projects of the state and federal governments, who promote the necessary lines of investigation to support aquaculture. Table 7.13.6 lists the different institutions that carry out aquaculture research projects.

Institutions that offer postgraduate studies (Masters and Doctorate degrees) in aquaculture are: (i) Marine Technological Institute No. 1 of Veracruz, (ii) Biological Research Center of the Northwest (CIBNOR), (iii) Research Center for Nutrition and Development (CIAD), (iv) Scientific Superior Education and Research Center of Ensenada (CICESE) and (v) Research Center and Advanced Studies of the National Polytechnical Institute (CINVESTAV, Mérida Unit).

Donors. Concerned about financing projects. At present, development agency providing support to the freshwater fish production sector in the Japanese International Cooperation Agency (JICA). Ongoing projects supported by JICA include that of feeding requirements of white fish and provision of expertise to develop technologies for breeding of trout outside its breeding season.

FUTURE PROSPECTS AND RECOMMENDATIONS

Production of fish for rural communities or home consumption is covered by federal and state hatcheries. This could be the reason why the fry production business is not a very attractive activity although it has the potential to be profitable. There is no tradition of eating fish in Mexico even though the market price is quite good for consumers when compared with other protein sources like cattle, chicken or pork. A strong educational program is needed in rural communities, to demonstrate the nutritional advantages of having fish in their diet, as well as the bonus of an extra money by selling the product. While several programs exist to support rural aquaculture, there exist no follow-up programs or appropriate training courses for rural farmers. If such kind of training are made available, rural farmers will be able to operate their own farms. Heavy government subsidy does not provide encouragement for self-sufficiency.

There are few benefits or financial support from state or federal governments for fry producers, or for new hatcheries. A clear example is the lack of hatcheries since the demand for trout fry are met through importation of eyed-eggs from the United States of America.

On the other hand, it is very important set up effective mechanism to collect information and this database must be regularly updated. Although registers of fry production at the state and federal hatcheries exist, these data do not reflect the impact that they could have in rural aquaculture. It seems that it is important that this information is obtained from all hatcheries from governmental, private, social or rural sectors, for proper evaluation of fish farm performance.

Communication and co-operation between federal and state governments concerning aquaculture is very poor and some times is non-existent. While production data are reported by both bodies, the data collected do not coincide. In the same way, federal publications does not describe all state hatcheries, for instance, the carp fry producer hatchery Tiacaque at the state of Mexico which produce almost 95 percent of carp fry, is not considered in the National Fishing Map. The lack of a good information system is reflected as well in specialized magazine reports, which presents private hatcheries facilities for freshwater fish fry, but are not registered by the federal government. This is one of the main problems facing the administration of the aquaculture industry, since many producers do not have the registry of the CONAPESCA. This situation is being gradually resolved through the actions of the state aquaculture health committees, who have been doing survey work in state hatcheries, thus, giving a much better picture of the real aquaculture development in each province.

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7.14 Freshwater fish seed resources in Nigeria

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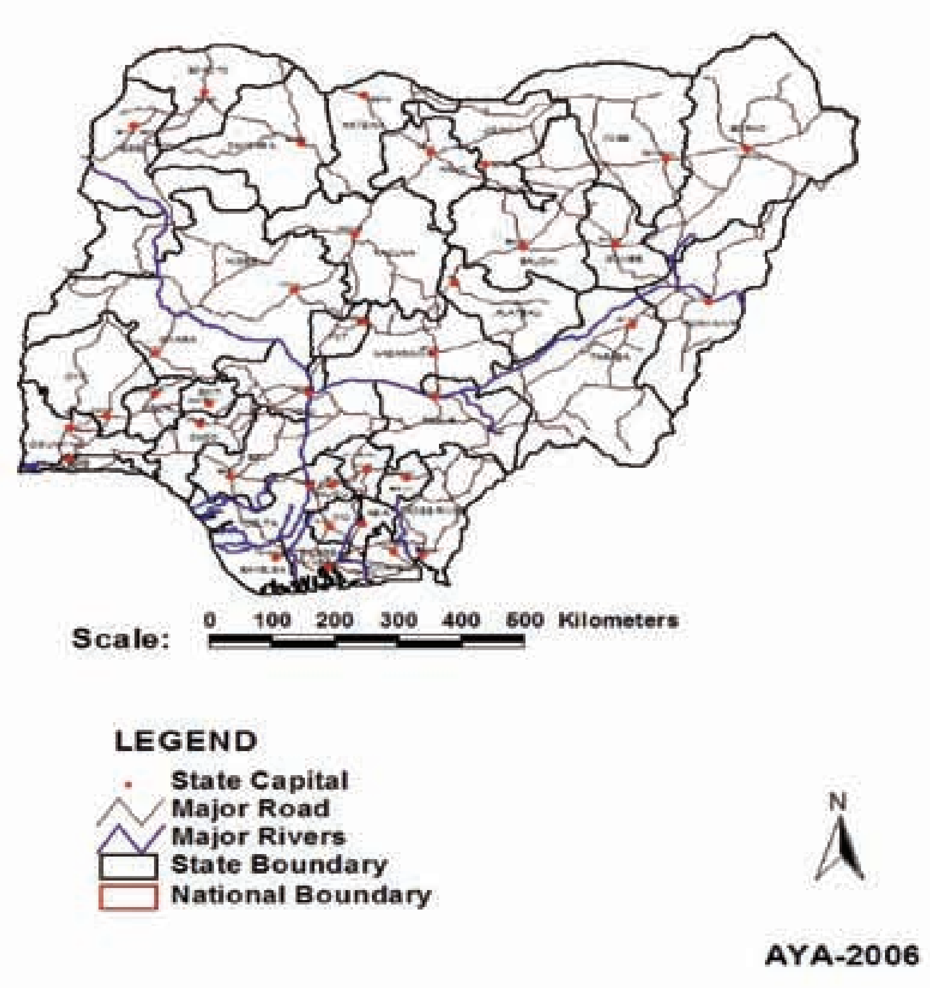
ABSTRACT

Nigeria is a country where the fish demand-supply gap is about one million tonnes per annum, due to dependence on fish for 40 percent of her animal protein requirement. The country is benefiting from an emerging commercial catfish farming industry, which is transforming the long-dormant aquaculture sector. More than 80 percent of cultured fish in Nigeria is catfish, mainly *Clarias* spp., *Heterobranchus* spp. and their hybrids. These are followed by the tilapias. Unfortunately however, the required quantity and quality of fish seed have never always been available. Even when total production and supply from all sources amounts to 55 million fingerlings, this is far less than the requirement of about 500 million per annum to satisfy the immediate needs of the market. More than 80 percent of the total pond and hatchery seed produced come from the southern part of the country, where most of the medium- and large- scale producers are located. The production systems consist of earthen ponds, flow through and water recycling systems. Producers are classified as small-scale, medium- or large-scale depending on management and infrastructure and the number of seed produced annually, i.e. small-scale (up to 20 000 seed per annum or season), medium-scale (20 000 to 100 000 per annum or season) and large-scale (above 100 000 per annum or season). Seed production in Nigeria is constrained by many technical problems principally among which are: (i) lack of and poor management of broodstocks, (ii) inadequate quality control regulation and standardization of the entire seed production chain and (iii) poor networking among stakeholders. All these affect production, marketing and distribution. The new National Aquaculture Production Strategy being put in place by the Federal Department of Fisheries is trying to address the above constraints. Production and supply of fish seed are dominated by the private sector (80 percent, 44 million); the other 20 percent contributed by the public sector (10 percent, 5.5 million), from wild collection (9 percent, 4.55 million) and importation and other sources (1 percent, 0.55 million).

INTRODUCTION

Fish is the cheapest source of animal protein consumed by the average Nigerian, accounting for about 40 percent of the total protein intake. Fish production in the country is mainly from the capture sector especially artisanal coastal and artisanal inland fisheries. This sector contributes over eighty percent of total domestic

FIGURE 7.14.1
Administrative Map of Nigeria



Source: Abdullah (2007)

production of some 510 000 tonnes per annum (FDF, 2004). Nigeria imports 700 000 tonnes of fish per annum and an annual deficit of almost half a million tonnes still exists if the demand supply gap were to be bridged. Thus, consequent upon over-exploitation of the marine fisheries resources which has resulted in gradual depletion of the stock, there is now concerted effort to harness the nation's enormous freshwater resources through aquaculture to boost fish production.

Aquaculture has been recognized as a viable means of increasing domestic fish production. The sector is estimated to have a potential of contributing between 0.65-1.2 million tonnes of fish annually from inland freshwater alone. Unfortunately, for now, even with the recent boost in production by private fish farmers, aquaculture is contributing only about 80 000 tonnes. One of the major problems identified as hindering the promotion and development of aquaculture in the country, at least until recently, is the scarcity of fish fingerlings of the desired cultured species. The desired quantity and quality have never always been available. If the above potential of say one million tonnes of fish were to be realized at a semi-intensive management level of fingerlings to adult to ensure survival of 50 percent, then at least two billion fingerlings would be required annually from all sources. An additional 500 million would be needed to stock inland water bodies such as dams and reservoirs. The present total production and supply from all sources is just about 55 million fingerlings.

TABLE 7.14.1
Freshwater fish species cultured in Nigeria

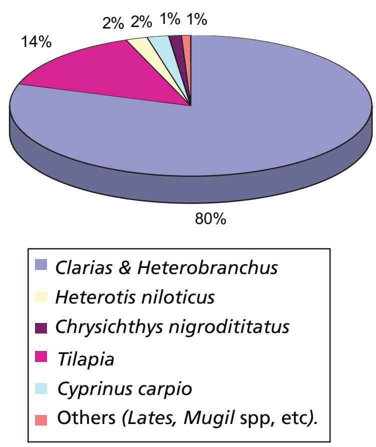
Common name	Scientific name	Origin (native or introduced)
African walking catfish	*Clarias gariepinus*	Native
Sharptooth catfish	*Clarias lazera*	Native
Catfish	*Heterobranchus* sp.	Native
Hybrid catfish	*(Clarias x Heterobranchus)*	Native
Tilapia	*Oreochromis niloticus*	Native
	Sarotherodon galilaeaus	Native
	Sarotherodon melanopleura	Native
	Tilapia zilli	Native
	Tilapia guineansis	Native
	Heterotis niloticus	Native
	Chrysichthys nigrodigitatus	Native
	Chana obscura	Native
	Gymnachus niloticus	Native
	Lates niloticus	Native
Common carp	*Cyprinus carpio*	Introduced
Grass carp	*Ctenopharyngodon idella*	Introduced
Indian carp	*Catla catla*	Introduced
	Labeo rohita	Introduced
	Cirrhinus mrigala	Introduced
Mullet	*Mugil* sp.	Native
Megalops	*Megalop atlanticus*	Native
Ornamental goldfish	*Carassius auratus*	Introduced
Freshwater shrimp	*Macrobrachium vollehonvenii*	Native

Modern aquaculture practices were initiated in Nigeria in the early1950s, when exotic species of carp *(Cyprinus carpio)* were introduced from Austria into the Panyam fish farm in north central Nigeria. Some carps were also imported from Israel in the late 1950s, to Ibadan in the southwest of the country. Before then the act of maintaining fish in ponds and reservoirs were relatively recreational.

The first national effort by the Federal Government at promoting fish seed production was in 1987 through the Directorate of Food, Roads and Rural Infrastructure (DFRRI). Under this programme, nationwide fish farming workshops were organized while some government hatcheries were commissioned to produce fingerlings in anticipation of increased demand from the public. Since this period, there has been steady increase in fish fingerling activities, especially by the private sector. Unfortunately though, the government fish farms which had served as models between the 1970s and 1980s went out of production as a result of poor management due to lack of funding and cumbersome policy and bureaucracy. During the last ten years, the private sector has virtually taken over the industry and invested massively in aquaculture especially freshwater catfish farming including seed production. Table 7.14.1 shows a list of fish species cultured in Nigeria during the last few years.

In order of importance and acceptability, the important cultured species are as follows: (1) catfishes and their hybrids (*Clarias, Heterobranchus*) – 80 percent; (2) tilapias – 14 percent; (3) *Heterotis niloticus* – 2 percent; (4) *Cyprinus carpio* – 2 percent; (5) *Chrysichthys nigrodititatus* – 1 percent; (6) others (*Lates niloticus, Mugil sp.etc.*) – 1 percent (Figure 7.14.2).

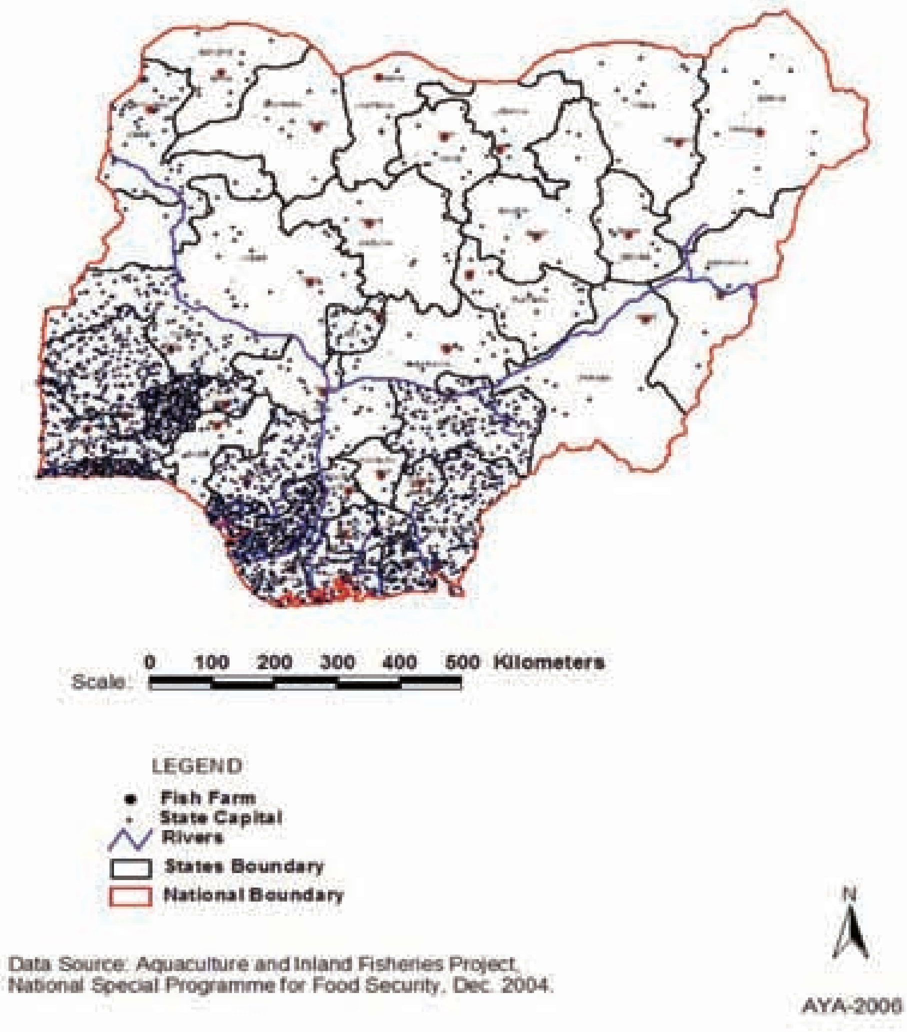
FIGURE 7.14.2
Important cultured fish species in Nigeria



Until recently, apart from a few large fish farmers who produce their own fingerlings, limited fingerlings are available for sale in Nigeria. There remains a large unmet (undetermined) demand for fish seed across the country and this has been a major constraint to the aquaculture industry next only to quality feed supply. Many private fish farms are abandoned across the country due to the lack of fish seed. Visits to several small fish hatcheries in the southern part of the country revealed severe under- production, which could be increased ten times or more with improved management techniques.

Many technical problems often exist which include poor management of broodstocks especially with regards to feeding and handling. Poor records are kept of all activities (e.g induced spawning, care of eggs, fry, feeding, etc.). High loss of eggs and fry are common due to lack of water exchange or aeration. Use of square tanks which lead to crowding of fry in corners caused high mortalities. Some hatcheries use unaerated pumped well-water. No graders are used in most farms, no precautions taken for controlling water entries in rearing ponds, allowing wild fish to enter to feast on young fingerlings. Most farms and hatcheries represented sizeable investments (in the range of US$10 000 to US$40 000) and yet inexperienced managers were sometimes hired

FIGURE 7.14.3
Distribution of fish farms in Nigeria



Source: Abdullah (2007)

off the street and paid low salaries. Few efforts were made to obtain training for such managers even though courses are frequently available in the country at universities and institutes such as the National Institute for Freshwater Fisheries Research (NIFFR). In contrast, the larger producers have sent managers to workshops in Nigeria as well as to Europe, the USA or Israel for intensive courses in aquaculture.

Another interesting feature of the fingerling supply industry is marketing and distribution, as a result of the seasonality of natural production. While there is always a surplus of fingerlings in many farms in the same zone at the same time, only the experienced and well-trained producers who could produce year-round enjoy monopoly of supply at dry periods. Unfortunately too, fish farmers in most part of the country especially the north, are perpetually searching for hatchery-produced fish seed for their farms.

SEED RESOURCES AND SUPPLY

The supply of fish seed in Nigeria can be from the following sources, namely: (a) collection from natural waters (wild sources), (b) from hatchery production based on controlled spawning and to a lesser extent (c) importation. Fingerling collection from the wild is found to be unreliable, because it is seasonal and usually contains mixed species, some of which do not meet the criteria of good aquaculture candidates. The correct age of fish and fingerlings are difficult to determine. This has led to the dependence on hatchery-bred fish with known history. Several fish hatcheries have been established in the country, many of them in the south.

The tilapias are usually allowed to spawn naturally in ponds and tanks, while the mud catfishes and carps are subjected to hormone-induced spawning. These practices require a lot of skill and the technology had been transferred to various interested practitioners around the country through short courses on fish seed multiplication. The earliest of such training programmes by the Federal Department of Fisheries was assisted by the Food and Agriculture Organization of the United Nations (FAO) between 1978 and 1981, when two Fish Seed

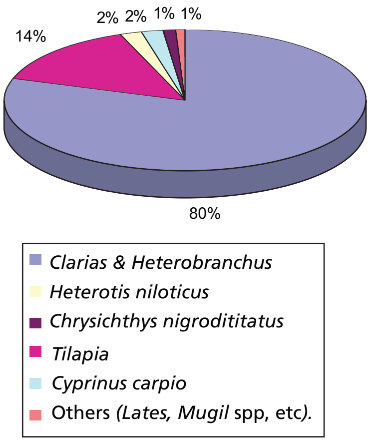
Multiplication and Fish Farming Demonstration Centres were established at Panyam Fish Farm in Plateau State (north central Nigeria) and Oyo Fish Farm (southwest Nigeria). Regular on-farm, hands-on training were organized for prospective fish farmers and fish seed producers at these centres. Two additional centres were later established at Umina-Okigwe (southeastern Nigeria) and Mando Road, Kaduna (northwestern Nigeria). The phases of fish seed development in Nigeria are described below:

Phase I (1940 to 1970): Popularization of fish farming in Nigeria

During the initial period from 1940 to 1970, fish farming was more or less practiced as a hobby and for limited research demonstrations. All fish seed were either collected from the wild or imported from abroad, especially *Cyprinus carpio* (common carp) which were imported from Austria and Israel at different times. In the case of wild fish, they were usually collected during their breeding season or during migration of the school. This period coincides with the rainy season in Nigeria (March to November in the south and May to

Mando Government Fish Farm, Kaduna, NW Nigeria, under rehabilitation as a broodstock centre by AIFP

FIGURE 7.14.4
Sources of fish seed in Nigeria



October in the north). The collection is made by artisanal fishermen using basket traps and fine-mesh nets most of which have been outlawed in recent conservation measures. The point of collection could be open waters for fish schools (e.g. *Heterotis niloticus*) or shallower ends of the river at the mouth of tributaries, which usually is the breeding ground of most species.

Phase II (1970 to 1992): Expansion and establishment of demonstrations fish farms

From 1970 to 1992, there were bold attempts to reduce major constraints concerning fish seed for aquaculture development. During this period there was remarkable increase in the number of public fish farms built by both federal and state government agencies, research institutes, universities and some private sector investors. Most of these fish farms were supposed to be commercial farms and many of them were complemented with small- to medium-sized hatcheries, at least to cater to the immediate needs of the fish farms. Few of them produce enough to satisfy their needs as well as to provide some excess to sell to other farmers. In essence, during this phase substantial quantity of fish seed still come from the wild. The importance, desirability, reliability and inevitability of hatchery-produced fingerlings have become obvious and well-established.

During this phase seed supply could be broken down as follows: (i) wild collection - 60 percent; (ii) natural spawning in ponds – 30 percent; (iii) hatchery production – 10 percent (Figure 7.14.4).

The introduction of modern hatchery infrastructure and facilities was facilitated by a US$1 million grant from Italian government in 1988 and subsequent construction of the hatchery at Oluponna Fish Farm in Osun State (southwest Nigeria) with a capacity to produce 10 million fingerlings. Since then, the model had been replicated in smaller versions in many other places in Nigeria today which has boosted tremendously hatchery-produced fish seed in the country.

Phase III (1993 to 2005): Current status of aquaculture development and fish seed supply in Nigeria

The characteristic feature of the current phase of aquaculture development in Nigeria is the emergence of investment from the private sector as the driving force. This is also complemented with the government policy of transferring its farms to the private sector. Most recent investment in aquaculture has been targeted towards catfish farming. Presently live catfish attracts premium price in Nigeria, with a high ROI (Return On-Investment) ranging between 30 to 40 percent in some very successful enterprises (e.g. IFC, Technoserve 2003). This is now a major attraction to private sector investors in Nigeria. Currently about 90 percent of farmed fish in Nigeria is catfish; during last four years almost all hatchery infrastructure and table fish production systems have been exclusively targeted towards catfish production.

It is estimated that within this period fish seed production has jumped from 3 million in 2000 to about 30 million in 2005, and 55 million in 2007. The emergence of high volume producers who have invested in intensive recirculating and flow-through fish production systems have been largely responsible for the phenomenal increase in the volume of production of both fingerlings and table fish.

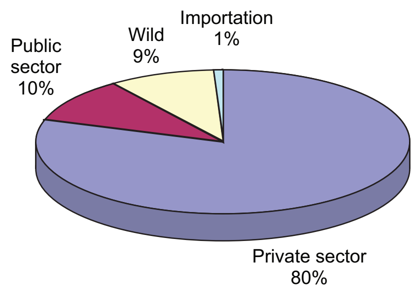
The estimated total current investment in aquaculture including hatchery facilities and equipment in Nigeria is about ₦10 billion (US$75 million). There are about 30 small-, medium- and large-scale intensive, closed recirculating and flow-through systems especially in the southwest and south-south zones where over 77 percent of all fish farms and hatchery infrastructures are located (Figure 7.14.3). Investment is still growing, especially with the renewed awareness being created by the government through the Presidential Initiative on Fisheries and Aquaculture and the recent continental NEPAD Fish for All Summit held in Abuja, Nigeria.

Of the 2 642 private fish farms that have been inventoried by the Aquaculture and Inland Fisheries Project (AIFP) in December 2004, while an estimate of 500 farms are at commercial level, most of them are poorly managed. More than half of these commercial fish farms have small- to medium-sized hatcheries built beside them and again most of these are either abandoned and at best under producing (at times no more than 5 percent of installed capacity). Abandonment has been due largely to the technical incapabilities of the hatchery managers, as most of them are either poorly trained or inadequately remunerated and in other cases, both.

Presently, seed supply from government and public sectors, hatcheries (including research institutes and universities) are about 10 percent of the total. The current picture of freshwater fish seed supply in Nigeria is presented in Table 7.14.2.

***Clarias gariepinus*, major cultured species in Nigeria**

FIGURE 7.14.5
Freshwater fish seed supply in Nigeria



SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

The various ways and methods by which fish seed are produced in Nigeria include the following:

1) natural spawning in open waters and rivers
2) natural breeding in ponds
3) spawning in tanks
4) induced natural spawning in ponds and tanks
5) artificial fertilization – hatchery production and management
6) genetic manipulation

Natural spawning in open waters

This describes the means by which fish breed in the wild to produce their seed. Different fish species usually choose different places in the aquatic environment for breeding. The reasons for the choice are not always fully known and depend on behaviour and adaptation of the fish species. For example, some breed on stones at the bottom of the water. Others make holes in the benthos for breeding; others lay their eggs in holes, on grass, or in a foam nest on the surface of the water. Some scatter their eggs in the water while others collect and brood the fertilized eggs in their mouths. In nature, the cues or signals that induce spawning

TABLE 7.14.2
Freshwater fish seed supply in Nigeria

Source	Percentage	Seed production
Private sector (ponds and hatcheries)	80%	44 million
Public sector (government fish farms, hatcheries, universities, research institutes)	10%	5.5 million
Wild collection	9%	4.55 million
Importation and other source	1%	0.55 million

Small scale cottage hatchery

are numerous, e.g. flooding (increase in water volume), rain events, changes water temperature, increase in food, etc.

As the natural aquatic environment is full of hazards or perils for the young fish, fish have evolved varying degrees of parental care to help reduce the level of mortality for the young. Some care for the eggs only, moving away some after the eggs are hatched. For others, protection continues until the young are able to fend for themselves.

Cichlids, i.e. some tilapias, have elaborate parental care, including carrying the young in the mouth at any approach of danger. As a rule, species with elaborate parental care lay relatively few eggs, while clupeids and catfishes (*e.g. Chrysichths nigrodigitatus, Clarias gariepinus, Heterobranchus bidorsalis*) with little parental care produce by far more numerous eggs, as a way of ensuring that some, at least, will survive to adulthood.

Fry, fingerlings and juveniles are collected from open waters by artisanal fishermen using baskets, fine mesh nets and cane traps. Collection is always easier during schooling (especially for *Heterotis niloticus*). Fish farmers purchase the collected seed and transfer them directly into ponds. Many fish farmers in the northern and north central zones of the country depend largely on wild fingerlings from the vast inland water resources such as lakes and reservoirs. However, wild stocking of fish farms has almost disappeared in the south.

Natural breeding in ponds

Some fish farms have specially dedicated ponds for breeding. These are usually small- to medium-sized ponds (e.g. 100-300 m^2). Depending on the species of fish, the pond bottom may be modified to simulate the desired depth preferred by the fish in nature. For example, one end of the pond may be shallower, or the shallow end may be in the middle potion to facilitate recovery of the parent after spawning. Substrate (e.g. grass, mat) for egg attachment may also be provided. During the breeding season, male and female may be placed either at random or in definite ratio in the breeding pond and left to spawn naturally after which the parents are removed and the fry nurtured to fingerlings. Fry and fingerling recovery is usually very low and in most cases hardly greater than 5 percent of hatchlings. This is the most common method for tilapia seed production.

High-tech water recirculation system

Spawning in tanks

Fish spawning can also be carried out in outdoor or indoor concrete or plastic tanks. Breeding tanks can be in the form of small aquaria (glass or plastic) or large fiberglass and concrete tanks. Broodstocks may be induced or just allowed to freely spawn by mutual stimulation resulting from proximity of the male and female parents. Outdoor spawning tanks are always covered with net mesh for protection against predation by insects, birds and reptiles.

Most commercial fish farms, which may not have a complete hatchery complex, always, have one to four concrete tanks dedicated for breeding/spawning, where fry can be harvested to earthen nursery ponds and then transferred to grow-out ponds. Depending on the type of management, up to ten percent of hatchlings can be harvested as fry.

Induced breeding by an FAO/TCDC Expert

Induced natural spawning in ponds and tanks

A further step in the controlled breeding of fish is to induce the broodstock through hormonal stimulation before pairing them up in breeding tanks or ponds. Natural production is inadequate due to the low survival of hatchlings caused by factors such as predation, poor water quality, pests and parasites in the natural environment. Apart from the fact that in nature most cultured species, especially *Clarias gariepinus,* do not spawn year-round, a better control of fry production is required.

At the inception of induced breeding trials in Nigeria in the 1980s, the following hormones are used: carp pituitary (fresh and acetone-dried) Desoxycorticosteroneacet ate (DOCA), human chronic gonadosterone (HCG) and fresh catfish pituitary.

With more research and networking, cheaper and more effective synthetic hormones are now in use, the most popular being Ovaprim used in catfish breeding. Various other derivatives are also available, especially those from Asia such as Suprefact and Motilium from Thailand.

Artificial fertilization

Artificial propagation through hormonal treatment and stripping under controlled environmental condition in the hatchery had become a necessity to ensure mass production of fry and fingerlings of the African catfish. This is the current status of fish seed production in Nigeria. The procedure has been generally standardized as a synthesis of local experience, trial and error as well as from literature and largely from the Manual on Catfish Hatchery and Production (Kamthorn and Miller, 2006) which has become the field guide for Nigeria catfish breeders.

Depending on available resources, infrastructure facility and experience of the hatchery manager, the standard procedure, for convenience, had been classified into small (cottage), medium (indoor) or large (flow-through and water recirculation) hatchery production and management.

Genetic manipulation – gene banks

A substantial percentage of broodstocks used in most hatcheries in the country still come from the wild, with the exception of high-volume producers who either have planned broodstock development programme or those who import broodstocks from Europe, Israel and South Africa. The act of breeding ensures species continuity and maintains certain important hereditary characters through manipulation. The most common genetic manipulation in the Nigerian fish seed production industry is the production of a hybrid from a cross between *Clarias* and *Heterobranchus.* These hybrids or strains generally exhibit better growth potential, taste and colour than their parents. Most work on the genetic manipulation of Nigerian fish species especially tilapia species are still in the laboratory phase conducted by research

Outdoor hatchery tanks at a private fish farm in Port Harcourt, SS, Nigeria

Artificial fertilization of catfish eggs

institutes and universities. For the country to respond to the immediate challenges of the supply of high quality fish seed, greater attention would have to be given to genetic research and establishment of gene banks for desired species.

SEED MANAGEMENT

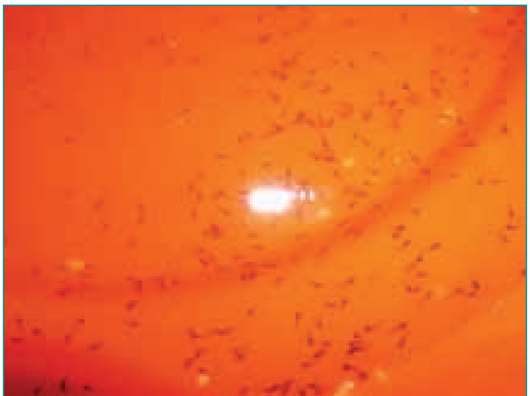
As explained above, the level of management of fish seed is directly related to the facilities available and technical capability of the hatchery manager. In general, the standard practice especially for catfish growers follows similar pattern, where a modern hatchery and fish seed production center has the following units: (i) broodfish pond, (ii) hatchery complex, (iii) nursery ponds and (iv) fingerling rearing ponds. The management procedures commonly practiced are described below:

Broodstock management

Broodfish can be procured either from existing fish farms or by capture from natural waters. It is necessary for the fish breeder to know the sources of the broodfish to be used for seed production. Care is always taken that the fish is purchased from a farm with no previous record of diseases. All newly-procured broodstocks are treated with appropriate medication before being introduced into the broodstock ponds. Broodfish collected from the wild are stocked at a rate of 2-3 fish/m^2 in prepared broodstock ponds. Proper health of the broodfish is assured by adequate feeding with nutrient-balanced feed for a sufficient time prior to spawning and maintaining the pond water at a satisfactory level. Depending on the size of the broodstock pond and preference of the farmer, males and females are placed in separate ponds. Some breeders keep both sexes together in the same pond until shortly before use. This might be due to space constraints or inadequate facilities.

Fry rearing and management

Eggs produced after spawning hatch into larvae; yolk materials act as a source of food for the young fish. The time of hatching (incubation period) varies according to species and is temperature dependent. For *Clarias gariepinus* in Nigeria, the preferred hatching temperature is from 25^{o}C to 29^{o}C and 24 to 36 hrs after fertilization. Newly-hatched fry searches frantically for food and at this time, the fish is very vulnerable to predation. Thus, the fry needs food, protection and a healthy environment in order to grow and survive to the fingerling stage.



Yolk sac fry of *Clarias gariepinus*

Fry rearing is carried out in nursery tanks, raceways and ponds. These are always protected against predators and the water quality is constantly monitored. Nursery facilities can be small-, average-size or large-scale depending on the extent of the hatchery operations. The early food of the fry has been pre-determined and the suitability and performance of natural planktonic organisms established. The brine shrimp, *Artemia salina,* is popularly used especially in large hatcheries and in recirculation systems as the first food of fry in nursery tanks and troughs. Zooplankton (especially *Moina*) culture is also widely used in many fish farms especially with the high cost of importing *Artemia*. Artificial diets are always introduced at age between seven to ten days.

Fry rearing is the most critical stage in catfish seed production in Nigeria. In most hatcheries, between 70 and 90 percent fry are lost before reaching fingerling stage (i.e. about six weeks). Fry rearing and management require training and expertise. Only sophisticated hatcheries achieve more than 50 percent survival.

SEED QUALITY

In recent times, awareness on aquaculture production had increased tremendously in Nigeria. However, of the various aspects of investment, seed production seems to be much more favoured, as there is higher revenue turnover from sale of fingerlings making seed production a profitable investment. However, with the low level of utilization of most installed facilities (many operating at between 10-15 percent of expected capacity), problems associated with high stocking densities has not yet become widespread. Common problems faced in hatcheries are related to poor water quality and nutritional diseases.

Seed obtained from reputable hatcheries, where all basic rules of hatchery production, management and hygiene are always followed, are of better quality in terms of post-stocking survival and growth rate than those seed collected from the wild or from poorly-managed hatcheries. Every hatchery therefore has to build a reputation for itself.

One aspect of the Nigerian seed industry which needs to be addressed is the standardization of fingerling size and pricing. Due to the absence of institutionalized quality control of practices, seed producers sell different sizes of fry and fingerlings to farmers, with neither standardization nor guarantee on the quality. While some hatcheries sell 1-2 cm fry as fingerlings, another farm may sell 5-6 cm fry for the same price. The market capitalizes on the ignorance and desperation of the buyers. The adverse effect of this is the heavy post-stocking mortalities which could discourage farmers from continuing the business. A good hatchery must always have a way of producing equal size of fingerlings of the same age. A good practice is to ensure that only fingerlings of uniform sizes are sold out as a batch to customers.

SEED MARKETING

The marketing and distribution of fish seed in Nigeria does not follow any particularly organized pattern. Farmers purchase directly from the source. Collection of fry, fingerlings and juveniles from the wild are usually done by artisanal inland and coastal fishermen. The sizes of fish caught usually contradict local and state fishing regulations which regulate the required net mesh size for fishing. All fish are transported live early morning or late evening to the market in calabash (a traditional container made from big melon gourd, processed and dried), clay pots, or plastic containers.

Packaging fingerlings for transportation

Normally, fish are primarily purchased for consumption especially by the resource-poor families and housewives. However, during flooding, men, women and children can collect a lot of fry which are then sold to interested fish farmers at prices that depend on individual bargaining skill. Fishermen may also be commissioned to collect particular species of fry or juveniles from the wild. In some states (e.g. Katsina in the northern part of the country), until very recently, nets are specifically provided to fishermen who collect

Harvesting of tilapia fingerlings by artisanal fishermen

Fingerling transportation in oxygenated fish box

fingerlings from the wild for stocking in government fish farms.

Intermediaries are involved in the marketing and distribution of farm or hatchery-produced fish seed. As there are no designated seed markets, purchases are made directly by farmers or intermediaries who are also responsible for their transportation. In most cases, purchase reservations are made in advance of collection. Some hatcheries insist on four to eight week-notice in order to make proper arrangement for harvesting, packaging and transportation.

Depending on the quantity, species and distance from hatchery or point of procurement, fish seed are transported using different types of packaging materials and means of transportation. Oxygenation and timing of transportation are very important in order to ensure optimal condition and reduce stress during transport. The seed distribution flow chart is presented in Figure 7.14.6.

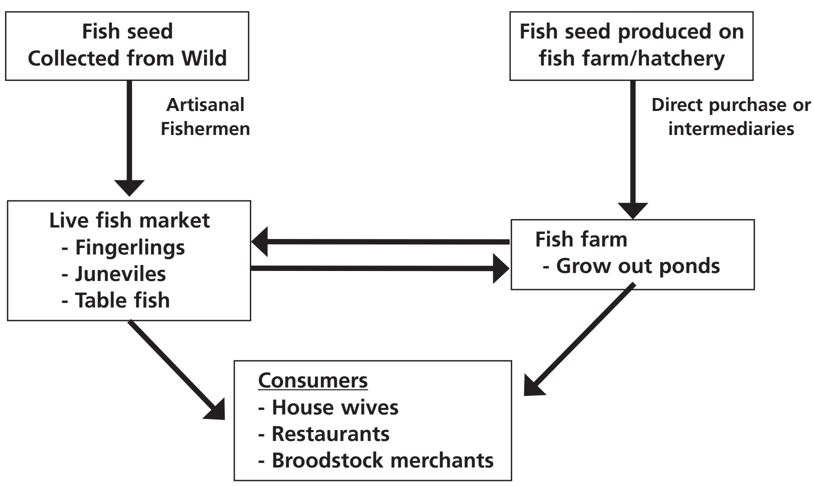
SEED INDUSTRY

The seed industry in Nigeria may be classified for convenience into:

- small-scale producers
- medium-scale producers and
- large-scale producers

Each scale of production is defined by the level of investment available facility, technical competence of manager and consequently the quantity of seed produced. In this way a combination of all these factors will be used to categorize each seed producer. For example, a farm or hatchery with high investment in infrastructure but with an incompetent and poorly remunerated manager with resultant poor production will only quantify as a small-scale producer while a modest hatchery with high capacity utilization in terms of high production may be a medium- or even a large-scale producer.

FIGURE 7.14.6
Fish seed flow chart



Small-scale producers

Seed producers who are able to at least produce enough to satisfy their own immediate needs, and depending on the size of their own farm may have up to about 20 000 fingerlings for sale to other farmers, during a production season, could be classified as small-scale producers. This category of producers do not always have an indoor hatchery, but may have, in most cases, few outdoor concrete tanks, usually for spawning and rearing of fry. These may also be completed with indoor plastic or may not have any concrete structures but their production ponds can also double as breeding ponds. These ponds are usually between 100 m^2 and 200 m^2 and not more than three or four in number. The species could be single species (monoculture) or mixed (polyculture).

There are about 1 500 of these small-scale producers in Nigeria mostly in the southeast and north central zones and are responsible for about 20 percent of total seed supply to the system. The average annual investment for this seed production system is usually less than ₦100 000 (US$600.00). This investment can be recovered from the proportion of the fingerlings sold out to other farmers.

Medium-scale producers

These producers usually produce and sell more than 20 000 fingerlings during a production season. In most cases, there are hatchery facilities complete with fry rearing and nursery ponds. Often the volume of production in a particular season is dependent on the level of management and competence of the fish breeder and hatchery manager. Almost all the farms and hatcheries are operating below installed capacity, at best between 20-50 percent production levels. In effect, a hatchery that produces between 50 000-100 000 fingerlings could easily have produced up to 500 000 with full capacity utilization. Factors responsible for low-capacity operation include amongst others:

i) lack of enough good broodstock supply throughout the year
ii) unreliability of year round high quality water supply to the hatchery
iii) poor handling and management of hatchings and frys
iv) lack of enough space to hold the frys coming out of the hatchery e.g. rearing and nursery ponds
v) lack of adequate operating capital.

Usually investment in seed production infrastructure at this level can range from ₦250 000 – ₦5 million (i.e. US$ 2000 – US$ 40 000) depending on the facilities available in the farm. Most government fish farms before abandonment fall into this category of producers. The Internal Rate of Return (IRR) at this level also varies so widely that it is very difficult to generalize.

There are about 200 medium-scale seed producers in Nigeria, mostly private entrepreneurs and are collectively responsible for about 60 percent of all the fish seed supply in the country especially catfish fingerlings. Most of these hatcheries are situated in the south-south (especially Delta State) zone and south-west zone. Many of them also use the flow-through system.

Large-Scale Producers

They produce and supply to the market consistently in excess of 100 000 seed every season or every year. Investment on infrastructure at this level is very high, always more than ₦5 million (US$40 000). The general characteristic of this group is the presence or availability of a large pool of broodstocks (usually in thousands), modern and functional hatchery complex complemented with many nursing and rearing ponds. The ultimate feature in this production category are the operators of intensive water recirculating system complemented with flow-through indoor systems. There is very high running cost with sophisticated and highly technical and intensive management. At this level, serious technical competence is indispensable. However, all the investment is justified by the high turnover of seed from the systems. At least ten of these systems, especially in the south-west operate from warehouses, and produce on the average between 200 000 to 400 000 catfish fingerlings/month. Each of them also provides input and services to between 100 and 500 fish farmers. They employ foreign technology including imported feed and many of them are in partnership with foreigners especially Europeans, Asians and South Africans.

These high-volume producers though few in number (about 30) cumulatively supply about 20 percent of all the fingerlings available in the seed market. Relative to the cost of fingerlings from small-scale and medium-scale producers, the fingerlings are cheaper, because of the economics of mass production. From the economy of scale, the future of seed supply in Nigeria clearly belongs to this system of production. This is evident in the proliferation of this system all over the country, in various scales depending on the available resources at the disposal of the investor. This group of investors has also shown interest in tilapia hybrid seed production by using intensive recirculating system.

SUPPORT SERVICES

The type of support services available to seed producers depend on the mandate and terms of reference of the service provider as well as demand from clients themselves. The following organizations assist seed producers in various ways: (1) Federal Department of Fisheries, (2) States Fisheries Divisions, (3) States Agricultural Development Programme, (4) Private extensionists/consultants, (5) Nigeria Agricultural Credit and Rural Development Bank (NACRDB) and other financial institutions, (6) Fisheries-based Research Institutes and (8) Aquaculture and Inland Fisheries Project (AIFP).

Federal Department of Fisheries (FDF)

This is the Federal Government public agency charged with the overall responsibility and mandate for fisheries policy and development in Nigeria. It is a department of the Federal Ministry of Agriculture and Rural Development. The Aquaculture Division of the FDF organizes occasional scheduled and non-scheduled short duration hands-on training on its many model fish farms and hatcheries scattered all over the country. Unfortunately now almost all the farms and hatcheries have been abandoned due to lack of funding. FDF is a repository of highly trained high level manpower many of whom have been trained both locally and abroad. Even in the absence of government farms many of these staff are always available to give technical advice on construction and management of the farms and hatcheries. FDF also facilitates the formation of professional organizations and private seed producers groups.

States Fisheries Divisions (SFD)

They perform similar functions as with FDF, including ownership and operation of hatcheries, but at the state level. Some SFD assist some seed producers in bulk procurement of inputs and at times even advise on pricing of fingerlings. For the same reason of poor funding and organization, most of them have become irrelevant in the present status of private-sector-led initiatives in the seed industry.

Agricultural Development Programmes (ADP)

These are state-based institutions, initially carved out from the states' Ministries of Agriculture, essentially to provide agricultural extension services including input supplies and distribution to the state farmers. They operate the unified extension system which provides for only one extension agent carrying messages from all agricultural sub-sectors to different target beneficiaries. The peculiarity and uniquely technical nature of the fish seed production technology, lack of manpower and the subsequent poor funding of the ADPs have not allowed them to be of any sustained and appreciable benefit to the seed industry. However, in some ADPs especially in the

Maritime states like Lagos and Delta States, technical support and some incentives are provided for seed producers. The incentives could include guaranteed interest- free loan and contract seed supply to government-assisted fish farmers.

Private extensionists/consultants

The seed industry benefits more from the services of private extensionists and consultants, for which they are ready to pay. Some very large producers can afford to even employ the services of foreign consultants or even enter into partnerships with such a group. Most of the local extensionists/consultants are currently serving or retired government officials with a lot of practical experience acquired locally and abroad. Because they are promptly paid for their services, they are usually more dedicated than when they work as government extension agents. They provide services such as advice on construction, preparation of feasibility studies, sourcing of broodstock, feed, management and even marketing advice. Unfortunately too, there are many impostors pretending to be experts and victimizing unsuspecting clients. This is one of the risks of the business.

Nigeria Agricultural Cooperative and Rural Development Bank (NACRDB)

This is a specialized agricultural bank that provides credit to all categories of farmers in Nigeria at concessional interest rates depending on the enterprise loans and can provide either for the development of the whole fish farm or a specific component such as building of the hatchery or even direct procurement of fish seed from other sources, if this is the request of the client. For loans that are not too big, good farm records and business plan usually suffice as collaterals. The possibility of cooperative loans for seed producer groups also exist and financing of group projects as well.

Fisheries-based research institutes

There are two fishery-based research institutes in Nigeria, one for freshwater fisheries research (NIFFR) in New Bussa and the other for marine fisheries (NIOMR) in Lagos. Both of them have fisheries training institutions affiliated to them to cater for the training of middle-level fisheries manpower. Apart from relevant basic and applied research carried out in these institutions, the products of their schools constitute the bulk of middle-level fish farm and hatchery managers in the country. They also organize hands-on training for fish seed producers regularly. The results of their researches especially in the areas of broodstock development, genetic manipulation and fry feeds have helped substantially in improving fish seed production technology in the country. The future of the seed industry, however, depend substantially on how these institutes are able to respond to the needs of the fish farmers in terms of new product and technology developments.

Aquaculture and Inland Fisheries Project (AIFP)

This is an intervention project being executed in collaboration with FAO. The Project which commenced in July 2003 is operating presently under the umbrella of the National Special Programme on Food Security (NSPFS) which is a global initiative of the FAO to address the problem of hunger in poor, developing countries. The broad objective of the AIFP is to increase ten folds the present national average production from a group of selected 50 private fish farmers nationwide over a period of five years. The other objective is to double the production from a total of 43 inland water bodies over the same time frame. These sets of objectives made it imperative that the project has to work with seed producers. So far, four clusters of 20 private fish farmers have been established of which at least 15of them are seed producers in addition to table fish producers. The type of services benefited from the project include technical assistance such as training, provision of manuals and free consultancy services including linking up with service providers (e.g. feed and seed) who may not be members of the clusters. Occasionally, the project intervenes by direct provision of input such as broodstocks and high quality feed. Presently the project is assisting each farm to develop business plans that would enable them attract credit on their own merit.

SEED CERTIFICATION

There is no formal organized fish seed certification process. However, quality assurance and quarantine services for fish and fishery products coming in and going out of Nigeria are regulated and supervised by the FDF. This is administered through a certification process. Fish seed are always treated as live fish and the production and distribution within the country are at present not under any known statutory regulation. Notwithstanding this, seed producers have built their own individual reputation in terms of quality assurances and performance over time. Certification of fisheries products and services is part of an on-going review by the Fisheries Society of Nigeria.

LEGAL AND POLICY FRAMEWORK

As explained above, the seed industry only benefits from generalized fisheries policy and legal framework that affects adult fish industry. The umbrella national fisheries legislation is the Inland Fisheries Decree No. 108 of 1992 and the Marine Fisheries Decree of 1991. The provisions in such legislation are directed mainly to wild and capture fisheries which are regulated through licensing. However, export or import of live fish (including seed) is carried under the authority of the Minister of Agriculture. States require registration of premises where any commercial activity (including seed production) is carried out. The Environmental Impact Assessment (EIA) Decree of 1988 also recommended the conduct of EIA studies for activities that may impact negatively on the environment, e.g. intensive water recirculation seed production systems which generate a lot of ammonium liquid and gaseous waste discharges and any land area up to 50 ha

ECONOMICS

Fingerlings production is a basic aspect of aquaculture necessary to ensure a continuous supply of seed for stocking. For any production system, evaluating the economic viability is expected. At the end of such analysis, it will become clear if such a production system is profitable or not. Since profitability in fingerling production is dependent on the volume of production, large-scale producers are more favored with higher ROI despite having high initial capital outlay and as long as it is supported by competent technical management. In addition, due to the enormously wide gap between demand and supply of seed in Nigeria, the future belongs to large-volume producers.

Fish farmers are generally convinced that they make more money on fingerlings than table fish production and there is higher profit in hatchery operations than fish farms. Many existing fish farms are grossly understocked as a result of non-availability of seed. Optimal stocking of existing farms can lead to substantial increase in fish production.

KNOWLEDGE GAPS

There are several information and knowledge gaps in determining the correct status of the fish seed industry as a result of the domination of the enterprise by the private sector. One of the bottlenecks usually encountered is the difficulty in obtaining accurate production figures either in terms of investment or revenue. At best, the computed figures are estimates based on the extrapolation of data collected and collated from easily accessible AIFP cluster farmers.

The level of interaction and networking among various stakeholders in the seed industry is still not the best. In addition, because of the poor funding of fisheries research in Nigeria, there are many aspects of seed production technology, marketing and distribution which need to be closely looked into and addressed. The area of development of standard manuals for the local production of the seed of various indigenous species is still lacking as those in operation presently are based on overseas publications and are only being adapted to local situations.

ROLES OF STAKEHOLDERS

Producers/farmers

Seed producers have the responsibility to ensure the production and supply of adequate quantity and quality of fish seed into the system. This is attainable through full capacity utilization and expansion of installed infrastructure. The needs in the short-term would be at least 500 million seed/yr. This would eventually provide the basis for eventually attaining the ultimate national demand of 2-3 billion fingerlings. Seed producers must also network among themselves and the market to ensure effective distribution and marketing.

The roles of other stakeholders have been substantially discussed under the support services providers.

Associations

The main professional associations that look after the interest of fish farmers and aquaculturists in Nigeria include: (i) Fisheries Society of Nigeria (FISON), (ii) Association of Fish Farmers and Aquaculturist of Nigeria (AFFAN), (iii) Catfish Farmers Association of Nigeria (CAFAN), (iv) United Fisheries Association of Nigeria (UFAN), (v) Association of Fingerlings Producers of Nigeria (AFPON), (vi) Nigeria Union of Fishermen and Seafood Dealers (NUFASD) and (vii) Association of Ornamental Fish Exports of Nigeria (AOFFN). Most of the associations have overlapping activities, with everybody doing almost everything and the same thing. Most of them are relatively new and not yet officially registered. In effect, they are almost powerless in influencing government policies and unable to take decisions that would be binding on members. Seed producers in Nigeria operate more on an individual basis.

Donors (funding agencies)

In the past and in recent times, various organizations, governments and multinational agencies have assisted in one way or the other fish seed production in Nigeria. These include the FAO, the governments of Italy, Japan and China, the World Bank and oil companies in Nigeria including Shell, Mobil and AGIP.

FAO

The very first government initiative in promoting fish seed production was assisted and funded by the FAO between 1978 and 1982. The project was named Fish Seed Multiplication Project which was executed by the FDF and FAO provided technical assistance in terms of training (hands-on) and demonstration. Short-term experts were provided by FAO to work in the different zones of the country to provide training and demonstration to practicing and prospective fish farmers and hatchery operators. Some Nigerians were also trained abroad (Hungary and Israel) under FAO Fellowship to acquire the necessary fish seed production skills.

FAO has at various times funded Technical Cooperation Projects (TCPs) which promoted seed production in Nigeria. The AIFP is also being implemented by the FAO on behalf of the Nigerian Government. FAO has contributed substantially to the success of the programme by engaging a TCDC expert from Thailand who has trained about 100 hatchery operators in modern hatchery management and catfish seed production. The impact is so greatly felt among the seed producers that the expert is being requested to return again.

Italian Government

The Government of Italy contributed to seed production in Nigeria through a US$1 million grant to the Government of Nigeria to build the first state-of-the art modern hatchery in terms of production capacity and sophistication in 1988. The grant was used to construct the hatchery at the FDF Farm in Oluponna, Osun State. Part of the grant was also used to demonstrate the feasibility of integrated fish farming. The production capacity of the hatchery complex, complete with nursery ponds is between 10-15 million fingerlings per annum. Unfortunately, since the Italian experts left, the management of the facility has collapsed. It is now a primary candidate for private acquisition.

Government of Japan

The Government of Japan has also contributed to the development of fisheries in general and seed production in particular through institutional strengthening by the provision of training facilities, hatchery equipment and hostel to the Federal Marine College of Fisheries Technology in Lagos in late 1980s.

Government of China

The Government of China has a standing Technical Cooperation among Developing Countries (TCDC) bilateral agreement with Nigeria since 1994 for training in both integrated fish farming and fish seed production. This involves the annual training of three to five Nigerians for three months at the Wuxi Freshwater Integrated Fish Farming Training Centre. To date, about 20 Nigerians have benefited in the programme and are now working in various fish farms and hatcheries all over the country. Also through the South-South Cooperation Programme, about 350 Chinese technicians including 70 in fisheries are currently working in Nigeria and a good number of them are attached to private hatcheries and fish farms. They have also held demonstrations on the construction and management of cottage hatchery.

World Bank

The World Bank has concluded preliminary work on the commencement of a US$32 million credit package for Micro, Small and Medium Enterprises (MSME) in which the catfish industry will benefit over US$22 million. This was based on a study carried out which revealed the enormous opportunities existing in the production, distribution and utilization of catfish products in Nigeria. A substantial portion of the fund is expected to go into catfish seed production in order to ensure its quality and ready availability. About 30 000 new employment is expected to be generated over the next four years as part of the package. There will be training as well as institutional capacity building components.

Shell Petroleum Development Company (SPDC)

SPDC has a track record of funding and assisting agricultural projects especially at their operational base in the Niger Delta area. They assist small-scale fish seed producers through soft loan, contract, supplies and funding of training/workshops. In recent times, the company is contemplating on establishing a number of intensive recirculating systems for the mass production of catfish fingerlings. The company is also investing in the establishment of freshwater shrimp hatchery and grow-out farms in collaboration with some riverine communities.

AGIP Oil Company

Apart from assisting small-scale seed producers in their areas of operation, AGIP Oil Company, as part of its Green Water Agriculture Project, funded the rehabilitation of the Oguta Fish Hatchery, owned by the Imo State Government. The hatchery has an installed capacity of producing about 5 million fingerlings per annum. Unfortunately, the state government could not sustain the management and it has currently been put up for private acquisition. The company also occasionally provides funding for some activities of professional associations.

FUTURE PROSPECTS AND RECOMMENDATIONS

Seed production in Nigeria is profitable. Governments at all levels need to facilitate and ensure continued profitability while increasing production. This can be achieved through the institutionalization of policies that would both encourage production and demand. Some of these measures could include:

- encourage establishment of more private fish hatcheries to produce a minimum of 500 million fingerlings per annum in the next five years
- facilitate the establishment by the private sector of aquaculture feed mills to produce at least 500 000 met annually in five years
- create fish farm "clusters" for cooperation, technology transfer, training/ demonstration and easier provision of inputs and technical assistance in groups of private farmers, using the AIFP approach as model
- create public awareness on aquaculture among banks and other lending institutions to increase loans to credible fish farmers
- identify suitable inland water resources for improved production through enhancements programmes which will include stocking of desirable species produced in hatcheries
- funding of applied aquaculture research to connect farmers with research institutions
- entrench sustained culture of fish farming in Nigerian households as with crops and poultry over the next four years
- divestment of government fish farm to the private sector within two years and
- enable professional organizations to drive the fish seed industry.

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7.15 Freshwater fish seed resources in Pakistan

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ABSTRACT

Pakistan is a diversified land mass, possessing vast plains in the Indus Basin, plateaus in the southwestern part and a series of high mountains in the north. The country covers an area of 796 096 km^2 with different types of climate and seasons in its four provinces (North West Frontier Province, Punjab, Baluchistan and Sindh). The natural water bodies of the country include the rivers Indus, Ravi, Sutlej, Jhelum and Chenab and some small rivers, streams and their tributaries. The water resources also comprise a network of canals, lakes, reservoirs, water-logged areas, saline waters, small dams, village ponds, etc.

These natural water bodies possesses 184 species of freshwater fish belonging to warm, semi-cold and coldwater species. Fish seed is an essential requirement for the development of fisheries and aquaculture. Before 1970, the main source of fish seed was natural water. From 1974 onwards, fish seed are being obtained through successful induced spawning techniques. The fish seed production industry varies from province to province and Punjab Province contributed a significant proportion. There is no certification system. There is a wide gap between supply and demand of fish seed in other provinces except in the Punjab Province. There is no special fish seed market. Punjab Province is the largest producer, supplying to other provinces millions of seed of major carp, i.e. rohu (*Labeo rohita*), mori (*Cirrhinus mrigala*), thaila (*Catla catla*) and the Chinese carps such as silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). In addition, carp hatcheries also produce fish seed of carnivorous fish species like saul (*Channa marulius*), singhari (*Arichthys aor*) and mahseer (*Tor macrolepis*).

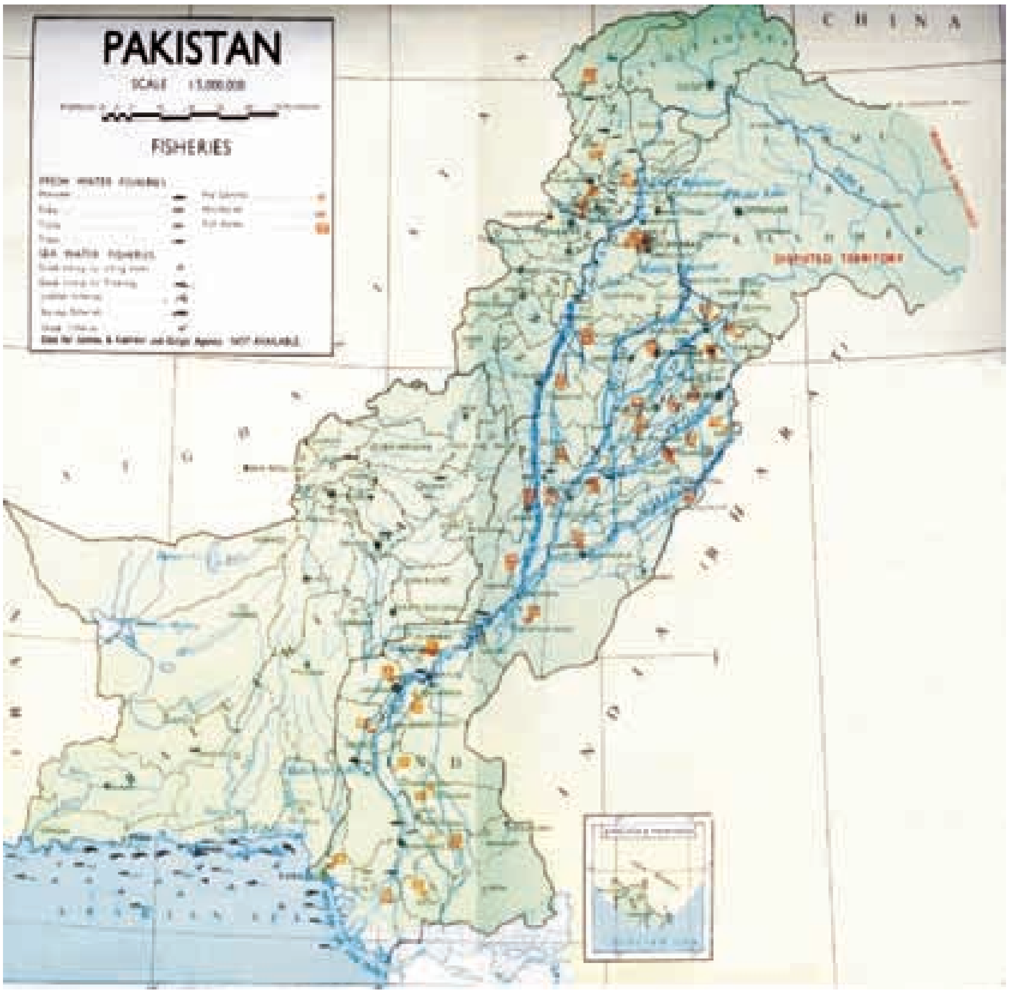
INTRODUCTION

Pakistan is surrounded by Afghanistan, China, Iran, India and in its south is located the Arabian Sea (Figure 7.15.1). The climate of Pakistan has the following five different types: (i) tropical semi-arid, (ii) tropical arid, (iii) cold semi-arid, (iv) snow forest climate and (v) extremely cold.

The country has four well-marked seasons, namely: (i) cold season (December to March), (ii) hot season (April to June), (iii) monsoon season (July to September) and (iv) post-monsoon season (October and November) (Survey of Pakistan, 1997).

Fish consumption in Pakistan is very low, i.e. 2 kg/capita/annum when compared to the world average of 11 kg/capita/annum (FAO, 2003). Fish is, however, the best

FIGURE 7.15.1
Map of Pakistan showing its neighbouring countries



alternate source to meet animal protein deficiency, since the livestock and dairy sub-sectors are not producing sufficient levels of the protein requirement. The nutritional value of fish is very high (protein content of 15 to 20 percent), it has low cholesterol content and many useful dietary supplements (NCA, 1988).

In Pakistan, fish has been depicted in objects excavated from Nal in Baluchistan, Mohanjodaro in Sindh and Harapa in Punjab. However, the history of the development efforts for fisheries along the scientific lines in the country is not very old (Ayub, 1985).

There are two major resources of fish in the country, i.e. marine and inland resources or freshwater fisheries resources.

TABLE 7.15.1
Data showing the importance of the Pakistan fisheries sector

Standard Protein Requirement	30 g/capita/day
Availability	17 g/capita/day
Fish Contribution	5 % of availability
Present Gap	13 g/capita/day
Growth Rate	
Fishery	4 % per annum
Population (Human)	2.10 % per annum
Net increase (Fish)	1.9 % per annum

The main natural water body of Pakistan is the River Indus and its tributaries. After originating from Tibet, the River Indus flows behind the Himalayan Mountains and after crossing the Northern Areas (NA) and Kashmir, it turns southwest. In the North West Frontier Province (NWFP), it receives small rivers (e.g. Kabul, Kuram and

Gomal). In Punjab, it receives the Haro, the Soan, the Jhelum, the Chenab, the Ravi and Sutlej. In the province of Sindh, near Karachi, the River Indus falls into the Arabian Sea. In Baluchistan, there are many small rivers and streams such as Lora-Pishin, the Mashkel, the Hub, the Purali, the Hingol and the Dasht.

TABLE 7.15.2
Contribution of fisheries to Pakistan's economy

Share in GDP	1 %
Share in Agriculture	3.5 %
Fish Production (tonnes)	
Marine	400 700
Inland	163 400
Employment Opportunities	365 000
Fisheries Products exported	84 000 tonnes
Foreign exchange contribution	US$ 156 254 000

Source: Anonymous (2003); Economic Survey of Pakistan (2002-2003)

Collectively, the freshwater resources of the country include Indus River basin, rivers, canals, man-made reservoirs attached to barrages, water-logged areas, natural lakes, saline waters, two large man-made lakes (Mangla and Tarbella) and more than 40 small dams, village ponds, etc. In total, the inland water bodies cover an area of more than 8 million ha.

There are about 184 species of freshwater fishes inhabiting the warmwater, semi-cold water and coldwater bodies lying in the four provinces of the country. Among the said fish fauna, *Labeo rohita, Cirrhinus mrigala* and *Catla catla* are being cultured successfully along with Chinese carps (*Ctenopharyngodon idella* and *Hypophthalmichthys molitrix).* In suitable areas in the province of NWFP and in NA of the province of Punjab, rainbow and brown trouts are also being cultured successfully. Mahseer (*Tor putitora*) is another important fish found in semi-cold sub-mountainous areas of the country. An anadromous fish, *Tenualosa ilisha,* is also found in the River Indus.

Keeping in mind the importance of the fisheries sector in Pakistan, the work of developing potential water resources for aquatic food production has seriously been undertaken during the last three decades. As a result, an area of 40 000 has been dedicated to fish culture with an annual growth of 8 to10 percent during the last decade. Presently, the contribution of fisheries to the country's economy is presented in Table 7.15.2.

Availability of quality fish seed is a key concern for the proper development of fisheries and aquaculture in the country. The main sources of fish seed for stock enhancement comprise of fish hatcheries, nurseries, wild spawning grounds, etc.

FIELD SURVEY

To collect information required for the country case study, various fish hatcheries in the provinces throughout the country were visited in addition to personal interviews and communication via telephone. In the province of Sindh, the following persons were contacted: (1) Mr Ghulam Muhammad Mehar, Director Fisheries, (2) Mr Khawar Pervez Awan, Deputy Director Fisheries, (3) Mr Habib ur Rehman, Assistant Director Fisheries. In the Province of NWFP, the following persons were engaged: (1) Mr Omar Hayat Khan, Director Fisheries, (2) Mr Muhammad Ayub, Deputy Director Fisheries and (3) Mr Shaukat Ali, Assistant Director Fisheries, Madyan; while in the province of Baluchistan, the following persons provided information: (1) Mr Sher Khan, Director Fisheries, (2) Mr Noor Khan, Deputy Director Fisheries and (3) Mr Abdul Malik, Assistant Director Fisheries.

SEED RESOURCES SUPPLY

Before 1970, the main sources of fish seed were the natural water sources. From 1974 onwards, successful experiments on induced spawning gave an impetus to promote fish culture. As such, both warmwater and coldwater aquaculture have been developed through the establishment of fish hatcheries and nurseries in the country as shown in Table 7.15.3.

TABLE 7.15.3

Number and distribution of freshwater fish hatcheries in Pakistan

Type of hatchery	Provinces				AJK and others
	Punjab	Sindh	NWFP	Baluchistan	
Government hatcheries	14	5	6	1	2
Private hatcheries	76	31	10	-	-
Trout hatcheries	1	-	8	1	7

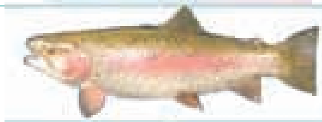
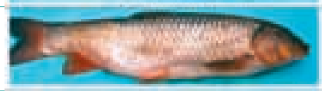
SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

The main seed production resources in the country are fish hatcheries operated by both government and private sectors (Table 7.15.4). Fish hatcheries can further be categorized on the basis of the types of cultured fish, i.e. carp hatcheries, trout hatcheries, mahseer hatcheries, etc.

Presently, there are 28 carp hatcheries in the government sector whereas 117 hatcheries exist in the private sector (Table 7.15.5). With regard to cold water fish culture, there are 17 trout hatcheries. One mahseer hatchery exists in the semi-cold

PLATE 7.15.1

Freshwater fish species used for seed production in Pakistan

No.	LOCAL NAME	SCIENTIFIC NAME	
1.	**brown trout**	***Salmo trutta/fario***	
2.	**rainbow trout**	***Salmo gairdneri***	
3.	**rohu**	***Labeo rohita***	
4.	**mori**	***Cirrhina mrigala***	
5.	**thaila**	***Catla catla***	
6.	**mahseer**	***Tor putitora***	
7.	**silver carp**	***Hypophthalmichthys molitrix***	
8.	**grass carp**	***Ctenopharyngodon idella***	
9.	**common carp**	***Cyprinus carpio***	
10.	**bighead carp**	***Aristichthys nobilis***	

water area of Malakand in NWFP, another full-fledged Mahseer fish hatchery is being established under a development project in District Attock in the province of Punjab.

Province-wise list of fish hatcheries in the government sector using carp, trout and mahseer fishes is attached as Annex 7.15.1.

TABLE 7.15.4
Fish seed production capacity in the four provinces of Pakistan

Province		Production capacity
Punjab	Government hatcheries	52 000 000
	Private hatcheries	22 500 000
Sindh	Government hatcheries	18 500 000
	Private hatcheries	-
NWFP	Government hatcheries	11 750 000
	Private hatcheries	-
Baluchistan	Government hatcheries	0.080
	Private hatcheries	-

TABLE 7.15.5
Information on fish hatcheries in Pakistan

Number of Carp Hatcheries (Government) including AJK and others	28
Number of private hatcheries	117
Trout hatcheries (government)	10
Trout Hatcheries (private)	7

Available Technologies

The breeding of various culturable species is undertaken through a series of scientific operations from broodstock management to induced spawning activities using synthetic hormones (LH-RH Analogue) and other relevant chemicals up to hatching using the Chinese system, glass jar and incubation troughs techniques. In most cases, the dry method is used for fertilization of eggs. Rearing, up to stockable size of fish seed, is undertaken through proper natural and artificial feeding using formulated diets in well-fertilized tanks/ponds with suitable water quality.

Breeding. Breeding commonly takes place by injecting the hormone Ovaprim to mature female and male fish keeping in view the climatic conditions, temperature and maturity of the broodfish. The spawning period of carps extend from April to late July. It cannot breed except through induced spawning. Pairing occurs during the period of spawning. There is external fertilization and no parental care. The temperature range required for reproduction is between 20 °C to 27 °C. The latest applicable techniques used in Pakistan for hatchling are: (i) glass jars, (ii) circular cemented tanks and (iii) rectangular cemented tanks.

Fertilization. The objective of fertilization and manuring is to produce an abundant supply of zooplankton, a cladoceran, a copepod, a rotifer or a protozoan regardless of size. Organic manure such as cattle or chicken manure alone and/or with inorganic fertilizer such as NPK mixture are used. If both organic and inorganic fertilizers are used, they may be applied either one following the other or as a mixture.

Nursing. To avoid any abrupt change in quality and temperature between water of the hatchling tank and that of nursery pond, the post-larvae are kept in a suitable container having water initially from the hatchery tank and to which water from the nursery pond is gradually added in stages eventually substituting almost the entire hatchery water. The container is then slowly dipped and tilted in the nursery ponds so that the post-larvae are free to swim out of the container into the nursery pond. Soon after being stocked in nursery ponds containing rich zooplankton, carp post-larvae start grazing voraciously on natural food. At this time feed requirements of spawn are so large that within two or three days of stocking, the plankton initially present in the pond gets exhausted and steps are taken not only to generate more natural food but also to administer artificial feeds. Artificial feeds are always given to carp post-larvae in finely powdered form. The fry taken from nursery ponds are transferred to rearing ponds which are prepared in the same manner as the nursery

PLATE 7.15.2
Hatchery facilities in Pakistan

Fish seed hatchery in Lahore, Punjab

Raceways at trout hatchery in Muree, Pakistan

Chinese system of breeding fish

Trays and tanks used for fish breeing at a trout hatchery in Madyan, NWFP

Breeding troughs for mahseer

Circular breeding tanks at a carp fish hatchery in Charbanda, Mardan District

PLATE 7.15.3
Breeding process

Stripping process in fish breeding

Mixing of milt and spawn in fish breeding operation

ponds. Ongoing activities in the rearing ponds include: (i) elimination of predatory and weed fish, (ii) manuring with organic and inorganic fertilizers, (iii) weed control and (iv) supplementary feeding.

SEED MANAGEMENT

In fish hatchery operations, management of broodstock is a key concern for the success of induced spawning of major carps and Chinese carps as proper development of gonads, rate of ovulation, fertilization, etc. are all dependent on proper broodstock management. This involves preparation of suitable sizes of broodfish ponds as per size and type of fish, maintaining optimum physico-chemical conditions of pond water and proper feeding of stocks with regular monitoring of general and gonadal development of brood fish.

In carp hatcheries, fish seed management involves two distinct phases, namely: (i) rearing of post-larvae to the fry stage which mostly takes place in nursery ponds and (ii) rearing of fry to fingerling stage which takes place in rearing ponds.

Under both conditions, preparation and maintenance of nursery, rearing and stocking ponds are very important functions which actually ensure the removal of the causes of poor survival, growth and health of the fish seed stocks.

As a whole, management of fish seed covers the following main considerations:

- physico-chemical compatibility of water in ponds;
- adequate quantity of fish food in nursery and rearing ponds;
- eradication of predatory aquatic insects;
- monitoring of pond conditions like excessive vegetation, seepage, etc.;
- elimination of factors causing toxicity of certain algal blooms;
- protection from parasitic, bacterial and fungal infections causing different diseases; and
- maintenance of wholesome fish husbandry conditions to avoid any abnormality or ill-health problems in seed stocks.

Feed management is another important concern in fish hatchery operations and plays a key role in good survival and maximum growth of fish fry. Fish seed are reared in tanks/ponds where food can be provided in adequate quantities (both living and non-living food items). Starter feeds used for fry are dense cultures of rotifers. Micro-encapsulated egg diet and powdered formulated feeds are also used for proper rearing of fish fry. For maximum uptake by the fish, the ration is supplied three to five times a day in parts.

SEED QUALITY

The most important objective of the fish hatcheries and seed production units in the country is to raise healthy and disease-free stocks of different species of culturable fish in hygienic and conducive conditions.

In this regard, the parental stocks or brood fish are meticulously selected based on proper weight, proper maturity, good health and feeding with particular brood fish diet.

Hatchery managers monitor the growth, survival and health conditions of the seed stocks during various stages of rearing, observing the weight/length ratios and general status of health.

Good husbandry, proper nutrition and compatible physico-chemical conditions of water are very important to avoid any health problem or occurrence of disease in fish seed. As such, strict hygienic measures are observed in seed production facilities.

Potassium permanganate (10 mg/l solution) and formalin (200-250 mg/l) are commonly used to clean and disinfect hatchery tanks, nets and other equipments used in seed production.

Prophylactic measures and treatment of fish diseases are also done depending on the situation and conditions of seed stocks. Dip, bath and flush treatments using suitable chemicals are commonly practiced in fish hatcheries.

To judge the quality of fish seed, proper monitoring is done by assessing the growth rate, survival and general health conditions of the stock. Another common practice of good hatchery managers is the proper segregation of different species since mixing of similar species causes problems to the farmers who have to stock their polyculture ponds in accordance with a specified species ratio.

SEED MARKETING

There are no special markets organized for fish seed sale in the country. Fish seed in hatcheries and other production units are either supplied directly to the farmers at the production points or transported to the farms. In case of transportation by road or by air, proper packing of seed in polyethylene bags with sufficient amount of oxygen is the normal practice.

The prices of seed are fixed as per species of fish and sizes of seed. The availability of seed of various species of fish and other relevant information are advertised through print media to promote sales. Almost all seed production points are easily accessible and transportation is always available.

The province of Punjab is the biggest producer of fish seed. From this province alone, millions of fish seed of major carps and Chinese carps are sold to other provinces. The largest buyer is the Sindh Province followed by NWFP and Baluchistan. Fish seed sold to other provinces come from both private sector and public sector hatcheries.

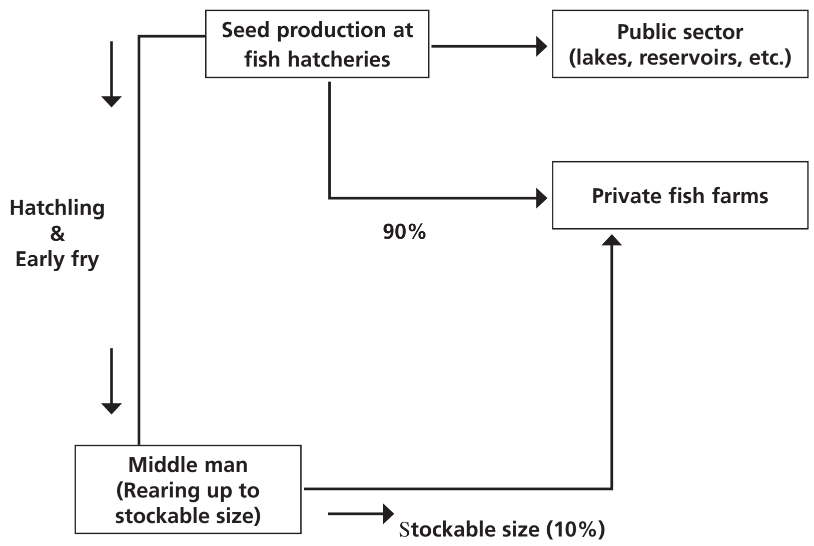
As a whole the marketing system of fish seed is rather simple mostly involving producers and buyers, as shown in the figure below.

Some of the private fish farms possess seed production facilities as well which fulfill the seed requirements of those farms and in some cases the extra seed are sold to other private fish farms.

Post-larval marketing

In some cases, the post-larval stage of fish seed are purchased at low prices from hatcheries by the nursery owners who also rear them up to fingerling size. This stockable size of seed are then marketed to fish farmers for profit. The seasons of fish seed sale relate to the production period of different species of fish, mostly peaking in May for exotic fish and from September onward for major carps.

FIGURE 7.15.2
Flow chart showing distribution channel of fish seed in Pakistan



SEED INDUSTRY

The level of fish seed industry varies from province to province. Seed production in the Punjab Province dominates the industry and can be categorized as a medium-sized industry. The provinces of Sindh, Baluchistan and NWFP have no significant contribution to seed production activities.

The seed production business is affected by a number of risks like climatical hazards, power failure and outbreak of some diseases which can cause economic losses.

SUPPORT SERVICES

Technical advisory services with regard to various fish culture operations are being provided by the government sector. These include preparation of feasibility reports, ponds design and construction, financial and economic analysis, farm management, fish stocking, culture ratios, feed, fish health, disease prevention and control, etc.

Communication through radio and television are arranged alongside with distribution of pamphlets and brochures on various aspects of fisheries and aquaculture as a way of raising awareness about the sector and informing other relevant sectors. Information about availability of fish seed and its sale are advertised through print media.

Training workshops at district level are also organized with special emphasis on extension of relevant services.

The annual fish farmer conventions, workshops, seminars and such other fora help farmers to present their problems and discuss ways of finding solutions to the specific technical and management problems experienced by their respective farms to enhance fish production.

SEED CERTIFICATION

At present, there is no system for certification of seed of any species of fish in the country.

POLICY FRAMEWORK

The draft Pakistan Fisheries and Aquaculture Policy Framework consists of a strategy to increase national fish supply based on sustainable production and improved marketing of aquaculture products.

One of the strategy axis for strengthening aquaculture production is to produce maximum fish seed and attract the private sector in seed/fingerling production of commercially important freshwater species of fish through appropriate investment incentives.

ECONOMICS

Since the fish farming sector is growing rapidly at about 8-10 percent, the demand for fish seed as a major input in the production system is also increasing rapidly.

Presently, there is a wide gap between supply and demand of fish seed particularly in Sindh, NWFP and Baluchistan provinces. In Punjab, even as government hatcheries are contributing significant quantities of fish seed for stocking from both public and private sectors, there is still a gap in supply and demand. Consequently, the prices of fish seed are reasonable and opportunity for some profit margin in the seed production industry are also there. The cost of fish seed for stocking by farmers is minimal. The prices of fish seed supplied for stocking in the Province of Punjab are given in Annex 7.15.2.

Seed production at public fish hatcheries involves expenditures on staff and other operational costs to produce and supply seed to private and public sectors. As per average unit price, seed supplied as such, give a net profit ranging from 20 percent to 30 percent and sometimes higher under much better conditions.

A summary of data regarding fish seed production economics at the Fish Hatchery Chhenawan, District Gujranwala, province of Punjab, for 2004-2005 is given below:

Expenditure 2004-2005		Fish Seed Supply		Price/Income from fish seed production (in millions)
Staff:	Rs. 3.246	Private sector:	1.260	Rs. 0.725
Others:	Rs. 0.733	Public sector:	3.670	Rs. 5.872
Total: production cost	Rs. 3.979	Total:	4.930	Rs. 6.597

Unit production cost: $\frac{3.979}{4.930}$ = Rs. 0.807   Unit Price: $\frac{6.597}{4.930}$ = Rs. 1.338

Unit Benefit : (Unit Price –Unit Cost) = Rs.0.531
Percentage benefit = 66 percent

Note: The price figures for 3.670 million fish seed stocked in public waters, have been obtained as per the average rate of Rs.1 600/1 000 fish seed

INFORMATION OR KNOWLEDGE GAPS

Fish seed production technologies, while well-developed in the province of Punjab, should be developed to the required level in other provinces. Training facilities on seed production and allied technical aspects are also not available for the private sector in the provinces of Sindh, NWFP and Baluchistan, unlike in Punjab where there is a Fisheries Research and Training Institute at Lahore which imparts such training to the private sector. This facility, nevertheless, needs further strengthening as per growing demands.

STAKEHOLDERS

At present, fish seed production activities in the country are generally carried out by large-size government hatcheries who are supplying quality fish seed to the private sector as well as for stock replenishment in natural water bodies. About 117 private hatcheries have very little production capacity. There is no proper marketing system regarding fish seed sale.

It is pertinent to mention here that there is so far neither any NGO nor producer association established in the seed production sector.

As far as research activities are concerned, at present, no significant research work is being carried out in the private sector. In the government sector, research activities regarding fish breeding, nutrition, soil and water chemistry, fish biology, fish pathology, management of natural resources and all relevant aspects of fisheries and aquaculture are being carried out.

FUTURE PROSPECTS AND RECOMMENDATIONS

Keeping in mind the importance of fish and recognizing that increasing demand for fish seed is a vital input for aquaculture, it is evident that the future prospects for the seed production sector in the country are bright.

The technical advancement and growing needs for quality fish seed to enhance fish production calls for development of fisheries resources to a level which can meet up the said requirements.

To come up to the required level of seed production, the following issues need to be addressed:

- introduction of new species having the qualities of fast growth, market value, taste, etc.;
- introduction of intensive breeding system of fish in the country;
- introduction of carnivorous fish species for aquaculture in Pakistan;
- enhancement of seed production area;
- development of suitable starter's diets as per species of cultured fish;
- research work on controlled production of live food for fish fry;
- development of suitable strains of cultured fish with characteristics such as fast growth and resistance to unfavourable environmental conditions; and
- studies on production of seed beyond routine breeding seasons of fish.

In this regard, establishment of two hatcheries, i.e. one for carnivorous fish and another hatchery for mahseer is in progress in the province of Punjab. Similarly, two pilot-level intensive seed rearing units are under construction.

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ANNEX 7.15.1
Province-wise list of fish hatcheries in the government sector of Pakistan

1. PUNJAB PROVINCE

Trout Hatchery

S. No.	Name of Hatchery	District
1.	Trout Fish Hatchery Murree	Rawalpindi

Pilot Mahseer Projects

S. No.	Name of Hatchery	District
1.	Hattian	Attock
2.	Kotli Arian	Sialkot

Mahseer Hatchery

S.No.	Name of Hatchery	District
1.	Mahseer Fish Hatchery Attock	Attock

Carp Hatcheries

S.No.	Name of Hatchery	District
1.	Central Fish Seed Hatchery	Lahore
2.	Fish Seed Hatchery Chhenawan	Gujranwala
3.	Fish Seed Hatchery Rawal Town Islamabad	Rawalpindi
4.	Fish Seed Hatchery Faisalabad	Faisalabad
5.	Fish Seed Hatchery Mianchannu	Khanewal
6.	Fish Seed Hatchery, Bahawalpur	Bahawalpur
7.	Fish Nursing Unit, Kotli Arian	Sialkot
8.	Fish Nursing Unit, Farooqabad	Sheikhupura
9.	Fish Nursing Unit, Shahpur	Sargodha
10.	Fish Nursing Unit, Fateh Jang	Attock
11.	Fish Nursing Unit, Pir Mahal	T.T. Singh
12.	Fish Nursing Unit, Hasilpur	Bahawalpur
13.	Fish Nursing Unit, Rakh Khanpur	Muzaffargarh
14.	Fish Nursing Unit, Pirowal	Khanewal

2. NWFP

Trout Hatcheries

S. No.	Name of Hatchery	District
1.	Shinu	Mansehra
2.	Madyan	Swat
3.	Alpuri	Swat
4.	Dubair	Kohistan
5.	Kalkot	Dir
6.	Jaghoor	Chitral
7.	Bombret	Chitral
8.	Allai	Batgram

Carp Hatcheries

S. No.	Name of Hatchery	District
1.	Ichrian	Mansehra
2.	Charbanda	Mardan
3.	Tanda	Kohat
4.	Ratta Kulachi	D.I. Khan
5.	Sher Abad	Peshawar
6.	Badakhel	Bannu

Mahseer Hatchery

S. No.	Name of Hatchery	District
1.	Mahseer Hatchery	Malakand Agency

3. SINDH PROVINCE

Carp Hatcheries

S. No.	Name of Hatchery	District
1.	Chilia	Thatta
2.	Mando Dero	Sukhar
3.	Boobak	Jam Shoro
4.	Badin	Badin
5.	Dhokari	Larkana

4. BALUCHISTAN PROVINCE

Trout Hatchery

S. No.	Name of Hatchery	District
1.	Quetta	Quetta

Carp Hatchery

S.No.	Name of Hatchery	District
1.	Dera Murad Jamali	Dera Murad Jamali

ANNEX 7.15.2
Prices of fish seed of various fish species in Punjab for 2005-2006

I. Major Carp/Chinese Carps

S. No.	Size	Prices (in Rs.)
1.	post-larvae	50/1 000
2.	up to 4 cm	500/1 000
3.	above 4 cm upto 6 cm	800/1 000
4.	above 6 cm upto 10 cm	1,600/1 000
5.	above 10 cm upto 15 cm	3,000/1 000
6.	above 15 cm	75/kg

II.	**Sol/Singhari and Mahaseer**	**Rs. 5/piece up to 10 cm**
III.	**Trout**	**Rs. 5/piece up to 5 cm**
		Rs. 10/piece > 5 cm

(Conversion rates used: Rs. 60 approx. = 1 US$)

7.16 Freshwater fish seed resources in the Philippines

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Tayamen, M.M. 2007. Freshwater fish seed resources in the Philippines, pp. 395–424. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fisheries Technical Paper.* No. 501. Rome, FAO. 2007. 628p.

ABSTRACT

As the main growth sector in the fisheries industry, aquaculture in the Philippines has shown a steady increase in production and is expected to be crucial in fulfilling the significant demand for aquatic products. The supply of quality fish seed for grow-out fish farmers is essential for the expansion of freshwater aquaculture in the country.

The review paper includes information relevant to: (i) fish seed resources and supply; (ii) fish seed production facilities and seed technology; (iii) fish seed management and seed quality; (iv) fish seed marketing and seed industry; (v) fish seed support services; (vi) legal and policy framework and (vii) economics of fish seed production in the Philippines.

The paper focuses mainly on cultured exotic and indigenous species like tilapia, carps, milkfish and giant freshwater prawn. The information included in this review came from existing literature, regional consultation, field survey, industry congresses and personal communication as basis on the current status of freshwater seed resources for sustainable aquaculture development in the Philippines. The paper also describes the different fish genetic improvement programs embarked by different institutions in developing new fish breeds specifically the tilapias to serve the aquaculture industry. Some general protocols and guidelines are described with emphasis on proper hatchery operation and management and quality assessment of promising species. A brief discussion of the tilapia germplasm in the country is described.

The role of the Department of Agriculture, the Bureau of Fisheries and Aquatic Resources, the National Broodstock Center and the different Fisheries Regional Outreach Stations strategically located nationwide as central hatcheries and private hatcheries serving as secondary multiplier sources of improved tilapia breeds are also described. Finally, future recommendations and conclusion on actions/issues still to be addressed and given immediate action are presented.

INTRODUCTION

Based on the 2005 Philippine Fisheries Profile, fisheries production grew remarkably by 44.9 percent from 2.87 million tonnes in Calendar Year (CY) 2000 to 4.16 million tonnes in CY 2005. The average annual production growth rate within that period was registered at 7.71 percent. In terms of value, the 2005 fisheries production was valued at Philippines Pesos (PhP) 146.39 billion compared to PhP 95.5 billion in 2000, showing an average yearly increment of PhP 10.18 billion.

The 2005 production figure also showed a remarkable 6 percent increase from 2004 production of 3.92 million tonnes valued at Philippine Pesos 146.4 billion pesos (Figure 7.16.1), 15.8 percent higher than 2004 valued at Philippine Peso 138.85 billion (BFAR, 2005).

The outstanding performance of the fishing industry was attributed to the excellent growth in production of the three sectors namely: aquaculture, municipal and commercial. The aquaculture sector registered the highest growth with 10.4 percent (1.89 million tonnes) followed by the municipal sector with 4.7 percent (1.13 million tonnes) and the commercial sector with 0.5 percent increase (1.13 million tonnes). The tremendous growth in aquaculture, thus, underscores the importance of maintaining the supply of fish.

Fishery resources in the Philippines come from marine and inland resources. The total inland resources is about 749 917 ha which include both freshwater and brackishwater swampland, existing fishpond and other resources such as lakes, rivers and reservoirs. The total freshwater resources from swampland is about 106 328 ha, from existing fishpond about 14 531 ha and about 250 000 ha come from other inland resources (lakes, rivers and reservoirs) (BFAR, 2005).

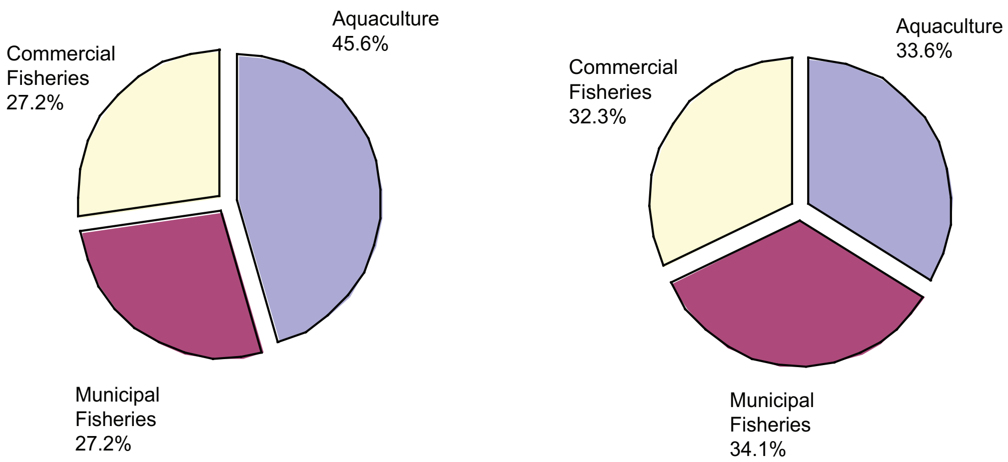
As already mentioned, aquaculture performed the highest in fish production from brackishwater fish ponds, freshwater fish ponds, fish pens, fish cages in fresh and marine waters and mariculture of oysters, mussels and seaweeds.

FISH SEED RESOURCES AND SUPPLY

The supply of fish seed for aquaculture mostly comes from hatcheries (private and government), from wild sources and sometimes from importation. The major freshwater fish seed produced in hatcheries belong to the following groups: tilapias, carps, catfish, milkfish and freshwater prawn. The tilapias are the most popular freshwater species being propagated by both government and private hatcheries (Cagauan and Tayamen, 2005).

Fish fry and fingerlings are raised from captive broodstock in hatcheries and nurseries. With the exception of tilapia, supply of indigenous freshwater fish seed species for culture in good quality and large volume is one of the major problems of the

FIGURE 7.16.1
Total fish production by sector (2005)



industry. In early 1980s, there were about 2 000 small-, medium- and large-scale tilapia hatchery operators in the country capable of producing more than 1 billion fingerlings per year but with inferior quality.

However, in the late 1980s, the Bureau of Fisheries and Aquatic Resources-National Freshwater Fisheries Technology Center (BFAR-NFFTC) had been involved in the development of tilapia. Together with the Central Luzon State University-Freshwater Aquaculture Center (CLSU-FAC), Norway Institute of Aquaculture Research (AKVAFORSK) and University of the Philippines Marine Science Institute (UPMSI), BFAR played a major role as one of the pioneering collaborative national partner in the implementation of the Genetic Improvement of Farmed Tilapia (GIFT) project. This project was coordinated by the International Center for Living Aquatic Resources Management (ICLARM, now known as the WorldFish Center) from 1987 to 1997 with funding from the United Nations Development Programme (UNDP) and the Asian Development Bank (ADB). The result was the development of a synthetic tilapia of African and Asian strains known since then as the GIFT strain. Upon the termination of the project in May 1997, the GIFT Foundation International, Inc. was established to continue selective breeding of the GIFT strain in a self-sustaining basis (Rodriguez, 2003). All the project collaborators were provided access to the GIFT family material technically known as the 8th generation GIFT fish.

The BFAR-NFFTC sustained the development of the fast growing fish through the use of genetically improved tilapia available in the country. GET EXCEL 2000 (which stands for Genetically Enhanced Tilapia – an Excellent strain that has Competitive advantage for Entrepreneurial Livelihood projects) is a product of a selection program combining strain crosses and within-family selection with rotational mating using the four parent lines. The 8th Generation GIFT strain - developed by crossing the best performing genetic groups from eight diverse Nile tilapia strains and their crosses (Eknath, 1993) where combined-family selection and within-family selection for growth in freshwater have been done.

The 13th Generation FAC-Selected Tilapia (FaST) was a product of within-family selection (based on body weight) of *O. niloticus* on a rotational mating scheme done at the Freshwater Aquaculture Center (FAC) (Abella, Palada and Newkirk, 1990; Bolivar, 1998). According to Lester *et al.* (1988), this strain is a combination of four *O. niloticus* “Philippine strain” known as “Taiwan”, “Thailand”, “Israel” and “Singapore”.

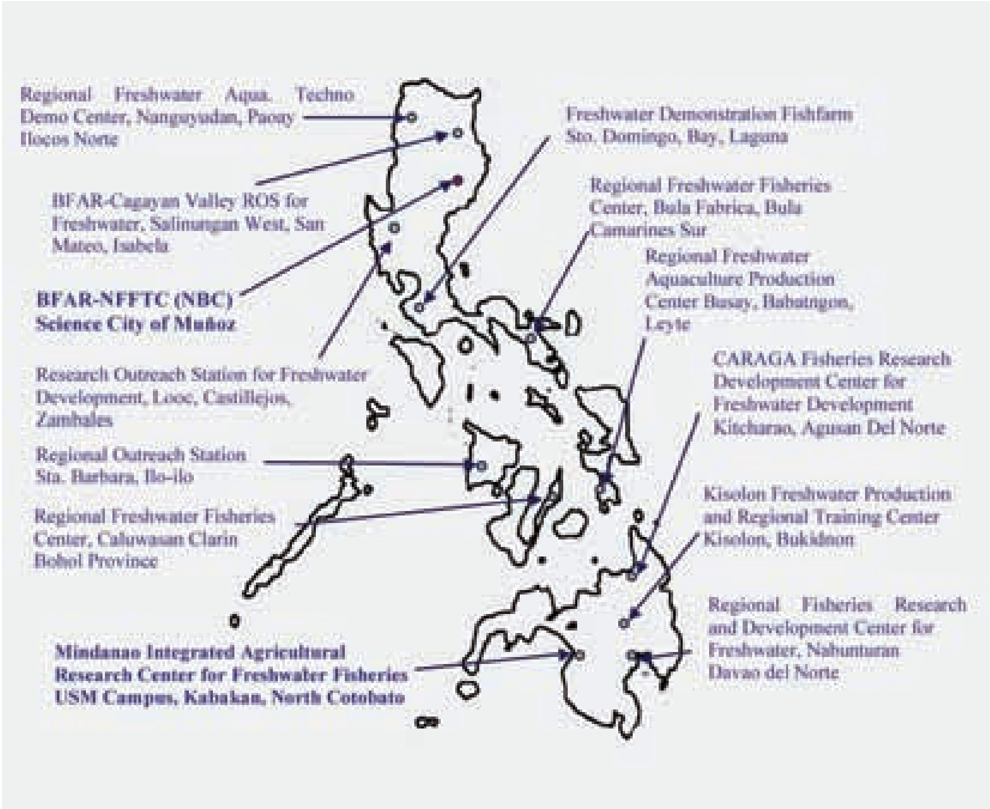
The “Egypt strain” originated from 8 locations in Egypt, namely: Monsour, Manzalla, Timsah Lake, Ismaillia, Abassa, Mariut, Suez Canal and Idku. This was introduced in 1992 through the GIFT Project, implemented by ICLARM.

The “Kenya strain” was a progeny of founder stocks collected in 1989 from Lake Turkana. This was introduced in 1989 through the GIFT Project, implemented by ICLARM.

Breeders used as parent line of the EXCEL tilapia were the selected fish produced through within-family selection not included in the GIFT base population.

Figure 7.16.2 shows the strategic location of the different government hatcheries in the country. The BFAR National Freshwater Fisheries Technology Center (NFFTC) is the National Broodstock Center (NBC); the BFAR-Regional Outreach Stations (ROS) produce GET EXCEL tilapia (BFAR, 2003). These government-operated regional hatcheries serve as focal distribution centers of the improved tilapia strains. The production capacity are minimal ranging from 1.5 million tilapia fry/fingerlings/ha annually. The bulk of fingerling are produced by private-owned and also province-based hatcheries operated by non-government, local government, foundations and corporations.

FIGURE 7.16.2
Location of NBC and Regional Outreach Stations (Central Hatcheries) for GET EXCEL Tilapia



About 5 percent of the fingerlings come from BFAR ROS and local government units, 10 percent is produced by NBC and 85 percent are produced by individual private hatcheries, foundations, corporations and non-government organizations. The tilapia industry requires a conservative estimate of about 1 billion fingerlings annually for stocking to grow-out fish ponds, cages, fish pens, communal waters, lakes, reservoirs, rivers, dams and inland bodies of water which are stocked by BFAR and local government units. About 2.3 billion fingerlings are still needed to stock more cages, freshwater fish ponds, brackishwater ponds, small water impoundments, small farm reservoirs to attain the required fish supply in the country. Existing numbers of GET EXCEL tilapia hatcheries are presented in Table 7.16.1.

SEED PRODUCTION FACILITIES AND TECHNOLOGY

The success of artificial propagation techniques for a number of valuable species on a commercial scale is often cited as the most significant contribution to the rapid development of aquaculture. Consequently, there are now very substantial numbers of fish seed production facilities in the country, especially for marine and freshwater species. These are owned and operated by both government and private entities.

As already mentioned, the Philippines has more than 2 000 unregistered and certified freshwater fish hatcheries, mostly small-scale facilities for tilapia and recently for carp, located predominantly in Luzon along the shores of Laguna de Bay or in Laguna de Bay itself where freshwater fish pen and cage culture practices are concentrated. The number of hatcheries is increasing in other parts of the country with new interest in cage farming in other lakes and in freshwater pond farming in inland areas.

The different center facilities involved in freshwater fish seed production in the country are the following:

FRESHWATER AQUACULTURE CENTER (FAC) OF THE CENTRAL LUZON STATE UNIVERSITY (CLSU)

This Center was among the earliest facilities established that produced and sell tilapia fingerlings in the country. It is located on a 40 hectare inside the compound of CLSU in the Science City of Munoz, Nueva Ecija. Research is the main activity of the Center although it also developed improved strain of tilapia for hatchery and grow-out operators.

One of the major undertakings of the Center is Phil-Fishgen, a project designed to disseminate the products of collaborative research on sex control in tilapia between FAC/CLSU and the University of Swansea with funding support from the UK Department for International Development (DFID). Phil-Fishgen was developed to address the problem of precocious sexual maturation in tilapia by producing monosex progeny.

The problem of early reproduction is apparent when a 5-6 mo old crop of mixed-sex tilapia can comprise 30-40 percent of unmarketable juvenile tilapia. An experiment at CLSU demonstrated that as little as 6 percent of the original stock being female could result in 10 percent of the harvested biomass being unmarketable juvenile recruits (Mair, 1997).

TABLE 7.16.1
Existing numbers of GET EXCEL tilapia hatcheries in Philippines

Location by region	Private farms*	h	Total
Luzon			
Region I	5	4	
Region II	23	3	
Region III**	50	9	
Region IV	28	9	
Region V	4	5	
CAR	2	2	
Subtotal for Luzon	**112**	**32**	**114**
Visayas			
Region VI	2	1	
Region VII	2	1	
Region VIII	2	1	
Subtotal for Visayas	**6**	**3**	**9**
Mindanao			
Region IX		1	
Region X		1	
Region XI	2	1	
Region XII		1	
CARAGA	2	1	
NMS	1		
ARMM		1	
Subtotal for Mindanao	**5**	**6**	**11**
Grand Total	**123**	**41**	**164**

* Production Capacity: range from 1 million – 5 million fingerlings per hectare per hatchery
** Region III – 59 private hatcheries can produce about 500 million fingerlings per year

Not only are these recruits unsaleable, but they also compete with the stocked fish for food and space resulting in reduced or stunted growth. Thus, it is very difficult to produce large fish (>200g) in ponds using mixed-sex tilapia. Growth is not only suppressed through direct competition for food and space but also through energy expenditure on gamete production. It has been observed that the gonad weight of females in the presence of males is greater than that of females stocked without males (Mair, 1997). Similarly, although the cost of sperm production is relatively less than that of egg production, the same cross-sex interactions produce a greater GSI in males. Other interactions which result in suppressed growth in mixed-sex populations of tilapia include:

- territorial behaviour;
- nest building;
- courtship and spawning and
- mating and incubation.

There have been a number of proposed solutions to early sexual maturation. These include:

1. Manual removal of recruits or stocked fish – this is impractical due to continuous and asynchronous breeding and time constraints.
2. Use of predators (piscivorous fish) – this is variable in success though it is difficult to prescribe a standard predator stocking rate and it doesn't prevent losses of energy wasted in reproduction.
3. Environmental management – *O. niloticus* will not spawn at high salinities (>10 ppt) or low temperatures (<22 °C). This method is not practical as most of

these parameters are not controllable and they also accompany a reduction in growth.

4. High density stocking – this can only be achieved in intensive systems or cages with supplemental feeding.
5. Cage culture – if the mesh of the cage is >2.5 cm spawned eggs will not be lost but the cage needs to be free of fouling organisms and it doesn't prevent losses of energy spent on reproduction.
6. Sterilization (via triploidy or hormonal treatment) – through the application of heat, cold or pressure shocks to fertilized eggs, sterile triploid juveniles may be produced. This is difficult on a large-scale due to small individual clutch sizes of tilapia. In addition, there is no evidence to suggest that growth performance of triploid tilapia is superior to that of diploids. Currently in the Philippines, it is estimated that 5 percent of hatchery production consists of hormonally sex-reversed tilapia (Mair *et al*., 1997). By far the largest proportion of fingerlings are either genetically selected for late maturation (e.g. GIFT or GET EXCEL strains) or bred to be genetically male populations.

Culture of monosex male populations

These methods have all been used in an attempt to produce all-male populations.

1. Manual sexing – this is difficult to achieve, >90 percent success and is also very labour intensive.
2. Hybridization – *O. niloticus* x *O. hornorum* and *O. niloticus* x *O. aureus* can produce 95-100 percent male offspring, however, the results can be highly variable depending on the parental strain. This method also risks the problem of introgression of genetic sources of tilapia with implications for the conservation of tilapia genetic stocks.
3. Sex reversal – this is achieved by administering feed containing 25-40 mg/kg^{-1} of 17 α-methyltestosterone to sexually undifferentiated fry for 25 days. This should result in >90 percent male, averaging >95 percent although 100 percent is seldom achieved. This technique is widely accepted in a number of countries but is facing problems related to environmental and health concerns of workers and consumers. There are also difficulties encountered in the mass production of sexually undifferentiated tilapia fry due to their small clutch sizes and continual breeding and the effectiveness of the hormonal treatment.
4. Genetic manipulation of sex-male *O. niloticus* are heterogametic and the female is homogametic. Those individuals processing a Y-chromosome will become males (XY) and those without will become females (XX). FAC/CLSU developed an all-male tilapia using YY male technology. The main objective of the Phil-Fishgen project is the development of YY male genotypes to be used as breeders for the production of all-male progeny. The production of YY males is achieved by manipulating the sex chromosomes through a series of feminization and progeny testing procedures. The basis of the technique is the crossing of YY genotype males with normal XX genotype females to yield all-male XY genotype progeny.

Mass production of all-male tilapia fingerlings

At FAC/CLSU, this process is carried out in a series of steps (Abucay, 1997):

Step 1. Isolation and identification of sex-reversed males (ΔF-XY)

- Feminization of progeny through the crossing of normal males (XY) with females (XX) using estrogen.
- A proportion of the broodfish is used as a control and then both groups are sexed following sexual maturity to check the success of feminization.

- Sex reversed males (ΔF-XY) are then identified by progeny testing (i.e. analysis of sex ratio of the progeny of these breeders once crossed with another known genotype).
- A number of hormone-treated female tilapia are crossed with positively identified masculinized genetic females (ΔM-XX).
- If the progeny from this cross is close to 100 percent female, then the tilapia broodstock is a normal XX female.
- If the progeny from this cross produces a 1M:1F sex ratio, then the tilapia broodstock used is a sex-reversed male (ΔF-XY).

Step 2. Isolation and identification of YY males

- Previously identified ΔF-XY are crossed with normal XY males with an expected 3M:1F sex ratio in the progeny (one third of the males should possess a YY genotype).
- To isolate YY males from normal XY males, a number of undifferentiated males are crossed to normal females (XX).
- If the progeny from this cross is close to 1M:1F, then the male parent will possess an XY genotype.
- If the progeny from this cross is close to 100 percent male, then the male parent will posses a YY genotype.

Step 3. Isolation and identification of YY females

- YY males are crossed with sex-reversed females (ΔF-XY) resulting in 100 percent all male progeny (50 percent YY + 50 percent XY males).
- The progeny are then feminized using estrogen to produce ΔF-YY and ΔF-XY.
- These feminized males are then crossed with already identified masculinized females (ΔM-XX)
- If the progeny from this cross has 1M:1F sex ratio, the tested broodstock will be a sex-reversed XY female.
- If the progeny from this cross is nearly 100 percent male, then the tested broodstock will be a sex-reversed YY female.

Step 4. Large-scale production of YY Males

- Once YY males and YY females have been identified, large scale production of YY males can commence.
- YY males x YY female produce YY male progeny.
- All these fingerlings can be used as YY male broodstock to be used in crosses with normal females to mass-produce nearly 100 percent male progeny. The product of this technique is known as genetically male tilapia (GMT).
- YY males can be perpetuated by occasionally feminizing some YY progeny to produce the next generation of YY males.

Mass production of all-female tilapia

FAC/CLSU use a similar but easier process for the mass-production of all-female progeny for use in hatcheries. There is a greater need for such broodstock as there is generally a three-fold demand for females over males in hatcheries due to skewed stocking ratio. These include:

1. masculinization of undifferentiated fry;
2. identification of (ΔM-XX) sex-reversed females by progeny testing, i.e. those broodstock producing all females;
3. crossing sex-reversed female (ΔM-XX) with normal females to produce all-female progeny; and
4. masculinization of progeny to produce (ΔM-XX) which can be used as male breeders with normal females for the mass production of all-female progeny.

FAC/CLSU has introduced the GMT technology to stop the reliance on hormone treatment for sex-reversal. In reality, although there is a high degree of success, there isn't always 100 percent males due to the effects of autosomal genes or the environment in sex determination (Abucay *et al*. 1999). It is hoped that further selection of YY male broodstock will produce GMT with >99 percent male progeny.

Saline tolerance project

In an attempt to increase the geographic range available for tilapia culture, BFAR/NFFTC in collaboration with other institutions and farms have been investigating the salinity tolerance of various tilapia species. *Oreochromis spilurus* from Kuwait, along with *O. mossambicus*, *O. aureus* and *O. niloticus* are currently being tested for growth and survival in brackishwater ponds both with and without fertilization.

From observations, it seems that although some tilapia species are capable of surviving in seawater, growth is minimal and reproduction is not possible. Tilapia reared in brackishwater ponds (≈12 ppt) receiving fertilization grew at a better rate although less than in freshwater. Watanabe *et al.* (1997) reports that Florida red tilapia are capable of reproducing in seawater (≈36 ppt) although optimal success and survival is achieved at iso-osmotic point (12 pt) and declines at salinities >18 ppt. While slower growing in seawater than the Florida red Tilapia, *O. spilurus* is more cold-tolerant and better suited for culture under arid or sub-tropical conditions (<25 °C). *Oreochromis mossambicus* is highly salt-tolerant but grows slower than Florida red tilapia in seawater and *O. aureus, O. niloticus* and *Tilapia zillii* can be acclimatized to high salinities but grow poorly.

BUREAU OF FISHERIES AND AQUATIC RESOURCES-NATIONAL FRESHWATER FISHERIES TECHNOLOGY CENTER (BFAR-NFFTC)

This center is a 35-ha facility located at CLSU in the Science City of Munoz, Nueva Ecija whose vision is to be a dynamic aquaculture hatchery center that serves the needs of the freshwater fisheries sector of the country and in Asia. The center serves as the National Broodstock Center (NBC) of Genetically Enhanced Tilapia (GET) fingerlings/breeders and freshwater prawn production center.

Developmental researches currently undertaken at the Center includes:

Development of genetically enhanced tilapia (GET)

The overall objective of this project is to develop genetically enhanced tilapia for aquaculture. Specific objectives are: a) to assess the performance (i.e., growth, survival) of new breed developed and b) to continue genetic improvement of tilapia for dissemination to fishfarmers.

Research findings/outcomes include: (i) evaluation of growth performance of four tilapia species in normal environment. Result from this testing indicated that improved breed of *O. niloticus* IDRC strain was the best breed for culture in normal environment, (ii) establishment of the base (synthetic) population. Seven cross combination were selected to be the base population to sustain continuous improvement in terms of growth and survival in normal conditions.

Development of cold tolerant tilapia

The overall objective of this project is to develop cold-tolerant breed of tilapia for aquaculture. Specific objectives are: a) to assess the performance (i.e., growth, survival) of new breeds of tilapia in low temperature conditions, b) to produce commercial breeds of tilapia that can tolerate cold water conditions and c) disseminate cold-tolerant tilapia to farmers.

Research findings/outcomes include: (1) evaluation of growth performance of four tilapia species in cold environment. Result from this testing indicated that (a) pure cross of *O. aureus* which is known to be cold tolerant was not the best strain for culture in cold environment. Crossbred of this species performed better than its pure cross; (b) improved breed of *O. niloticus* IDRC strain was the best breed for culture in cold environment and (2) establishment of the base (synthetic) population. Five crosses out of eight cross combination were selected as base population to sustain continuous improvement in terms of growth and survival in cold environments.

Development of saline tolerant tilapia - brackishwater enhanced selected tilapia (BEST)

This project is a collaborative research between BFAR/NFFTC and FAC/CLSU with funding from the Bureau of Agricultural Research (BAR).

The overall objective of the project is to develop saline tolerant breed of tilapia for aquaculture. The specific objectives are: a) to assess the performance (i.e., growth, survival) of new breeds of tilapia in saline conditions, b) to produce commercial breeds of tilapia that can tolerate saline conditions and c) to disseminate saline tolerant tilapia to farmers.

Research outcomes/findings include: (1) documentation and isolation of the different species of tilapia for more detailed evaluation of their culture performance; (2) evaluation of growth performance of four tilapia species in different test environments which indicated that: (a) pure cross of *O. mossambicus* which is known to be saline tolerant was not the best strain for culture in brackishwater environment, (b) crossbred of this species performed better than its pure cross and (c) little change on ranking of the species/strains across a range of test environments; (3) estimation of the magnitude of heterosis when species are crossed. The results indicated low heterosis effects for growth rate across environments although two crosses namely *O. spilurus* x *O. aureus* and *O. mossambicus* x *O. niloticus* (IDRC) gave a positive percentage heterosis of 21.97 and 24.88, respectively.

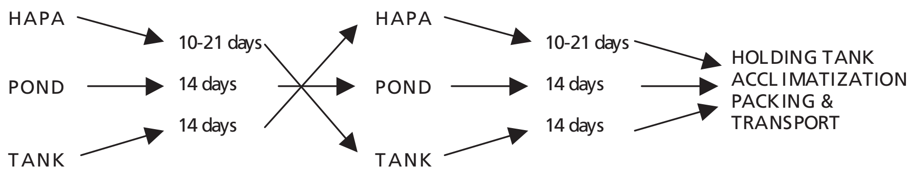
GENETICALLY IMPROVED FARMED TILAPIA FOUNDATION, INC. (GIFT FI)

Following the termination of funding for the GIFT Project in 1997, the institutional partners decided to establish a private non-profit foundation, the GIFT Foundation International, Inc. (GIFT FI), located in the Center of Applied Fish Breeding and Genetics Research, CLSU campus, Science City of Muñoz (Eknath and Acosta, 1998). The foundation occupies about 8 ha consisting of multi-purpose building, staff house, fish pond system, holding tanks and hatchery incubation facilities. Currently, GIFT FI distributes fingerlings throughout the Philippines using a network of seven private satellite hatcheries as well as direct sales through the GIFT FI center. This revenue allows ongoing selective breeding and research on the GIFT strain. (Rodriguez, 2003).

At GIFT FI, tilapia broodstock are conditioned in net pens or hapas or approximately 1 x 2 x 1.5 m constructed with nylon knotless mesh called B-net (i.e., 17 mesh units/6 inches) for 7-10 days. The broodstock are then transferred into either 200 m^2 breeding ponds at a density of 200-500 g/m^2 (3F:1M) or 2 x 5 x 1 m breeding hapas at at ratio of 2F:1M. The average body weight is usually between 100-200 g and the average fecundity is 200-300 eggs/100 g fish with approximately 80 percent hatchability to larvae. Some tilapia hatcheries use concrete tanks. However, maintenance of optimum water quality parameters and high water exchange makes this a less popular method. Stocking densities range from 7-14 breeders/m^2 at the ratio of 3F:1M with a depth of 50-70 cm in these systems.

Fry collection starts after the 10^{th} day of stocking and continues up to the 21^{st} day post-stocking. Fry are collected manually by the hatchery workers using fine mesh dip nets early in the morning. The remaining fry are concentrated in the drainage basin and harvested as ponds are emptied. Similarly, in the hapa and tank methods, fry

FIGURE 7.16.3
Different hatchery process used in the rearing of tilapia fingerlings



are harvested after about two weeks post-stocking and then transferred into nursery hapas, tanks, ponds for supplemental feeding with a high-protein mash for culture until fingerling size. The different culture methods employed in tilapia hatcheries in the Philippines are shown in Figure 7.16.3.

GIFT FI also treats the fry during the nursery phase with 25 mg 17α–methyltestosterone/kg feed to induce sex-reversal to males. The fry are fed 304 times daily between sunrise and sunset. The average fingerling size distribution is 60 percent (size # 24, 0.11g) and 40 percent (size #22, 0.33g) during the cold months (December, January, February) and the reverse in the summer months.

SOUTHEAST ASIA FISHERIES DEVELOPMENT CENTER-AQUACULTURE DEPARTMENT (SEAFDEC-AQD)

This Center is located in Tigbauan, Iloilo Province with the following development programs on commercially cultured fin fishes, namely:

Milkfish (*Chanos chanos*)

Broodstock management. This project aims to develop an improved broodstock diet and a reliable transport and handling technique for broodstock and eggs. It also seeks to evaluate the reproductive performance of milkfish broodstock that are kept in various holding facilities.

Seed production. This project is aimed at refining and improving the existing hatchery technology for milkfish and determining its economic viability. It also aims to develop criteria for fry quality evaluation.

Tilapia (*Oreochromis niloticus*)

Selective breeding and broodstock management. The tilapias have become the focus of several genetic improvement programs in the Philippines and other countries in Southeast Asia. Most of these are centralized, large-scale and quite expensive. Fishfarmers depend on dispersal centers for improved fingerlings. A viable option for fishfarmers is to engage in small-farm selection as an alternative to large-scale projects and make their fish economically competitive. Thus, this project aims to develop appropriate and cheap selection procedures, develop a desirable red tilapia, and explore the potential of farmer-based participatory research on breed selection.

Asian Catfish (*Clarias macrocephalus*)

Breeding and seed production. The breeding and seed production project for Asian catfish is designed to prevent its permanent loss as fish for food. This species is getting scarce in its natural freshwater environment in the Philippines. Studies are conducted on breeding, hatchery and nursery practices aimed at mass production of catfish fry.

Bighead Carp (*Aristichthys nobilis*)

Broodstock management and genetic improvement. This project aims at developing a sustainable and efficient technique for bighead carp broodstock development using compensatory growth character. It will also investigate the genetic structure of bighead carp population and correlated genetic diversity with sex ratio and number of breeders used for spawning in different carp hatcheries.

NATIONAL INTEGRATED FISHERIES TECHNOLOGY DEVELOPMENT CENTER (NIFTDC)

The BFAR National Integrated Fisheries Technology Development Center is located in Binloc, Dagupan City, Pangasinan which serves as the National Broodstock Center for milkfish (W. Rosario, pers. comm., 2005). It has a regionwide satellite central hatcheries of milkfish in Luzon, Visayas and Mindanao. The activities of the Center include:

- nursing and larval rearing of milkfish;
- egg staging of fertilized eggs;
- collection of day 1 (D1) eggs;
- natural food production, i.e. live/artificial studies being undertaken; and
- culture of other finfish such as grouper, sea bass, perch, siganids.

NATIONAL INLAND FISHERIES TECHNOLOGY CENTER (NIFTC)

This Center, also under the management of BFAR, is located in Tanay, Rizal. It is a breeding facility for carp species such as common carp, Chinese and Indian carps. The Center is capable of producing 5-10 million carp fry/fingerlings annually (Palma, pers. comm., 2006). The activities of the Center include:

- induced breeding of carps using pituitary gland HCG and other hormone injections;
- improvement of technologies on larval rearing;
- use of artificial/ natural diets in nursery management for fry production;
- egg quality studies;
- broodstock improvement and development through selection;
- improvement of hatching percentage of the different carp species; and
- hybridization studies.

FISH SEED MANAGEMENT – SEED PRODUCTION AND HATCHERY OPERATION

Tilapia

Oreochromis niloticus is a prolific breeder capable of undergoing successive breeding cycles spawning every 4-6 weeks. Precocious sexual maturation can occur as early as three months depending on environmental factors and reproduction within a population is asynchronous. Tilapia is a maternal mouth-brooder. The male establishes a territory and builds a round nest in the pond bottom of 30-60 cm diameter (depending on size). Following courtship, the female then collects and incubates the eggs in the buccal cavity for the next 5-7 days. Following hatching, the fry remain in the mouth for the next 4-7 days. At this pond the fry begin to swim freely in schools, but may return to the mouth of the mother if threatened. Females don't generally feed during the incubation period.

The key to good hatchery management is obtaining and maintaining good quality broodstock. Maintaining good quality breeders denotes: preventing the introduction of other tilapia species into the brood ponds to avoid genetic contamination, eliminating fish that have questionable characteristics, avoiding random introduction of breeders from different sources and draining the brood ponds completely and eliminating all stocks during pond conditioning to avoid inbreeding depressions (Guerrerro, 2002).

Better management systems for tilapia broodstock can provide the additional control necessary to achieve large scale production of fry and fingerlings. Some of the recent advances in broodstock management include: (i) conditioning of broodstock before spawning, (ii) removal of eggs for artificial incubation, (iii) regular replacement of broodstock with rested and conditioned fish which improves spawning synchrony to enable them to regain lost weight and hasten their next spawning.

During reproduction, the nutritional requirement of tilapia are generally affected. Tilapia females undergo a non-feeding stage during buccal incubation which last for 10-13 days. Female tilapias need to feed actively after this period to regain body condition lost during incubation and to obtain energy to support further reproductive activity. Broodstock should be fed 2-3 percent body weight daily or to satiety.

Nursing of swimming fry is carried out in nursery hapas or nursery ponds. Nursing in ponds is simpler than in hapas. Hapas require more attention and supervision. Water management is more important in ponds where hapas are located.

Generally, fry are phytoplankton feeders so the best condition and highest growth rates will be in well fertilized systems with good natural production. Stocking densities of 1000/m^2 would require a feeding rate of 35-40 percent of fish biomass per day and feeding frequency of three to four times a day.

Milkfish

Milkfish broodstock are developed in earthen ponds or seacages. Bigger size broodstock may be obtained by growing them in brackishwater ponds at low density. Feeding in ponds may include the use of natural food and commercial diet given twice daily at 2-3 percent of fish body weight. When grown in cages, they are stocked at low density and their diet totally depends on commercial feeds. Feeds with about 28-32 percent crude protein is given *ad libitum* twice daily. Management of ponds includes regular flushing of water and water quality monitoring. In cages, changing of nets must be done regularly to provide the broodstock with good water circulation. Rearing of fry to broodstock size takes three to five years. Potential broodstock are selected among the lot after four to five years. Broodstock may be kept in other cages at lower density or in concrete tanks. The stocking density in tanks is 1 fish per 2 m^3. Strong aeration is provided to prevent oxygen depletion. The broodstock are provided with high protein diet given at 3 percent of fish body weight daily. Vitamins C and E maybe incorporated in the diet. Water management in tanks includes changing 50 percent of water three times a week. The broodstock usually reach sexual maturity in 5-6 years (Dickson, Tayamen and Rosario, 2003).

Catfish

Adult native catfish (*C. macrocephalus*) from the wild are are becoming scarce and hybrids of *C. batrachus* and *C. gariepenus* have dominated the market. The provinces of Cagayan and Aurora and many island provinces in the Visayas and Mindanao are possible sources of native catfish breeders. These provinces are reported presence of wild population of native catifhs (Cagauan and Tayamen,2005)

The breeding of *C. macrocephalus* is done during rainy months when many of the female breeders are likely to be gravid. The most gravid female breeders are selected. Male breeders with weights equal or heavier are paired with the females. Males are placed together in one holding container. The female breeders are injected with human chorionic gonadotropin (HCG) at a dosage of 2 IU/g of fish body weight. The breeders are placed individually in separate containers. Stripping is done after 12 hrs (Dickson, Tayamen and Rosario, 2003).

The male breeder is sacrificed in the preparation of the sperm solution. The belly of the male is cut open lengthwise and reproductive tract is extracted. The organ is washed in saline solution to remove blood. The cleaned reproductive tract is then macerated in another petri dish filled with about 5 ml of clean saline solution. The prepared sperm solution is now prepared for dry method fertilization. The female breeder is dried using tissue paper or hand towel. Eggs are stripped by gentle massage into a dry plate. Immediately, the sperm solution is poured into the eggs. Debris is removed by straining the solution with a piece of mosquito net. The plate is swirled gently to allow mixing of eggs and sperm and evolve fertilization. The eggs are distributed in a hatching trough. A house basin can also serve as incubator. A platform made of mosquito net placed inside the incubator is also used to improve water circulation. A water drip is provided to the incubator. The eggs are expected to hatch after 24 hrs. Feeding starts when yolk sac is about to be absorbed. Mashed hard-boiled egg yolk is used as initial food. *Artemia* and *Moina sp.* can also be used as live food. Steamed mussel and oyster meat are cheaper food given until harvest of fry (Dickson, Tayamen and Rosario, 2003).

Catfish fry are grown to fingerlings (3 cm) size in concrete tanks. They are stocked at a density of 500 to 1000/m^2. Initially, aquatic weed like water hyacinth or water lettuce are provided in one-fourth of the surface area to provide the fry with something to cling on. Ground trash fish and commercial feeds are given two to three times daily. The fry are graded every week or when "shooters" are observed. The fingerlings are harvested as soon as the desired size is attained.

There is lack of information on the present production of native catfish (*C. macrocephalus*) mainly because of the unavailability of fish seed in either government or private hatcheries. Many farmers prefer the exotic *C. gariepinus*, which grows faster than the *C. macrocephalus* (Dickson, Tayamen and Rosarion, 2005).

Carp

Common carp are stocked in ponds which are grown with plankton. Growing of plankton can be intensified by fertilization or feeding with formulated farm-made feeds (A. Palma, pers. comm., 2006).

Selection of healthy and matured broodstock are used for breeding with 3 males and 1 female sex ratio. Segregation or separation of sexes may be done before breeding to avoid prolonged extended reproductive foreplay which may result to weakening or death of female. The breeders can be held separately in concrete tanks or hapas (Bersamin, pers. comm., 2006). Natural breeding is practiced for common carp using egg collectors like aquatic weeds, arenga fibers, as breeding mats.

Hatching period of common carp ranged from 46-144 hrs or equivalent to 2-6 days.

Concrete tanks, plastic basins, fibreglass etc. can be used for culturing the fry to fingerlings. These however, should be equipped with aerators to supply oxygen.

Regular sampling is done to evaluate their growth. This includes careful examination of parasites and diseases to know the general condition of the stock.

In nursery pond condition, fertilization is being practiced. Combined organic and inorganic fertilizers are applied. This is to ensure continuous supply of natural food to the fry. Supplemental feed in the forms of rice bran and fish meal is given at 70:30 ratios. Feeding is given twice daily at 5 percent of their body weight (Recometa, Santiago and Vera Cruz, 1985).

Giant freshwater prawn

The BFAR-NFFTC pioneered the first commercial production of freshwater prawn post-larvae (PL) during the ASEAN- Aquaculture Development Coordination Project (AADCP) in the late 90's. With limited facilities and about 2,000 juvenile breeders of Philippine and Thailand strains, the center has produced more than 3.5 million post larvae and juveniles were dispersed to grow-out techno-demo farmers, pilot communal water areas like SWIPs/SFRs in the different regions of the country. With the on-going expansion of hatchery facilities, development of more breeders and conduct of on the job training courses to BFAR technicians and cooperators/clientele, the production of seed is expected to increase in the coming years (Tayamen, 2003).

Berried freshwater prawn are collected in earthen ponds and stocked in well-aerated concrete tanks or aquarium. Selected individuals with smaller heads are highly preferred for breeding purposes (Tayamen, 2005)

Breeders of *M. rosenbergii* are developed and maintained in earthen ponds. Post-larvae (PL 20) are stocked at a density of 3 PL/m^2. They are fed with any commercial sinking fish diet with CP content of about 7 percent. Feeds are broadcasted along the periphery of the dikes or by use of feeding trays. Excess feeding is avoided by monitoring excess feeds in the morning. Water level is maintained at an average of one meter. The freshwater prawn is expected to attain sexual maturity in four of five months. Large berried breeder prawns are collected and stocked in well-aerated concrete tanks and large un-berried females are separated in another tank (Tayamen, 2005).

The broodstock are kept in a concrete tank at a density of 10-15 breeders/m^2 and at a sex ratio of 1 male:5 females. The water level is maintained at 0.5 to 1.0 m. Sufficient aeration and moderate flowing water are provided. Two thirds of the water is changed twice weekly. During water change, berried breeders with dark brown eggs are selected. Those with similar egg colors are placed together in one tank at a density of one breeder/1 .5 m2. The water level is about 30 to 50 cm. Continuous aeration is provided. Upon hatching, the spent breeders are returned in the broodstock pond or into another tank. Feeding of larvae starts immediately after hatching. *Artemia* is given as initial food at 10 nauplii/ml of water of the rearing tank. In larval rearing, water management requires salinity of 12 ppt from stage 1 to stage 11. Water salinity is decreased by 2 ppt daily from 12 ppt to zero starting first PL appearance until PL 20 is reached and ready for stocking in grow-out ponds. Other natural food such as copepods like *Moina* sp. and formulated feeds are added to *Artemia* from larval stage VIII until becoming PL. Feeding is done twice daily. Excess feeds are siphoned out before feeding. The post larvae are harvested after 20 days (PL 20) or more to ensure high survival (Tayamen, 2005).

Macrobrachium rosenbergii post larvae or juvenile are directly stocked in grow-out ponds. Long holding period in tanks or hapas will result to high cannibalism, thus lowering the survival rate (Tayamen, 2005).

FISH SEED QUALITY

A major constraint to increasing the productivity of farming systems is widely recognized to be the inadequate supply of good quality seed. Emphasis needs to be placed on the importance of the role of local hatchery production, alongside quality certification and accreditation of seed and the development of strategies to further improve seed quality. The development of breeding and hatchery technology, genetic improvement and domestication are additional key objectives for securing the seed supply for major aquaculture species (Sarmiento and Tayamen, 2001).

Fish seed quality is judged by growth rate, survival, uniformity of size at harvest and, for SRT and GMT seed, whether there is any breeding in the production stock from unwanted females. Growth performance and the marketable size product classification of the different strains are also considered in judging the fish seed quality by the producers.

Larval quality assessment of giant freshwater prawn in the Philippines

Larval quality evaluation and condition index using modified Apgar scale is presented in (Tables 7.16.2 and 7.16.3). The use of this Apgar index has provided effectively to monitor state of health of larval production at any stage of larval rearing. (Tayamen and Brown, 1998) This larval quality index can determine the status of the hatchery operation during larval development. This Apgar index enables the technician/ worker in the hatchery to make a quick assessment of the larval stages using a dissecting microscope. Criteria to check and explanatory glossary are used to guide the technician/ worker in scoring the larvae whether they are healthy or not. The giant freshwater prawn hatcheries apply this scoring technique to monitor performance of larval production

Quarantine procedure of freshwater fish species at NFFTC

In aquaculture, the role of disease has been underestimated in terms of economic losses. Presently, it is now generally recognized that disease represents a major threat to successful fish culture. Research findings revealed that many of the fish pathogens that cause sporadic mortalities or regular occurrences of disease were previously unknown to the Southeast Asian countries and were just introduced along with exotic fish species upon importation is implemented by BFAR-NFFTC (Morales, 2000).

Quarantine is the period of isolation imposed to lessen the risk of spreading an infectious or contagious disease. Some procedures to ensure effective treatment of fish species prior to transport is implemented by BFAR-NFFTC (Morales, 2000).

From fishpond to conditioning tank:

Day 1. Fingerlings are harvested on the coolest time of the day either early in the morning or late in the afternoon. Fingerlings are immediately transferred in the conditioning tanks with flow-through water system, possibly with added aeration. After several hrs of conditioning, grading and sorting of fish will be done. Parasitological examination of fingerlings will be done by necropsy procedure.

Day 2. Prophylactic treatment should commence during the coldest time of the day.

1. Conditioned fingerlings should be dipped into a salt solution at a concentration of 5 percent or 50 ppt 9 500 g salt for every 10 l of water) for 3-5 min.
2. Alternative treatment may be used in the quarantine such as methylene blue or potassium permanganate (KPO4). Concentration of 20-40 ppm for 3-5 min may be used. After quarantine treatment, fish should be immediately restored in a freshwater environment with continuous aeration. If fingerlings are rested, feeding of fry mash with 2-3 percent body weight is necessary. Fingerlings will be monitored and examined for parasite load.

Day 3. Fish can be transported early in the morning and Issuance of fish health certificate

1. The following alternatives can be applied for reducing pathogens.
2. Prior to packing for transport to the pond, fingerlings should be dipped into salt solution at a concentration of 5 percent for 3-5 min.
3. Before introducing the fingerlings to the polyethylene bag for transport, place 2 g salt in every l of water (2 ppt) or 0.1 mg of methylene blue or potassium permanganate.
4. Before stocking the fingerlings in the pond, fish should be dipped into salt solution at a concentration of 5 percent for 3-5 min

FISH SEED MARKETING AND SEED INDUSTRY

In the Philippines, the marketing of fry and fingerlings is a lucrative business because there is high demand for seed. For tilapia, the major sources of seed are the hatcheries and nurseries in Nueva Ecija, Bulacan, Pampanga, and Laguna. These areas are also the final market destinations of seed, in addition to Batangas, Isabela, Bataan, and Camarines Sur. Figure 7.16.4 is the flow chart of supply of tilapia fry/fingerlings from NBC to grow-out operators. The NFFTC serves as the National Broodsotck Center that produce two groups of future broodstock for the multipliers that will then produce the fingerlings for grow-out.

To ensure better quality and steady supply of tilapia fingerlings, the BFAR-NFFTC continuously pursue genetic improvement following the selective breeding approach protocol of the GIFT project (Eknath and Acosta, 1998). Figure 7.16.5 shows the institutional arrangement in the dissemination of GET EXCEL Tilapia broodstock

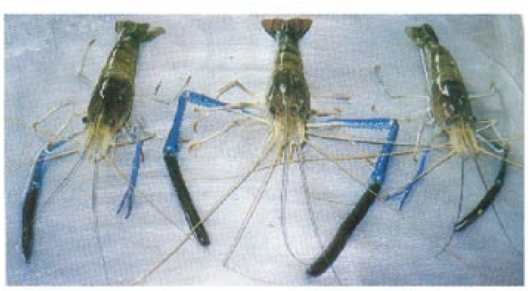
PLATE 7.16.1
Freshwater fish seed production facilities at the National Freshwater Fisheries Technology Center of the Bureau of Fisheries and Aquatic Resources (BFAR-NFFTC)

A view of the BFAR-NFFTC facilities

Dewar tanks for keeping cryopreserved tilapia genes

Battery of hapas for intensive seed production

Tilapia fingerlings loaded in plastic bags for transport



Giant freshwater prawn broodstock

***Macrobrachium rosenbergii* post larvae**

from the NBC to ROS and private hatcheries (certified and registered) who will in turn produce the fingerlings for the grow-out farmers operators. Nationwide dissemination of GET EXCEL tilapia has been presented during the 6th International Symposium of Tilapia in Aquaculture (Tayamen, 2004).

In order to systematize the purchase of fingerlings for grow-out or future broodstock, the NFFTC implements a one stop unit for the clientele/ cooperator to serve once fish seed request is completed. This process facilitates the incoming clientele on a first come first serve basis especially on the scheduling of pick-up and walk-in cooperators. Cooperators are also given free seminar and information on proper fish transport and fish pond management.

PLATE 7.16.1
Freshwater fish seed production facilities at the National Freshwater Fisheries Technology Center of the Bureau of Fisheries and Aquatic Resources (BFAR-NFFTC)

Reference tanks where live collection of different tilapia species are maintained

Artificial incubation sytem of GIFT strain

Stocking of GET EXCEL broodstocks

Moina production tanks at BFAR-NFFTC

The archipelagic nature of the country poses a challenge for the seed market to expand nationwide, unless more hatcheries are established in remote islands and coastal provinces. The market channels for fish seed is still unorganized in the private hatcheries. A hatchery operator usually sells directly to grow out farmers. The seed are usually delivered or pick-up by the costumer. Product delivery facilitates and strengthens seed supplier-farmer relationships. A few hatchery and nursery operators use agents to increase sales, especially in remote areas. Others sell directly and employ agents at the same time. For tilapia. this practice is quite common among nursery

TABLE 7.16.2

Modified Apgar scale for evaluation larval quality of Macrobrachium rosenbergii (Tayamen and Brown, 1998)

No.	Criteria to check	Score			Sample									
		0	1	2	1	2	3	4	5	6	7	8	9	10
1	Gut fullness	Gut empty	Moderately full (30%-60%)	Full gut with faecal strands										
2	Gut lipid content (state of the hepatopancreas)	No lipid vacuoles	Very small vauoles (10%-40%)	Relatively full (60%-90%)										
3	Pigmentation state of chromatophores	No colour/pigments (fully contracted chromatophores)	Moderate chromatophores in one area	Well dispersed chromatophores (pinkish/amber colouration)										
4	Body coloration	Gray/dark/bluish on abdominal segment	Moderate light orange on abdominal segment	Tan/orange/red blend on abdominal segment										
5	Setation	Disfigured/damaged setae on rostrum, pereopods, telson, uropods	Curled/kinked setae on rostrum pereopods, pleopods, telson, uropods	Straight/whole setae on deformities on rostum, pereopods, pleopods, telson, uropods										
6	Muscle to gut ration	Gut appears wide, muscle narrower on VI abdominal segment	Gut appears narrow and slightly wider muscle	Gut appears narrow and muscle appear thick and wider on VI abdominal segment										
7	Muscle appearance of abdomen (appearance of abnormal muscles)	Opaque/grainy	Slightly transparent	Clear/transparent smooth										
8	Melanization (presence of black spots)	Appendages and parts of body affected	Very minor necrosis	No necrosis, absence of protozoans, ciliates, organisms										
9	Fouling organisms	Major parts of body affected	Minor parts of body affected	Body clean/absence of protozoans, ciliates, organisms										
10a	Swimming behaviour (between stage VIII to X)	Sluggish/circular motion, erratic movement	Moderate movement with head upside down	Very active tail first lateral motion/ jump-like towards the side										
10b	Photo positive (between stage 1 to VI)	Negative response	Slow positive response	Fast positive response										
Score ratings 0=poor 1=fair 2=excelent				Total Score										
				Larval Stage										

Number of days ____________ Batch/Tank No. ____________

Date: ____________ Scored by: ____________

TABLE 7.16.3
Explanatory glossary for condition of index (Tayamen and Brown, 1998)

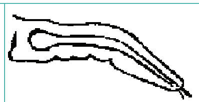
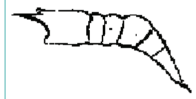
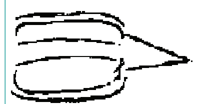
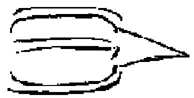
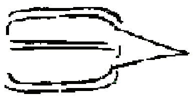
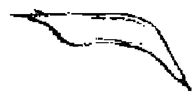
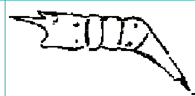
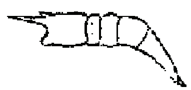
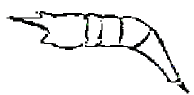
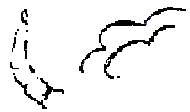
1	GUT FULLNESS	 GUT EMPTY OF FOOD Score 0	 GUT MODERATELY FULL Score 1	 FULL GUT WITH FACIAL STRANIDS Score 2
2	GUT LIPID CONTENT (STATE OF HEPATOPANCREAS)	 LARVAE APPEARS THIN. NO LIPID GLOBULES VISIBLE Score 0	 VERY SMALL GLOBULES VISIBLE IN THE DIGESTIVE GLAND Score 1	 GLOBULES IN THE DIGESTIVE GLAND VISIBLY FULL Score 2
3	PIGMENTATION (STATE OF CHROMATOPHORES	 FULLY CONTRACTED CHROMATIC ASSOCIATED W/ DARK, BLUISH COLOUR Score 0	 MODERATE CHROMATOPHORES IN ONE AREA W/ LIGHT ORANGE Score 1	 WELL DISPERSED CHROMATOPHORES W/ AMBER/ TAN/RED PIGMENTS Score 2
4	BODY COLOURATION	 GREY/DARK/BLUISH APPEARNCE ON ABDOMINAL SEGMENT Score 0	 MODERATE APPEARANCE ON ABDOMINAL SEGMENT Score 1	 TAN/ORANGE/RED/AMBER LIKE APPEARNCE ON ABDOMINAL SEGMENT Score 2
5	SETATION	 ROSTRUM DAMAGED/ DISFIGURED (Check setae also) Score 0	 ROSTRUM CURLED BENT/ KINKED (Check setae also) Score 1	 ROSTRUM STRAIGHT/WHOLE (Check setae also) Score 2
6	MUSCLE TO GUT RATIO	 GUT APPEARS WIDE, MUSCLE THIN IN VI SEGMENT Score 0	 GUT APPEARS THIN, MUSCLE IN VI SEGMENT WIDE Score 1	 GUT APPEARS THIN. MUSCLE IN VI SEGMENT WIDER Score 2
7	MUSCLE APPEARANCE OF ABDOMEN (APPEARANCE ABNORMAL MUSCLES)	 ABDOMINAL MUSCLE OPAQUE/ GRAINY Score 0	 ABDOMINAL MUSCLE SLIGHTLY CLEAR Score 1	 ABDOMINAL MUSCLE CLEAR/ TRANSPARENT, SMOOT Score 2
8	MELANIZATION (PRESENCE OF BLACK SPOTS)	 BLACK SPOTS SEEN ON APPENDAGES AND/OR BODY Score 0	 MINOR BLACK SPOTS ON APPENDAGES/BODY Score 1	 NO BLACK SPOTS (MELANIZATION) Score 2
10a	SWIMMING BEHAVIOUR (BETWEEN STAGE VIII TO X)	 SLUGGISH MOTION Score 0	 MODERATE MOVEMENT SCORE Score 1	 FAST JUMP LIKE MOTION Score 2

FIGURE 7.16.4
Flow chart of fish seed distribution in the Philippines

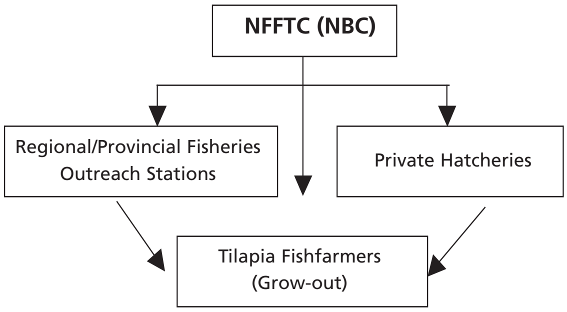
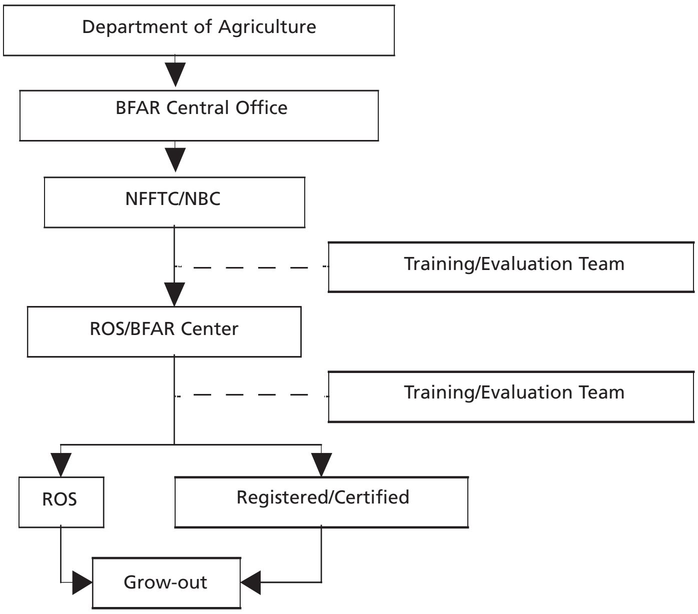


FIGURE 7.16.5
Institutional arrangement in dissemination of GET EXCEL tilapia in the Philippines (2005)

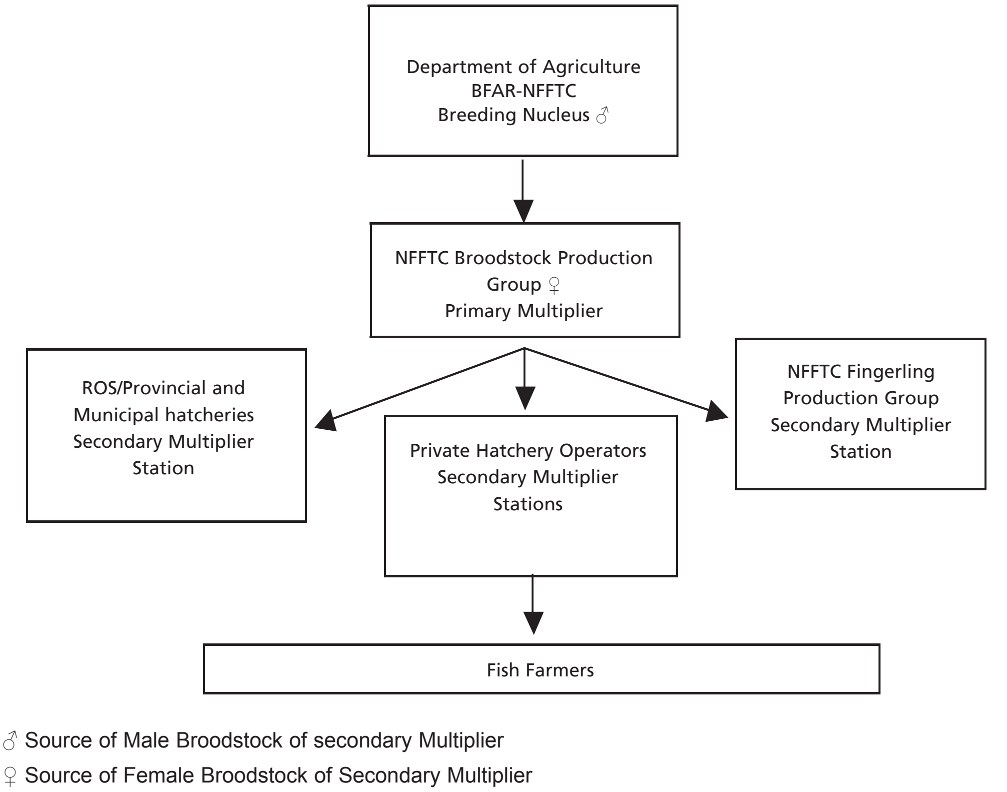


operators in Batangas, who resort to intermediaries to buy fry from Laguna, which they nurse to fingerlings for sale to cage grow-out farmers in Lake Taal.

Fish seed agents obtain their incomes by a mark-up of P0.01–P0.02 per fingerling or through pre-agreed commissions. Large-scale seed suppliers make use of market promotions such as printed materials, brochures and leaflets, signboards, and sometimes Internet websites for the promotion and advertisements for their product.

Delivery is sometimes priced higher than pick-up, but in Central Luzon prices for delivery and pick-up sales are similar because suppliers usually pay for delivery costs. Most seed suppliers monitor their performance by ensuring that their clients' farms and husbandry are suitable. This lessens the risk of claims for mortality replacements. Moreover, after-sales support is a good marketing strategy to enhance or maintain hatchery-farmer relationships and hatchery reputations. This is a common practice among medium- to large-scale hatcheries in Central Luzon. For example, Central Luzon hatcheries use agents for seed sales to more distant areas in Luzon (e.g., Isabela and Zambales) that have good potential for tilapia farming because of increasing demand and suitability of the areas for tilapia production.

FIGURE 7.16.6
Organizational scheme in the acquisition of broodstock



SEED INDUSTRY – TILAPIA GERMPLASM

The world's richest repository of valuable genes of tilapia can be found only at Department of Agriculture-Bureau of Fisheries and Aquatic Resources, National Freshwater Fisheries Technology Center, Central Luzon State University Compound, Science City of Muñoz, Nueva Ecija Philippines. The ex-situ tilapia germplasm collection comprised of various live and cryopreserved spermatozoa Nile Tilapia (*Orechromis niloticus*).

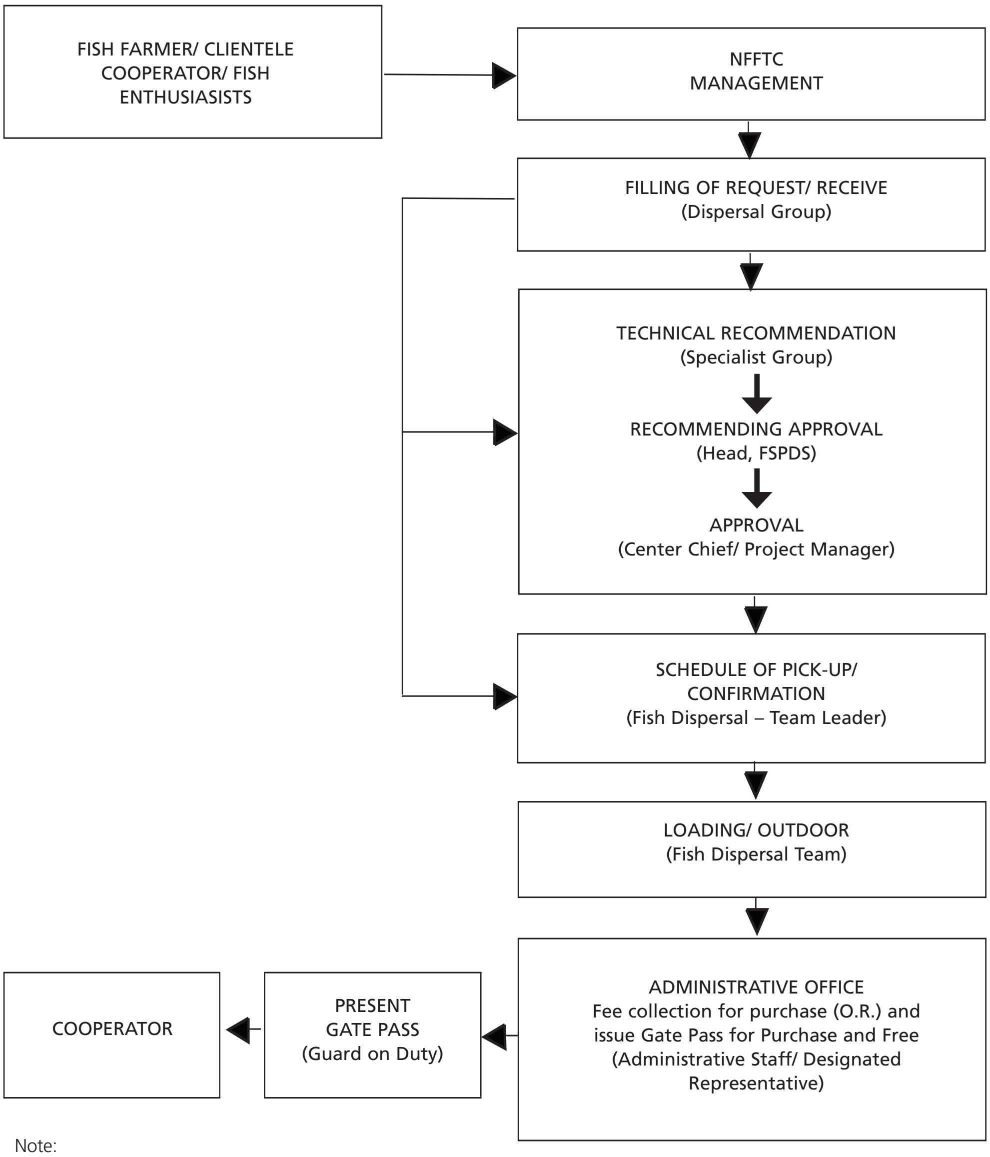
The collection of Nile Tilapia Germplasm includes the four African wild strains imported during 1988, 1989 and 1992 from Egypt, Ghana, Kenya and Senegal and four Asian farmed strains popularly known in the Philippines as Israel, Singapore, Taiwan and Thailand. The cryopreserved spermatozoa encompass collections made during the GIFT Project from 1987 to 1997, the gene collection developed by BFAR-NFFTC as the new genetically enhanced tilapia (GET) after the completion of the GIFT Project in 1997 and other collections from selected stocks: base population, 1st, 2nd, 3rd, 4th, and 5th of GIFT strain and 13th generation of FaST (FAC Selected Tilapia)

The Philippine Tilapia Germplasm Bank provides a continuing long term storage of spermatozoa from tilapia stocks used in GIFT'S major breeding experiment and the presently developed Genetically Enhanced Tilapia strains at the BFAR-NFFTC.

In Seed industry, most of the seed producers in the Philippines are small-scale, only few are into large scale hatcheries due to the lack of capital for the construction of important facilities needed in the production of freshwater fish seed. Small scale hatcheries and nurseries are usually located near the operator's homestead for close monitoring and the use of family labor. Broodstock are usually obtained from government or private hatcheries, although some small and medium-scale operators keep their own broodstock.

For tilapia, more advanced commercial operators or the Large scale hatcheries achieve continuous and higher seed production by collecting eggs from female

FIGURE 7.16.6
Flowchart on the purchase of fingerlings at BFAR-NFFTC Philippines



Note:
1. Fish Seed Request Order (In duplicate) is made by means of the following: office visit, letter/ correspondence, telephone call, fax and email
2. Walk-in cooperator who did not file request shall likewise fill up the fish seed request order form and is invited to participate in the Center's scheduled Wednesday Seminar or on one on one discussion or group basis during the week.
3. Original Request Form and gate pass will be returned at the Administrative Section for filling purposes

broodstock and rearing them in artificial incubators before the fry start to feed. Tilapia seed production is year-round but has seasonal variations. The peak season for tilapia seed are during the summer months (March, April, May).

In the typhoon belt, supply and demand for seed in the Philippines is low when there is high risk from typhoons. The productivity of the different sizes and types of hatchery and nursery operations is very variable and there are few reliable comparative data.

FISH SEED SUPPORT SERVICES

The aquaculture extension programme is presently implemented by BFAR through its 15 regional offices, and the local government of the province and municipal offices. Extension function is devolved to the local government units as mandated by Local Government Code (LGC) of 1991.

Some private enterprises in aquaculture provide assistance to private farmers in the design, construction, and operation of their farms. Philippine feed companies like San Miguel Corporation (SMC), Feed Mix, C.J., Vitarich, Selecta, Purina Corp. and other popular feed brands have technicians who conduct site evaluation, assist in pond design and layout and give technical assistance during the operation. This free assistance is intended to ensure good yields for the grow-out/ hatchery operators. At the same time, the participating farmers are benefited by the free transfer of technology provided by these feed companies.

A number of regional organizations provide opportunities in specialized aquaculture practices. The SEAFDEC Aquaculture department (SEAFDEC-AQD) at Tigbauan, Ilo-ilo trains national and international extension agents in various production methods and techniques, such as freshwater fish farming. SEAFDEC-AQD also offers trainers training courses for extension workers.

Other services available to the industry in the country includes laboratories which perform water and soil analysis, feed proximate analysis, and disease diagnosis. Most of these facilities are government-owned are linked with research and academic institutions. However, Private fish farmers have also covered this area due to the lack of government-provided facilities.

Local architect and design engineering firms serve the industry. The Society of Aquaculture Engineers of the Philippines (SAEP) and Philippine Aquaculture Society (PAS) are tapped and render technical services to beginner and new entrepreneur. The two societies play a very active role in the development of aquaculture industry. Their involvement range from the conduct of simple topographic and hydrographic surveys, facility and engineering design, and construction supervision. Engineering contractors who undertake construction work are usually available in the locality of the project. Local labour for construction and operation of projects is abundant in the region at a low cost.

Information, education and communication materials like technical journals, newsletter, trade magazines and papers, and manuals – are available to producers in the country. These include publications produced within the country itself and those published by American and European publishers.

Among the publications useful to producers are newsletters regularly published by SEAFDEC, by the International Center for Living Aquatic Resources Management (ICLARM) now World Fish Center (WFC), and by Network of Aquaculture Centres in Asia-Pacific (NACA).

There are also numbers of published information which is useful to aquaculture producers. A special publication entitled “Aquaculture Buyers’ Guide” is available in the local market. It is actually a directory of suppliers of goods and services to the aquaculture industry. There are also newspapers and magazines which feature articles on agriculture including the fisheries, and on aquaculture.

Many national technical and semi-technical manuals for the practising aquaculturist are circulated within the country. Manuals published by the Philippine Council for Agricultural Resources Research and Development (PCARRD) and Philippine Council for Aquatic and Marine Research and Development (PCAMRD), such as the “Philippines recommends” series, include works on farming tilapia, milkfish, and mussels. The Council has also published a series called “Technoguides” which are extension manuals dealing with specific commodities, and are written in local dialects. (www.fao.org/docrep/S9805E/s9805e05.htm)

SEED CERTIFICATION

At present BFAR has a seed certification and registration system for tilapia seed to ensure that good quality seed of tilapia will be disseminated to grow-out operators.

BFAR distributes its GET EXCEL Tilapia strain seed and broodstock to BFAR multiplier stations and to private hatcheries that are encouraged to breed their own fish and to feedback information and superior breeding material. Genomar Supreme Philippines, formerly with GIFT FI, on the other hand, distributes Genomar Supreme Tilapia (GST) strain as their brand name. GMT strains are distributed by Phil FishGen, an outcome of the YY technology project.

Most Nile tilapia farmed in the Philippines now have genes that originated from the genetically improved farmed tilapia (GIFT), either as GIFT strains or as hybrids developed with some GIFT material. The GIFT FI maintains the GIFT strain as their marketing brand. There is no standard strain nomenclature and no independent strain certification. The result is a confusing mixture of marketing claims. Small-scale farmers, however, are risk averse and hesitate to try new strains based solely on suppliers' claims about performance (www.worldfishcenter.org/demandsupply/inception_reporttaug02/ir_aug02_appendix2.asp).

In order to ensure the supply of high quality tilapia fingerlings for grow-out operations, the following guidelines/criteria in the selection of fingerling are followed by BFAR registered/certified private hatcheries.

The hatchery site should be accessible by any kind of land transportation especially during rainy season for ease of monitoring and pick-up of fingerlings.

The project site should have clean and sufficient water supply throughout the year (with back-up deep well pump).

The following conditions/facilities should be available in the farm:

1. nursery ponds
2. breeding ponds/hapas/tanks
3. conditioning tanks
4. water supply system
5. hatchery materials: seine nets, scoop nets, oxygen tanks, fish grader, weighing scale, etc.
6. incubation system (for tanks and hapa-based hatcheries)
7. good peace and order situation in the site
8. farm should be free from flood
9. no other species should be introduced/stock in the hatchery area
10. willingness to attend trainings and accept new technologies
11. willingness to sign Memorandum of Agreement (MOA) and put sign board
12. willingness to use the farm for research studies/test station of BFAR-NFFTC
13. at least 1 year experience in tilapia culture or equivalent experience/training
14. willingness to receive BFAR visitors

Tilapia broodstock for fingerling production used for grow-out farming are usually kept for 1.5 years by private hatcheries and government-owned hatcheries. Replacement of broodstock are carried out by the center's Fish Seed Production and Dispersal Section who monitors each hatchery, private or government (Tayamen, 2004). A record of hatchery operators are kept in a data bank as to when they have acquired the broodstock. Notice are sent to private/government owned hatcheries on their life term. Certificate of registration of GET EXCEL multipliers is renewed every year.

The quality of fingerlings are also checked by means of techno-demo of a prospective grow-out cooperator. The grow-out farmer also executes a memorandum of understanding with our center. Techn-demo projects are promoted nationwide by every Regional Field Office (Sarmiento and Tayamen 2001).

LEGAL AND POLICY FRAMEWORKS

Philippine Fisheries Code Republic Act 8550

The new fisheries code of 1998 known as Republic Act (RA) No. 8550 serves as the national fishery management policy which provides the overall guidance to national and local government units in the disposition of fishery resources based on scientific research and practical information of the country's resources. The Administrative Order No. 3, series of 1998 dated May 8, 1998, of DA, prescribed the implementing rules and regulations pursuant to RA No. 8550: "An act providing for the development, management and conservation of the fisheries and aquatic resources, integrating all laws pertinent thereto, and for other purposes."

ARTICLE III. Sec. 57 Registration of Fish Hatcheries and Private Fishponds, states that:

> "... All fish hatcheries, fish breeding facilities and private fishponds must be registered with the LGU's which shall prescribe minimum standards for such facilities in consultation with the Department: *Provided*. That the Department shall conduct a yearly inventory of all fishponds, fish pens and fish cages whether in public or private lands; *Provided, further*, That all fishponds, fish pen and fish cage operators shall annually report to the Department the type of species and volume of production in areas devoted to aquaculture".

Various laws that affect freshwater aquaculture and can benefit small-scale farmers have been enacted in the Philippines. If properly implemented, appropriate legal provisions may enable these farmers to overcome binding constraints confronting them. Inadequate funding and institutional capacities have restricted their effective implementation. The Local Government Code of 1991 (RA 7160) devolved many of the functions of the central government offices to local government units, including extension services, regulation and licensing and law enforcement in municipal waters. Increased capacity-building efforts at the local level are required if local governments are to fulfil their new mandates. The Agriculture and Fisheries Modernization Act of 1997 (RA 8435) provides a blueprint for modernizing the agriculture sector in the context of global competitiveness and is concerned with the allocation of appropriate budgetary and technical resources, but actual funding has generally fallen short of planned levels. The Fisheries Code of 1998 (RA 8550) aims to ensure sustainable resource management, food security, and development, including the reconstitution of BFAR as a line bureau for improved service delivery. It also recognizes the active participation of local fishers and coastal communities in policy formulation, planning, and program implementation. However, the overall management of fisheries and aquatic resources has been partly dependent on the priority accorded by local government units to this sector and on the presence of strong fisheries and aquatic resource management councils (FARMCs). Improving resource management capacity and consensus building are required for addressing the needs of stakeholders, together with monitoring impacts on poor and small-scale farmers. In some areas, fishers have organized themselves to create FARMCs and have been able to influence policymaking and benefit from aquaculture operations (www.worldfishcenter.org/demendsupply/inception_reporttaug02/ir_aug02_appendix2.asp).

ECONOMICS

Fish is an important component of the Filipino diet and a valuable source of animal protein and other nutrients. Seed prices depend on supply and demand conditions. When seed production is high or demand is low, prices are lower and mortality allowances are higher. This occurs mainly in private hatcheries attempting to dispose of their produce quickly because of space constraints and maintenance costs. Freshwater fish seed from government hatcheries have remained relatively stable. The Philippines Commission on Audit (COA) reviews proposed price increases, suggesting that any price change is based on cost recovery or production cost. Price of fish are also presented through consultative meetings with the FARMC.

TABLE 7.16.4

Size grading and standard price/piece for non-sex reversed tilapia in Philippines

Size	Average body weight (g)	Lenght (mm)	Price (PhP)
#24	0.1129	14.20	0.15
#22	0.3250	25.00	0.25
#17	0.7850	38.12	0.35
#14	0.1895	48.57	0.45
Broodstock (any size)			1.00

For tilapia, fish seed prices vary according to size, strain and whether they are mixed-sex (males and females) or sex-reversed tilapia (SRT) comprising 95–100 percent males. BFAR applies mandated prices for its accredited/certified hatcheries; private hatcheries not registered by BFAR have their own set of prices. The case studies of Central Luzon and Lake Taal suggest that the market share of SRT seed is significant, i.e. 45 percent of cage farmers and 62 percent of pond farmers interviewed have been using SRT. The BFAR GET EXCEL strain and F4/GST are the most popular strains. Aside from their performance, the popularity of these strains is attributed to the proximity of the suppliers of these strains to farms, the number of accredited suppliers of these strains and the aggressive marketing and technical assistance provided by their respective accredited hatcheries. BFAR issued Fisheries Administration Order (FAO) 205 Series of 2000 to standardize the price of fingerlings for tilapia and carp according to size and weight as presented in Table 7.16.4.

Prices of GIFT FI SRT seed are higher due to added costs arising from the sex-reversal treatment. The price of SRT size #22 range from Php 0.40 – Php 0.50 per piece. For the GMT-YY fingerlings the cost range from Php 0.20 to Php 0.60 per fingerling depending on the size (Abella, personal communication). Some private hatcheries impose additional mark-up to cover the costs of delivery or transport, particularly for distant clients. Market competition for small-scale operators in the long run because they receive competitive prices and technical services. However, small-scale farmers put a premium on the growth characteristics of strains.

For carp and catfish, there are several factors that determine the price of the seed. The price of seed will depend on the seasonality and availability. Carp seed ranges from 1-2 pesos each, while catfish price ranges from 2-3 pesos each. High price of catfish is relatively due to the difficulty of management for the catfish fry. Catfish fry are marketed when they reach the length of 1-2 cm.

In marketable tilapia, fish supply is all produced domestically in the Philippines for about 79 percent from aquaculture and 21 percent from inland fisheries. Tilapia prices are generally lower if there is an abundant supply compared to bangus, more affordable to poor consumers. Consumer's demand for fish as substitute product will adjust depending on the prices of meat, poultry products and other fish like bangus, carp, catfish and other fin fishes.

STAKEHOLDERS

There are various stakeholders involved in freshwater fish seed production in the Philippines. These are:

Producers/farmers

The Philippines has a total of 164 BFAR certified freshwater hatcheries and estimated 2000 nurseries, small-, backyard-, medium- and large-scale operators that are not GET EXCEL registered. The GIFT FI has 8 accredited hatcheries, Phil FishGen has about 40 accredited hatcheries and Genomar Philippines has two accredited hatcheries.

Research institute and national broodstock centers

BFAR and SEAFDEC are two of the major research institutions in the Philippines. There are 13 broodstock centers for tilapia in the Philippines and the main tilapia broodstock center is BFAR-NFFTC.

Government institutions

The DA through BFAR is responsible for providing legal and policy framework and fishery laws concerning the freshwater fish seed industry.

Education and training institutions

There are several fisheries school in the Philippines. The University of the Philippines Visayas (UPV), Central Luzon State University (CLSU), University of the Philippines Marine Science Institute (UPMSI) and Don Mariano Marcos Memorial State University (DMMSU) are among the top schools for fisheries.

CONCLUSIONS/ RECOMMENDATIONS

Unbalanced and seasonal supply of fry and fingerlings

Shortage of fry and fingerlings has always been the problem of the tilapia industry before. Since the development of different improved strains of tilapia with corresponding accreditation/registration of hatcheries by respective institutions, supply of fry and fingerlings in some places is not a problem anymore. In far flung areas, however, availability of seed is still a problem while in Central Luzon, seasonal supply of seed is observed. During summer, there is a oversupply of fingerlings from hatcheries. During rainy season and cold months, production decreases such that shortage of fry/ fingerlings is a problem during this season. The creation or establishment of a central marketing center for seed of commercial fish species should be conceptualised into a feasibility proposal to ensure year-round availability of quality fish seed stocks for the producer.

High cost of operating expenses

Operating expenses especially farm inputs are continuously increasing every year while the cost of the product output is stagnant and sometimes decreasing depending on the supply and demand situation. Feeds are the most expensive operating expenses in tilapia culture, followed by crude oil.

Stagnant and unstable price of tilapia

The information presented in Table 7.16.5 showed that there is an average decline in wholesale price by PhP 1.61 in 2000-2002. The retail price is unstable; in 2000-2001, there was increase in price by PhP 0.59; in 2001-2002, there was a decline in price by PhP 1.46 and again in 2002-2003, there was an increase of PhP 0.87. This clearly showed that the price of the product is declining or slightly increasing while the production cost is continuously increasing.

With regards to fingerlings, the cost is negligible compared to the cost of feeds. In fact the price of tilapia fry and fingerlings remains the same since 2000 which had been followed by BFAR's registered tilapia hatcheries for almost six years now. With the proliferation of many hatcheries, during the season of peak production, the price is going down as low as PhP 0.10 for normal or mixed-sex as a result of competition in marketing among tilapia hatcheries.

Outbreak of diseases and occurence of fish kills

Because of the intention of fish farmers to attain the highest possible yield, they tend to shift from extensive to semi-intensive and semi-intensive to intensive culture system. This is done by stocking more fish/unit area without considering the carrying capacity of the pond. More stocks will mean more inputs needed particularly feeds. Later on problems with space, competition for food and eventually, water pollution follows resulting to outbreak of diseases and occurrence of fish kills. This is now a rampant problem in tilapia hatcheries and growers who have no sufficient knowledge in water quality management.

Environmental degradation

Environment degradation is now one of the main causes of declined production. This is very much related to water quality because water is the basic environment of fish. Environmental viability is dependent on maintaining water quality at or above minimum standards for producing fish within the pond environment and for discharging pond water into the external environment. Damaged environment and poor water quality is brought about by over utilization of the area, excessive feeding, overstocking beyond the carrying capacity, use of chemicals that are not necessary and over-intensification. Awareness of proper environmental management is very important to have sustainable aquaculture and in order to maintain good income for the tilapia operators.

Government policy on the application of Best Management Practices (BMPs) and implementation of Hazard Analysis Critical and Control Point (HACCP)

The government should have a strict policy on the application of practices of Best Management Practices (BMP) and implementation of Hazard Analysis and Critical Control Point (HACCP). Although BMPs and HACCP have been the focus during meetings, seminars, symposium and trainings - the application of such practices have not been given full attention. The fish seed industry players need to be aware of these codes of practice for responsible fisheries and aquaculture. A massive information through participatory training is needed.

Creation of Fish Seed Board

The Department of Agriculture through BFAR must establish guidelines and protocols in the formulation of fish seed criteria. The Fish Seed Board could serve as the screening and certifying body for all fish strains developed by different institutions. The Fish Seed Board should register/certify the strains before undertaking commercial production by the hatchery operators.

Strengthening of extension services

The devolved function of technology transfer to the local government unit has weakened the transfer of appropriate technologies to fish farmers. Capacity building of local grow-out technicians to deliver and disseminate information and render technical assistance through training and participatory approach must be given full support by the government. Latest technologies have not reached out to the remotest barangay/municipality because of the lack of technicians/extension workers. Information and other educational materials should likewise be made available and translated to the different dialects in the country. Local or international funding agencies should be tapped to provide assistance through aids or grants. The Internet could be one source

TABLE 7.16.5
Five year tilapia production and price trend (2000-2004)

Year	Quantity (tonnes)	Percentage increase/decrease	Wholesale price/kg (PhP)	Retail price/kg (PhP)
2004	145,868	7.26	51.36	67.38
2003	135,996	11.18	44.01	58.80
2002	122,316	14.59	43.53	57.71
2001	106,746	29.23	45.80	59.17
2000	82,601	9.49	46.75	58.58

of information and enable interactive participation, however, funding is required to pursue this objective.

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7.17 Freshwater fish seed resources in Sri Lanka

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ABSTRACT

In Sri Lanka, commercial large-scale freshwater aquaculture for food fish production has not been established unlike her south Asian and southeast Asian neighbours due primarily to low domestic prices offered for freshwater fish. The other main reason is that Sri Lanka, being an island nation, has abundant sea fish and consumers traditionally prefer sea fish than freshwater fish. However, with increasing prices of sea fish, programmes for popularizing the consumption of freshwater fish became successful especially in rural areas. In this respect, the most successful program has been the initiation of culture-based fisheries in perennial and seasonal tanks. The latter, by far, is the closest achievement of Sri Lanka in terms of freshwater aquaculture, also known as freshwater fish culture in large community-based village ponds.

Freshwater fish seed are produced at the three Aquaculture Development Centers (AQDC). The main species of fish are the Chinese carps (silver carp and bighead carp) and the Indian carps (rohu, mrigal and caltla). Common carp and tilapia species are also produced at the three centers. The AQDC at Pambala, Chilaw in the northwestern province produces post-larvae of the freshwater prawn *Macrobrachium rosenbergii.* Fry produced at these centers are sold to private pond operators and community-based organizations for rearing to fingerlings and sale to fisheries societies, provincial councils and non-governmental organizations for the purpose of stock enhancement and culture-based fisheries in perennial and seasonal tanks.

At present, the demand for fingerlings is mainly for culture-based fisheries, where the harvest is assured in eight months time. In addition to this, the fingerlings are also purchased by the provincial councils for stocking small-, medium- and large-scale reservoirs in their respective provinces.

The biggest constraint to the development of the freshwater seed resources in Sri Lanka is the comparative lesser demand for freshwater fish seed in relation to other countries in the region. This is mainly due to the absence of commercial scale freshwater aquaculture in the country. However, with the seasonal tank stocking program getting into full gear under the ADB-funded project, it is envisaged that the demand will increase in the future.

INTRODUCTION

Sri Lanka did not have a tradition for freshwater or brackishwater fish aquaculture for production of food fish and as means of livelihood, unlike her south and southeast Asian neighbors, at least not until the early and mid-1980s. Firstly, this is because Sri Lanka being predominantly a Buddhist country, partaking of fish from a pond, killed after being harvested alive, was not encouraged according to the philosophy. Secondly, sea fish was made available throughout the country in a matter of hours. The third and the most significant reason is the because of the low prices offered for freshwater fish in the local market, aquaculture operations on a commercial scale were not viable. However, a freshwater fish capture fishery was in operation at the subsistence level from the early 1960s to mid-1970s, since the introduction of *Tilapia mossambica* to perennial man-made lakes in Sri Lanka in the 1950s. Today, nearly 90 percent of inland freshwater fish production is from capture and culture-based fisheries in perennial and seasonal tanks.

TABLE 7.17.1
Freshwater resources in Sri Lanka

Resource Type	Area (ha)
Large Irrigation Reservoirs	70 850
Medium Irrigation Reservoirs	17 004
Minor Irrigation Reservoirs	39 271
Seasonal Village Tanks	100 000
Flood Lakes (Villus)	4 049
Upland Reservoirs (Estate Tanks)	8 097
Mahaveli Reservoirs	22 670
Total	**261 941**

Source: Ministry of Fisheries and Aquatic Resources, Sri Lanka

Although the government's attempts in developing the capture fishery in perennial reservoirs on a major scale in the early 1970s was successful, its programs to encourage pond fish culture in fresh or brackish water failed to produce significant results due to above reasons. In the early 1980s, under the first Asian Development Bank (ADB)-funded Aquaculture Development Project (ADP), culture-based fisheries in seasonal tanks (considered to be large community ponds) commenced on a pilot scale and later developed into a major aquaculture activity with the participation of the village agriculture and fisher communities. Today, under the second ADB-funded Aquaculture Resource Development and Quality Improvement Project (ARDQIP), culture-based fisheries in seasonal tanks is a major activity and it is envisaged that 3 600 ha of seasonal tanks will be stocked with fish by the end of the project period of six years.

FRESHWATER RESOURCES IN SRI LANKA

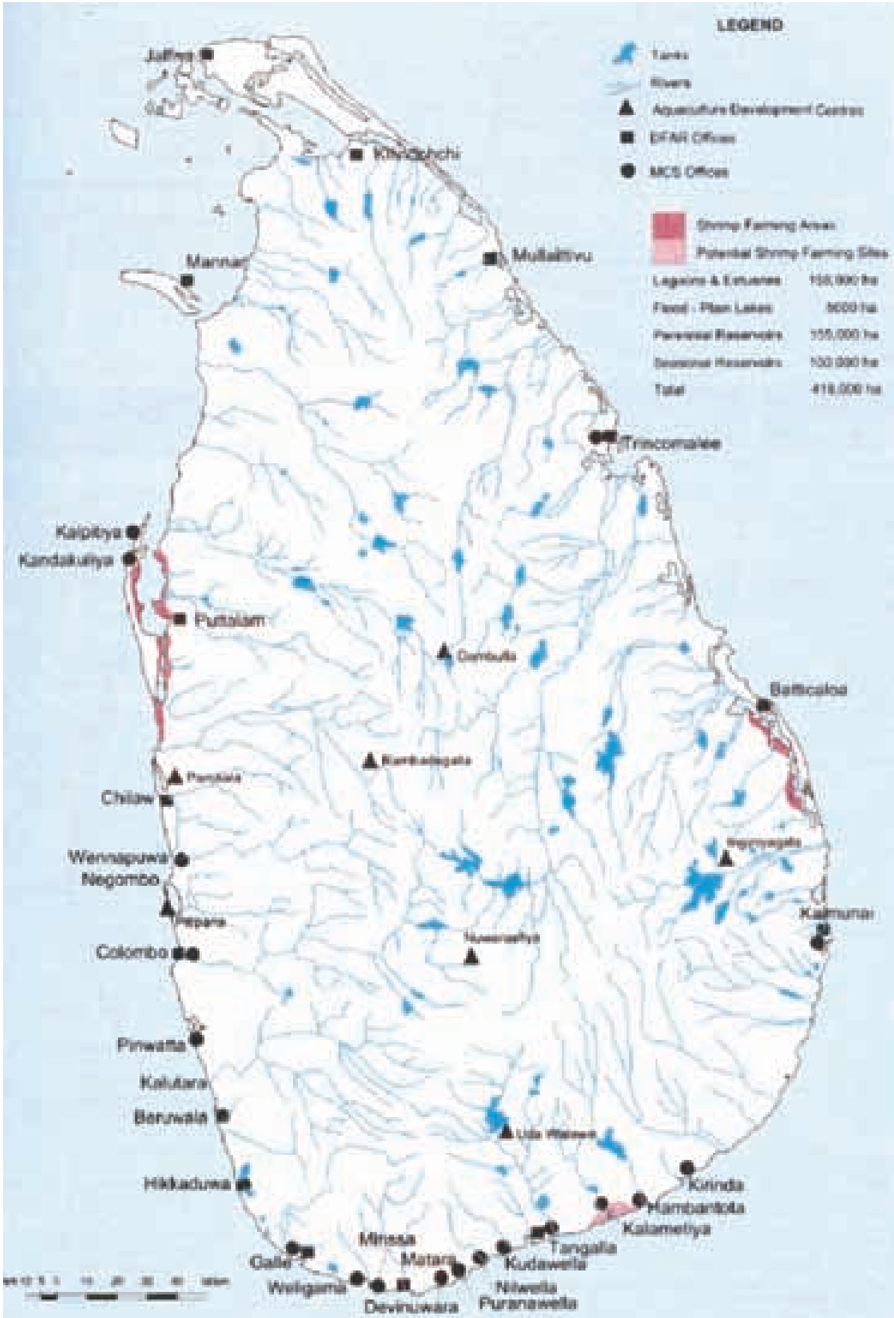
Table 7.17.1 shows the freshwater resources of the country consisting of large-, medium- and minor-irrigation reservoirs, village seasonal tanks, flood lakes, upland reservoirs and Mahaveli reservoirs.

Freshwater species

Three varieties of Chinese carps, namely: grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristhychthys nobilis*), were introduced to Sri Lanka in the mid-1970s for the purpose of producing fingerlings for stock enhancement of the perennial reservoirs. The government took this decision as it was felt that the marine catch from ocean resources was reaching maximum sustainable levels and that production from freshwater resources was the key to achieve an increment in the per capita consumption of fish among the population. Subsequently, in the beginning of the 1980s, three varieties of Indian carps, i.e. catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) were also introduced for production of fingerlings for stock enhancement, mainly, of the minor perennial reservoirs and seasonal tanks.

Through a 90 percent subsidy scheme for the purchase of fiberglass boats and gear, the government encouraged fishing activities in the perennial reservoirs. Under the first ADB-funded Aquaculture Development Project, culture-based fishery was established in seasonal tanks in the early 1980s. Through these efforts, it was possible to increase

FIGURE 7.17.1
Inland fresh water resources for inland fisheries and aquaculture development



the freshwater fish production in the country from inland waters from 8 000 tonnes in the early 1970s to nearly 40 000 tonnes by the end of 1990.

The government also encouraged aquaculture of freshwater fish, e.g. tilapia, common carp, Chinese and Indian carps, by offering a 35 percent subsidy on pond construction in mid to late 1970s to late 1980s. This program, however, failed to achieve the desired results due to lower market prices for the varieties in question and non-economic viability. Even at present, aquaculture of carps and tilapia is almost non-existent due to low economic returns. However, in recent times, with an export market being created for tilapia species, some interest has been aroused among certain investors with one or two big tilapia projects in the pipeline.

Milkfish (*Chanos chanos*) is another species that had been promoted for aquaculture during the 1980s under the 35 percent subsidy scheme in the coastal areas of the North Western Province (NWP). However, this species, too, failed to produce any impact on aquaculture production during that time, especially because of the popularity of shrimp farming which started to boom in the NWP in the late 1980s and thereafter. Today, milkfish culture is undertaken by certain private sector enterprises mainly for the production of juveniles for the tuna bait industry.

Contribution to aquaculture production

The contribution of freshwater fish production from aquaculture in ponds is less than 0.1 percent at present. However, the contribution to the total inland freshwater fish production from culture-based fisheries in seasonal tanks, considered as community-based aquaculture in large village tanks, is around 2 percent. The major portion of freshwater fish production in the country comes mainly from capture fisheries in perennial water bodies. Almost all the freshwater fish from culture-based and capture fisheries are consumed by the population in inland production areas of the country and the people in these areas have now developed a preference for the above-mentioned varieties, through continuous consumption and especially because the prices for freshwater fish are comparatively low when compared to marine varieties.

Consumption and consumer acceptance

The present production of freshwater fish is around 35 260 tonnes in 2006 and about 95 percent of this production comes from capture and culture-based fisheries from perennial reservoirs and seasonal tanks contributing 1.7 percent to the per capita consumption of the country. Freshwater fish is mainly consumed in inland areas of the country and mainly by the poor, lower-middle and middle classes of the community. Freshwater fish is comparatively cheaper than marine fish and for this reason alone the bulk of freshwater fish is marketed in inland areas. Consumer acceptance in urban coastal areas of northwestern, western and southern coastal belts is comparatively poor compared to urban areas of central parts of the country, especially in the dry and semi-dry zones where the largest number of inland reservoirs are concentrated.

SEED RESOURCES AND SUPPLY

The main seed supply for the various programs of the country comes from the three Aquaculture Development Centers (AQDC's) functioning under the National Aquaculture Development Authority of Sri Lanka (NAQDA). These three centers produced 45 million post-larvae of Chinese and Indian carps in 2005. However, these AQDC's have very limited fry to fingerling rearing capacity. Under the ARDQIP, a number of mini-nurseries have been constructed and managed by Community Based Organizations (CBOs), where the fry produced at the AQDC's are reared to fingerlings for distribution to fisher communities at a price for stocking the perennial and seasonal tanks. The following are the main AQDCs (Table 7.17.2, Plate 7.17.1) that, which produce post-larvae and fry for distribution to stakeholders.

- Aquaculture Development Center – Udawalawe (New) (carps)
- Aquaculture Development Center – Udawalawe (Old) (carps)
- Aquaculture Development Center – Dambulla (carps)
- Aquaculture Development Center – Inginiyagala (carps)
- Aquaculture Development Center – Pambala (freshwater prawns)

Following are the mini-nurseries constructed under the ARDQIP and managed by CBOs:

- Mini-nursery – Padaviya
- Mini-nursery – Mahadiulwewa
- Mini-nursery – Kesellanda
- Mini-nursery – Dozer wewa
- Mini-nuresry – Hakwatuna Oya
- Mini-nursery – Kathnoruwa
- Mini-nursery – Ardiyangama wewa
- Mini-nursery – Ridiyagama
- Mini-nursery – Nawamadagama
- Mini-nursery – Elle wewa

Other relevant details are provided in Table 7.17.3.

TABLE 7.17.2
Details of Aquaculture Development Centres (AQCDs) in 2005

AQDC	Mud pond type	No. of mud ponds	Area m² per pond	Cement tank type	No. of cement tanks	Area m² volume cuft*/ tank* lrs**/tank	No. of hatchery jars	Capacity/ quantity of eggs per jar
Udawalawe (New)	brood stock rearing	10	1750	fry rearing	52	20	08(Chinese type)	1.0 million
	-do-	08	800	-do-	06	40		
	fry/fingerling rearing	04	1000	-do-	08	60		1.0 million
Udawalawe (Old)	brood stock rearing	06	600	fry rearing	02	225	01(Tilapia)	0.1 million
				-do-	10	20		
	-do-	01	330	-do-	08	02		
	-do-	01	460					
Dambulla	brood stock rearing	10	1800	fry rearing	20	24	04(Chinese type)	1.0 million
	-do-	10	1200					
	-do-	10	300					
	fry/fingerling rearing	20	400					
Inginiyagala	brood stock rearing	04	2016	fry rearing	20	12.9	04(Chinese)	1.0 million
				-do-	15	21.6		
	fry rearing	20	1000					
	-do-	10	750					
Pambala	-	-	-	brood stock rearing	03	400*	10	0.01 million
				post-larvae rearing	06 (FG)	1000**		

TABLE 7.17.3
Details of mini-nurseries in operation as of 2005

Name of mini-nursery	District	No. of pond	Area m² per pond	Date of construction	Fingerling production to date	Average production/ pond/ cycle fingerlings	Average production/ mini-nursery/ cycle	Average production per 500m²
Padaviya	Anuradhapura	10	2250	25-08-2004	151 345	10 089.6	100 896.0	22 421.30
Mahadiulwewa		09	2750	10-09-2005	-	-	-	
Kesellanda	Moneragala	06	1950	20-07-2004	108 250	9 020.8	54 124.8	13 878.15
Dozer wewa		09	2900	27-04-2005	101 125	11 236.1	101 124.9	17 435.32
Hakwatuna oya	Kurunegala	09	2680	20-09-2004	143 486	11 957.2	107 614.8	20 077.38
Kathnoruwa		10	3480	14-08-2005	-	-	-	
Ardiyagama wewa	Hambanthota	08	2600	05-03-2005	263 650	16 478.1	131 824.8	25 350.92
Ridiyagama		11	3390	27-06-2005	64 975	10 829.7	119 126.7	17 570.30
Nawamedagama	Polonnaruwa	10	3100	20-07-2005	-	-	-	
Elle wewa		10	3100	28-08-2005	-	-	-	
Average							102 452.0	19 455.56

PLATE 7.17.1

Aquaculture Development Centers (AQDC's) functioning under the National Aquaculture Development Authority of Sri Lanka (NAQDA)

Aquaculture Development Center - Udawalawe

Aquaculture Development Center - Dambulla

Aquaculture Development Center - Inginiyagala

In addition to the above, there are private pond operators who purchase fry from the above-mentioned AQDC's and rear the same to fingerling stage for sale and distribution to fisheries societies and farmer organizations. A list of private pond operators is given in Table 7.17.4. Except for milkfish juveniles caught from the wild, no wild collection of fish fry are carried out for distribution to stakeholders.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

AQDC Udawalawe (New)

The AQDC at Udawalawe is situated about 170 km from Colombo in the Sabaragamuwa Province (Figure 7.17.1) in the semi-arid zone of Sri Lanka. The distance can be covered by car for about 3 to 3.5 hrs from Colombo. The Center was established under a grant from the People's Republic of China in 1975 and mainly specializes in the production

TABLE 7.17.4

List of private pond operators in the Anuradhapura District

Name of pond operator	Address	No. of ponds	Total area (m²)
1. H.A.Premadasa	Mannar Junction, Pemaduwa	03	1 200
2. K.M.Geethani	Srawasthipura	01	400
3. Y.M.Nimal Bandara	Randoowa, Pemadura	01	500
4. 'Meemesso'farmer Organization	Seenikkulama, Srawasthipura	10	4 000
5. S.D.Juwan Appu	D-3, Galkiriyagama	02	800
6. B.M.Punchibanda	Puliyankulama,Wijithapura	01	750
7. T.P.Chandralatha	No.48,Mihintale Rd, Kunchikulama	12	5 000
8. I..W.Kapilawansa	Kudapaladikulama, Paladikulama	03	1 250
9. A.Wijedasa	Seenikkulama, Srawasthipura	02	1 000
10. Nihal Darmasiri	Sama Mw, Stage 111, A'pura	01	400
11. W.M.Dissanayake	No.35, Randoowa, Pemadura	03	1 500
12. J.A.Asanka Roopasinghe	No.35, Randoowa, Pemadura	04	2 000
13. Ekasath Pubudu Farmer Organization	Galkulama , Padaviya	10	8 000
14.T.M.Wikramadasa	No. 09, Jayasiripura A'Pura	04	1 200
15. A.K.D.Perera	Track 17, Pahalamaragahawewa	04	1 300
16. Samagi co-op society	Padaviya	07	2 100
17. Susantha Wijethunge	Track 17, Pahalamaragahawewa	03	4 000
18. M.Somapala	Kalaththewa, A'pura	03	1 200
19. M.S.Kabral	Yahalegama, Gnanikkulama	02	800
20. Manel Sreemathee	Turuwila, Hidogama	01	375
21. K.G.Rajitha Priyadarshani	Kawarakkulama, Galkulama	01	400
22. Northern Army camp	Ranasewapura, A'pura	03	900
23. Lalith Kumara Bamunuge	Kadaweediya, Madatugama	01	500
24. M.Meera Sahib	Bandarapothana, Pubbogama	01	500
25. H.M.Keerthirathna Bandara	No. 24, Track 04, Senapura	01	350
26. S.Janguwa	Gomarankalla	03	1 000
27. R.U.Munasinghe	Puttalam Rd, Pahalamaragahawewa	01	500
28. Mahadiulwewa F.C.S.	Kahatagasdigiliya	09	2 700
29. Sunil Mannapperuma	No.96, Medawachchiya	01	4 000
30. R.B.Rathnayaka Banda	Ranawa, Galkiriyagama	01	500
31. W.M.Kazeem	Mahasiyambalagaswewa, Gambirigaswewa	01	500
32. M.Gunathilaka	Sirimapura, Rajanganaya	02	600
33. B.M.Gamini Senevirathne	Pahalagama, Palagala	01	300
34. M.Harischandra	No.163,Track 06,Rajanganaya	01	600
35. N.B.Nuwarawewa	Balaluwewa, Palagala	01	500
36. W.H.M.Anurasiri	Sandaresgama, Eppawala	01	400
37. G.A.J.C.Abeysinghe	85,Tissawewa, Pandulagama	01	800
38. D.M.Wikramasinghe	Makulewa, Hoorigaswewa	01	500
39. K.G.Aberathne	Makulewa, Hoorigaswewa	01	500
40. W.T.G.Asoka	Wannitammennawa,A'pura	02	1 000
41. G.A.Jayawickrama	Wanamaluyana,Walagambahuwa	01	500
42. Nahur Kahir	Mahasiyambalagaskada, Medawachchiya	01	500
43. N.M.S. Ibrahim	Mahasiyambalagaskada, Medawachchiya	02	1 000
44. R.Rathnasiri Banda	Kokawewa, Getalawa	01	1 000
45. M.Bandarathna	Abayagiri para ,A'pura	01	3 500
46. M.Chandana Senevirathna	Teldeniya, Horowpothana	08	7 000
47. Y.M.S.Yapa	Track 13,Rajanganaya	03	750
48. Ajantha Kumara Alahakoon	2nd Mile Post ,Alankulama ,A'pura	06	2 600
49. Ajith Edirisinghe	Rambewa, Pandukabayapura	08	4 000
50. Chandana Sampath	Galenbidunuwewa	02	1 200
51. K. Weerasinghe	Galenbidunuwewa	01	250
52. Aluthdiulwewa F.C.S.	Galenbidunuwewa	02	1 000

of Chinese and Indian major carps. The total extent of land available, inclusive of the space for the mud ponds and cement tanks, are about 40 ha. The Center comprises of 40 mud ponds and 66 cement tanks, a hatchery comprising of 8 Chinese designed hatchery tanks, each with a water holding capacity of 11.34 m³ capable of hatching 1 million eggs. The total capacity of the hatchery is 8 million eggs per spawning session. The Center also has a spawning tank situated adjacent to the hatchery complex. Other details are given in Table 7.17.2.

AQDC Udawalawe (Old)

This Center, also situated in the same location but separated by a distance of 1.5 km from the new Center, was established in the early 1960s by the now defunct River Valley Development Board (RVDB) which played a major role in the main rivers diversion schemes in the early 1960s and 1970s. The Center has an area of 4 ha inclusive of the pond area. It has 8 mud ponds and 20 cement tanks. The details are given in Table 7.17.2. *Tilapia* spp. are the main species cultured; the tilapia hatchery has a capacity of producing of 0.1 million eggs per spawning.

AQDC Dambulla

The AQDC at Dambulla is situated about 148 km from Colombo in the Central Province of Sri Lanka (Figure 7.17.1) in the arid zone. The Center, constructed in the mid- to late-1970s and mainly specializes in producing Indian and Chinese major carps, has a total area of 24 ha inclusive of ponds composed of 30 mud ponds and 20 cement tanks. The Center also has a hatchery comprising of 4 Chinese style hatchery tanks, each with a capacity to hatch 1 million eggs per spawning session. Other details are in Table 7.17.2.

AQDC Inginiyagala

The AQDC at Inginiyagala is situated about 395 km from Colombo in the North Eastern Province in the arid zone of Sri Lanka. By car, the distance can be covered for about 6 to 7.5 hrs from Colombo. It is located just below the great bund harnessing the water of the Gal Oya, the first river to be dammed for conserving water for irrigation and power generation in the early 1950s. The Center has a total land area of 16.8 ha inclusive of mud ponds. Altogether there are 34 mud ponds and 35 cement tanks. The details are given in Table 7.17.2. The hatchery comprises of 4 Chinese style hatchery tanks with a capacity to hatch 1 million eggs per hatchery tank per spawning session. The main species produced at this Center are Indian major carps and tilapia.

AQDC Pambala

The AQDC at Pambala, situated about 60 kms from Colombo in the coastal belt of the North Western Province of Sri Lanka, is at present the only Center, which produces freshwater prawn (*Macrobrachium rosenbergii*) larvae in the country. The Center comprises only of one hatchery with three broodstock holding tanks 600 m³, six post-larval rearing tanks (1 000 l capacity), two spawning tanks (2 000 l capacity) and six. artemia hatching jars and plankton culture tanks. The annual production capacity is 0.6 million.

SPECIES AND AVAILABLE TECHNOLOGIES

The main species cultured for breeding are three varieties of Chinese carps and three varieties of Indian carps as mentioned earlier. The main technology used for breeding these varieties in the hatcheries is through artificial insemination with the use of Ovoprim, Sufrefact, Human Chorionic Gonadotropin (HCG), Luteinizing Hormone Release Hormone Analog (LHRH Analog) and Pituitary Glands (PG).

In addition to the above varieties, tilapia is also being bred naturally at the three centers. Hatching takes place in the ponds and the post-larvae are collected manually and stocked in ponds for rearing up to the fry stage. At present gene banks are not maintained at the AQDCs.

SEED MANAGEMENT AND SEED QUALITY

The broodstock of Chinese and Indian major carps are nurtured separately in ponds at the AQDC at Udawalawe and Dambulla. Only Indian major carps are nurtured in Inginiyagala. The aquaculturists attached to these three centers were trained at the People's Republic of China and India and apply the same culture techniques and husbandry practices being employed in those countries, with special emphasis on water quality management, monitoring of biological oxygen demand (BOD) and chemical oxygen demand (COD) levels, plankton productivity in the ponds, control of plankton blooms and disease control. Special attention is also paid to post-spawning care of the broodstock released to specially-prepared ponds with replenished water. As far as possible, the spawners are handled with care during and after spawning, using cloth bags for holding the brooders during spawning and subjecting them to potassium permanganate baths for both Indian and Chinese carps, before releasing them to the respective ponds. Fish feeds manufactured locally by a private sector company are used at the three centers. Imported fish feeds are not used as they can escalate the cost of production. All other standard operating procedures in pond preparation, such as cleaning dikes, liming the pond bottom, ploughing and removal of dead fish and other predators, fertilizing the water with cattle manure (no inorganic fertilizer used) and finally filling with water to a depth of 2 to 2.5 ft are adhered to, before stocking the ponds with post-larvae.

Members of the CBOs and private pond operators (PPOs) have also been trained on practical aspects of aquaculture, including pond preparation prior to stocking with fry, culture techniques, feeding, feeding frequencies, disease prevention and control and harvesting methods. Aquaculturists from AQDC's assigned by NAQDA to CBOs and PPOs periodically visit the sites to provide advice and other technical assistance.

It takes about three weeks duration for post-larvae (PL) to reach a size of 3 cm when stocked at a rate of 200 PL per m^3 for Chinese and Indian carps. From the fry stage, it takes about 45 to 60 days to reach 5 to 7 cm when stocked at 100 fry/m^3. The survival rate of PL at the AQDCs is around 50 percent which is quite low. The main reason for this is that at certain AQDCs, some PL rearing ponds cannot be completely dried due to water retention, which makes cleaning of the pond and removal of predators difficult (these ponds are almost 25 years old, with repairs done from time to time). The second reason is the presence of metacercaria in ponds which has been now been overcomed at the AQDCs through methodologies for eradicating this parasite and as advised by a Consultant Fish Pathologist under the ARDQIP. The PL, fry and fingerling production details for the years 2004 and 2005 are given in Table 7.17.5.

SEED MARKETING

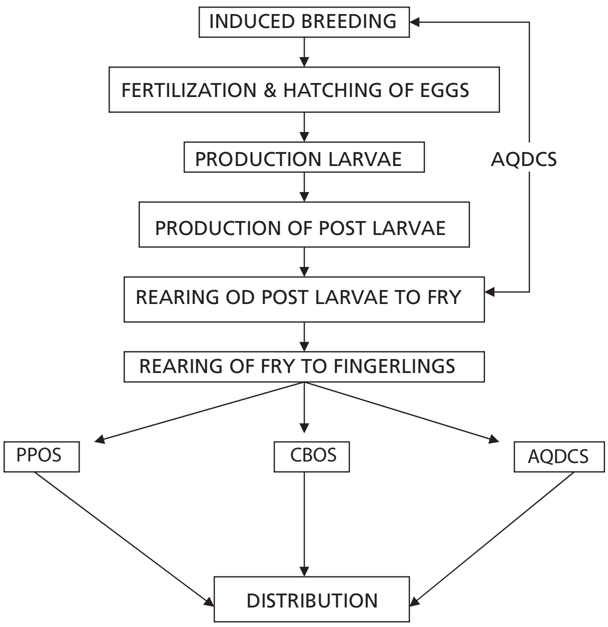
At present there is no sophisticated marketing channel for fish seed in Sri Lanka. This is mainly because the demand is mainly for stock enhancement of culture-based fisheries in seasonal and minor perennial tanks. The distribution channel could be illustrated as in Figure 7.17.3:

There are three ways (apart from operator's own resources) in which funds are generated for the purchase of fry and fingerlings as shown in Figure 7.17.4.

All CBOs have been trained by NAQDA under the ADB-funded AQRDIP to develop business plans for generating loans from banks through loan schemes promoted under the project. Most private pond operators who have been rearing fry to fingerlings as a business venture (especially in the Anuradhapura District in the North Central Province, where the seasonal tank culture-based fisheries program successfully took off initially) have already started generating their own funds for the purchase of fry from NAQDA's AQDCs.

Thirdly, in certain perennial tank areas where fisheries societies/farmer organizations are not active buyers of fingerlings for stock enhancement, the respective Provincial

FIGURE 7.17.2
Flow chart illustrating the process from induced breeding to distribution of fry/fingerlings and the roles played by AQDCs, CBOs and PPOs



Source: Aquaculture Resource Development and Quality Improvement Project of NAQDA

Councils (PCs) allocate funds in their annual budget for the purpose of purchasing fingerlings from NAQDA's AQDCs for stocking in these reservoirs on behalf of the fisheries aociety/farmer organizations. This strategy is practiced in order to create awareness on the importance of stock enhancement and in order to create a subsequent market demand for fingerlings.

The more established CBOs and PPOs use their own vehicles (personally-owned vehicles or hired vehicles) to transport the fry from the AQDCs to their respective facilities for grow-out operations. In some instances, fry are transported to CBOs or PPOs facilities by NAQDA vehicles, the cost of fuel being reimbursed by the respective CBOs or the pond operators at the point of delivery.

Once the fry are grown to fingerlings by the CBO, the fingerlings are transported to respective customers (fisheries Societies/farmer organizations) by their own means. In some cases, for new CBOs and pond operators, NAQDA helps to transport the grown fry to required destinations using NAQDA vehicles, the cost of fuel being reimbursed

TABLE 7.17.5
Fish seed production in Aquaculture Development Centers (AQDCs) of NAQDA (2004)

AQDC	Carp			Tilapia		Freshwater prawn
	Post-larvae	Fry	Fingerlings	Fry	Fingerlings	Post-larvae
Dambulla	11 295 000	4 055 000	517 000	498 559	264 179	-
Udawalawe (New & Old)	21 462 000	5 758 750	1 800 863	721 645	263 445	-
Inginiyagala	4 380 000	1 695 000	217 000	214 500	113 500	-
Pambala	-	-	-	-	-	645 074
Total	37 137 000	11 508 750	2 534 863	1 434 704	641 124	

Fish seed production in Aquaculture Development Centers (AQDCs) of NAQDA (2005)

AQDC	Carp			Tilapia		Freshwater prawn
	Post-larvae	Fry	Fingerlings*	Fry	Fingerlings	Post-larvae
Dambulla	16 058 000	7 504 850	1 321 310	-	-	-
Udawalawe (New & Old)	19 099 000	5 977 870	1 940 825	2 025 500	669 265	-
Inginiyagala	7 200 000	3 052 000	849 670	338 000	336 600	-
Pambala	-	-	-	-	-	655 572
Total	42 357 000	16 534 720	4 111 805	2 363 500	1 005 865	655 572

* Quantity of fingerlings reared at the Center. Most of the fry have been distributed to mini-nurseries

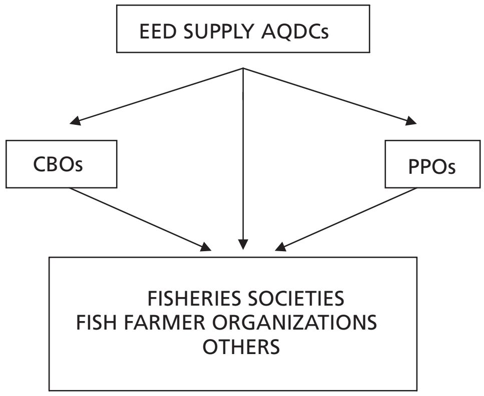
by the PC in the respective areas.

NAQDA's AQDCs, in some occasions, directly supplies fingerlings to fisheries societies/ farmer organizations using NAQDA's own transport, the funds for fuel being paid off by the respective fisheries society/farmer organizations or from the budget allocations of the PC of the respective province for that year.

At present, since freshwater fish farming is virtually non-existent in Sri Lanka and the demand for fingerlings is mainly for the seasonal tank culture-based fishery, the need for marketing agents have not arisen. Loans and financing are already in place under the ARDQIP.

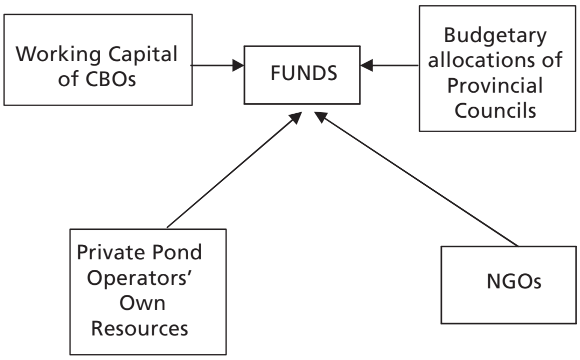
7.17.3

Distribution channel of fish seed produced in AQDCs



7.17.4

Sources of funds for purchasing fry and fingerlings



SEED INDUSTRY, SUPPORT SERVICES AND SEED CERTIFICATION

The seed industry is still at a low level in Sri Lanka, limited only to production for culture-based fishery. Breeding activities are also confined to the AQDCs; PPOs and CBOs still have not taken up fish breeding activities on their own. At the AQDCs, broodstock of Chinese and Indian major carps are maintained with the best husbandry practices and no mass mortality of and fry/fingerlings have been reported. All precautionary measures for the prevention and treatment of diseases have been put in place. For replacement of old stock of brooders, under the ARDQIP, several batches of Indian and Chinese major carp fry have been imported to Sri Lanka in the recent past with proper health certificates and quarantine measures.

Every effort is being made by NAQDA extension officers to recover the funds due from the sale of fry to PPOs and CBOs. Training and awareness programs on fry to fingerling rearing are being conducted by NAQDA officers to PPOs and members of CBOs. Since the industry is still at a lower scale compared to other south Asian and southeast Asian countries, significant impacts as a result of natural disasters and fish mortality due to disease occurrence have not been reported. There is also no certification program for fish seed in Sri Lanka at present.

LEGAL AND POLICY FRAMEWORKS

Prior to 1990, fingerlings were issued to fisheries societies and farmers free of charge in order to enhance production of freshwater fish from perennial reservoirs and seasonal tanks. After NAQDA was established in 1998, a policy decision was taken to sell the fry/fingerlings to stakeholders. Since then, NAQDA extension officers and other NGOs who were interested in creating livelihoods for the fisher communities have been promoting the sale of fish fry/fingerlings to the fishers by educating them on management of the water body in terms of stocking and harvesting and also teaching these fisher's societies to develop business plans. In this manner, a demand has been created to market fish fry/fingerlings for seasonal tank fisher groups and the normal

PLATE 7.17.2
Mini-nurseries in several locations in Sri Lanka managed by Community-based Organizations (CBOs)

Mini-nursery – Dozer wewa

Mini-nursery - Mahadiulwewa

Mini-nursery - Kathnoruwa

market forces of supply and demand applies here. The sale of fish fry/fingerlings is governed by the same legal framework applicable to other products as well, under the common law of the land.

The Support to Regional Aquatic Resources Management (STREAM) Initiative is not very active in Sri Lanka. STREAM has so far been involved in a livelihood analysis study in the tsunami affected areas in the eastern and southern coasts of Sri Lanka, which has been concluded already.

ECONOMICS

At the AQDCs, fry of carps are sold at Sri Lanka Rupees (LKR) 0.25 cents per unit. This had been costed taking into account the annual overheads of the AQDCs and the maximum production levels. The fingerlings are sold at LKR1.50/unit.

The CBOs and the PPOs purchase fry from AQDCs at LKR 0.25 cents and the fingerlings are sold (after rearing for 45 days) at LKR 1.50/unit. The construction costs of the mini-nurseries have been shouldered by the ARDQIP and the CBOs are expected to pay back the cost of construction after the first culture cycle from a revolving fund maintained by the CBO from profits earned. According to ARDQIP, the average profit earned by a CBO is in the range of LKR 65 000.00 to LKR 90 000.00 per culture cycle, which is a generalized figure. The earned profits can be as high as LKR 50 000.00 per cycle, varying from site to site and depending on the interest of the CBO. Table 6 illustrates the income generated per cycle for a 500 m² production unit. This is a very generalized presentation using available data from CBO-managed mini-nurseries, to enable a comparison with the economic data available from the PPOs of Anuradhapura. There is a marked difference in the income generated between the two groups per cycle. The reason is that, the PPOs in Anuradhapura are more experienced having started this venture much earlier, long before the CBO operations under the ARDQIP, which is only 2 years old. The CBOs are expected to perform four culture cycles per annum, bringing in a profit of around LKR 254 000.00/yr/2000 m² unit. Since the CBOs functioning at present were established about one year ago, they have been able to complete only 1 to 3 culture cycles per annum.

The PPOs (Table 7.17.3) are mostly concentrated in the Anuradhapura district in the North Central Province of Sri Lanka. This is a district with the most number of seasonal

TABLE 7.17.6

Production economics, fry and fingerling rearing (500 m² pond) - data from Community-Based Organization (CBO)

Cost of construction of a 3 500 m² mini-nursery	LKR 500 000.00
Cost of construction of a 500 m² unit	LKR 71 430.00 (appr)
Average income/cycle/500m²–19 455.56 @ Rs.1.50 per fingerling	LKR 29 184.00 (60 fry/m² stock density at 60% average survival)
Variable costs (cost of fry + fish feed)	LKR 13 308.00 (appr)
Earnings	LKR 15,876.00 x 4 cycles/annum = LKR 63 504.00
1 US$	LKR 101.00
Assumptions: Culture aspects are carried out by an active working group as selected among members of the CBO, who take turns in carrying out their respective functions as assigned. These members are active fishermen of the reservoir in which the fingerlings are supposed to be stocked. No payments are made to these members for the work carried out. However, profits will be shared among them. All construction costs, inclusive of labour and materials amounting to LKR 500 000.00 has been contributed under the ARDQIP. The calculations have been averaged to show income and expenditure for 500 m² production unit for comparison with production of private pond operators at Anuradhapura.	

tanks and a major effort was put in place, especially after the ban on inland fisheries was lifted, in 1995, by organizations such as the Australian Center for International Aquaculture Research (ACIAR) and the FAO/UNDP to develop culture-based fisheries in seasonal tanks. As a result, pond rearing of fry to fingerlings and some water-based nurseries came in to early operation in the district as a market had been created for fingerlings. Most of the ponds have been constructed by the operators using their own funds, while some had obtained bank loans for it. At present, there are almost 100 PPOs in the district. The operators also purchase the fry from AQDCs at LKR 0.25 cents/unit and sells at LKR1.50/ unit. The details of pond construction and operational costs are given in Table 7.17.7.

There is no seasonality of demand at present, as both private operators and CBOs are producing fingerlings for the seasonal tanks as well as for stocking the perennial tanks on a year-round basis. As mentioned earlier, funds, for marketing fingerlings

TABLE 7.17.7

Production economics, fry to fingerling rearing (500 m² pond) (data from Private Pond Operators)

Pond construction costs (in LKR)	
Pond excavation	30 000.00
Labour	4 000.00
Polythene and nets (protection from predators)	5 000.00
Transport (for materials to site)	5 000.00
Water pump and accessories	35 000.00*
Sub total	76 000.00
Operating costs (in LKR)	
Fish seed	10 000.00 (@ 80 to 100 fry/m²)
Fertilizer (inclusive of lime)	3 000.00
Feed	3 000.00
Transport	3 000.00
Sub-total	19 000.00
Grand total	95 000.00
Income (in LKR)	
Expected production (per cycle)	36 000 fingerlings (survival rate around 80% - long time operators with more experience than CBOs)
Earnings	54 000.00 x 4 cycles per annum = 216,000.00 (@ 1.50/fingerling)
1 US$	101.00

*This need not necessarily be an additional expense as most pond operators are agriculture farmers who are in possession of water pumps for agriculture uses.

for stocking in some tanks where there is a reluctance to purchase fingerlings by the fisheries societies, are being provided from the decentralized budgetary allocations of the PCs with jurisdiction over those tanks.

Most of the PPOs are agriculture farmers and agriculture product vendors; agriculture is the main income source. Some others are ornamental fish producers engaged in fry rearing as an additional income source. The profits earned by these groups of operators are therefore an added bonus to their regular income. At present, the main factors that affect the price of fingerlings, which is fixed by NAQDA, are the cost of feeds and cost of treating fish during disease outbreaks. The feeds are a mix of formulated chicken mash (available in the market), dried fish powder (available in these areas made by grinding dried sprats), rice bran and soya powder. The average cost of feeds made in this manner is around LKR 25.00/kg. Fish are fed at 3 percent body weight. At present, there has been no report of any major disease occurrences from the PPOs and the CBOs. In cases where diseases are reported, aquaculture officers of NAQDA will visit such locations and after diagnosis, treatments will be provided free of charge to the operators. This is done by NAQDA in order to encourage the continuation of fry to fingerling rearing, until such time the operators and the CBOs are in a position to deal with such situations on their own. However, in the Anuradhapura district, this need has not arisen yet except on a few occasions as the pond operators are capable of purchasing their own stocks of medicine for treatment when the need arises.

INFORMATION AND KNOWLEDGE GAP

Fry and fingerling production on a commercial scale is a recent occurrence in Sri Lanka. In the absence of large-scale commercial fish farming, at present, the most significant market for fingerlings is culture-based fisheries in seasonal and minor perennial tanks. Although fingerling demand is much less for stock enhancement of perennial reservoirs at present, with extension and promotional activities carried out by NAQDA extension staff, it is expected that a demand for fingerlings would be created for this activity too. NAQDA has and will play a key role in the foreseeable future in producing the much needed fry of Chinese and Indian major carps for sale to different stakeholders in culture-based fisheries and for stock enhancement of perennial reservoirs.

Information on fry and fingerling production on a commercial scale carried out in other countries in the region is lacking and there is a need to disseminate and share such information among countries in the region to enable viable commercial production. Also breeding techniques of different fish species are also lacking among the stakeholders and such a need for training stakeholders in fish breeding techniques has not yet arisen in Sri Lanka, as the market for fry and fingerlings is limited. However, information on methodologies adopted by stakeholders in other countries is of paramount importance for NAQDA to upgrade the knowledge and skills of the personnel involved in production. Information dissemination and training in milkfish breeding among stakeholders, is an immediate need at present.

STAKEHOLDERS

NAQDA: National Aquaculture Development Authority of Sri Lanka. At present, AQDCs of NAQDA are the main producers and suppliers of fish fry/fingerlings to various stakeholders in the country. The three main AQDCs are at Udawalawe, Dambulla and Inginiyagala. The various stakeholders have been trained in culture techniques from fry to fingerlings. In the next stage, NAQDA intends to distribute fish seed to stakeholders for rearing to fry and fingerling stages, in order to minimize transport costs.

Fisheries Societies. Active fisheries societies in well-managed perennial and seasonal tanks, which are not serviced through CBOs, purchase fry direct from AQDCs of

NAQDA for the purpose of rearing in cages located in the reservoir. The members of the society who are essentially fishermen are trained by NAQDA extension officers in cage culture of fry/fingerling. They are also encouraged to create a revolving fund by collecting Rs. 5.00 to Rs.0.00/kg of fish harvested by the fishermen operating within the reservoir.

CBOs: Community-based Organizations. Members of CBOs are drawn from among the members of fisheries societies who are active fishermen of the various perennial and seasonal tanks in the country. The mini-nurseries managed by these CBOs are located close to the tanks in which the members of the CBO are operating. A list of CBOs is included in this report (Table 3)..

PPOs: Private Pond Operators. These are private individuals who have their own lands for pond construction. They are not necessarily fishermen and are mostly agriculture farmers or traders of agriculture products. Some are even engaged in ornamental fish rearing as out-growers. A list of private pond operators can be found in Table 2.

NGOs: Non-Governmental Organizations/Donors. NGOs assist agriculture farmers in rural areas to engage in culture-based fisheries in seasonal tanks through various projects supported by various organizations (e.g. ACIAR, FAO/UNDP, Fisheries Community Development and Resource Management Project (CDRMP) funded by the German Technical Cooperation [GTZ]). Activities include reorganization of fisheries societies, training on aspects of culture-based fisheries, business plan development, creation of revolving funds, etc. In most occasions, the NGOs purchase fingerlings from AQDCs for stocking the tanks, until the society is in a position to purchase the fingerlings on their own.

PCs: Provincial Councils. Provincial Councils mainly assist the fishermen of perennial and seasonal tanks in the respective provinces by purchasing fish fingerlings from AQDCs for stock enhancement of reservoirs in the provinces.

FUTURE PROSPECTS AND RECOMMENDATIONS

Sri Lanka is blessed with an inland water resource of 261 000 ha which can be used effectively for culture-based fisheries. If a market could be created for fry and fingerlings to stock these water resources, commercial scale production of fry and fingerlings on a large-scale would be a reality. In culture-based fisheries in seasonal tanks, this is gradually becoming successful and there is a need to extend this activity to encompass perennial tanks as well. At present, fish production in some major perennial reservoirs have gone down due to various reasons. One of the major factors was the decreasing state patronage for inland fisheries and aquaculture by the government in the early 1990s, when unauthorized fishing due to lack of proper implementation of Fisheries Regulations may have brought about resource depletion in the perennial reservoirs. Even today, the use of unauthorized fishing gear by fishermen have reduced the size of harvested fish, especially *Tilapia* spp. which constitute around 80 percent of the total inland fisheries production from reservoirs. Therefore, there is a need for stock enhancement of these reservoirs with tilapia species to rejuvenate natural stock and enhance production.

In minor perennial tanks, there is also a need for stock enhancement with Indian carp species to increase production. Under the ARDQIP, there is a special program to stock selected tanks with carp fingerlings. When the stock enhancement programs being carried out will eventually result to a significant increase in fish production from these tanks, a market would be created for commercial production of fry and fingerlings for sale to various stakeholders.

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7.18 Freshwater fish seed resources in Thailand

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ABSTRACT

Aquaculture in Thailand has developed considerably since the beginning of the century. At present, it has long-term potential for increasing fisheries production for both local consumption or export as well as contributing to national economy through earnings from high value shrimp and other fish species. Freshwater aquaculture has been practiced in Thailand for more than 80 years. At present, more than 50 freshwater aquatic animals have been cultured. Among these, 50 percent are indigenous and the rest have been imported and domesticated for a long time. The main cultured species are walking catfish (*Clarias sp*.), the hybrid catfish (*C. macrocephalus* x *C. gariepinus)*, Thai silver barb (*Barbodes gonionotus)*, snakeskin gourami (*Trichogaster pectoralis)*, giant prawn (*Macrobrachium rosenbergii)*, river catfish (*Pangasianodon hypophthalmus)*, snakehead (*Channa striata),* common carp (*Cyprinus carpio)* and soft-shell turtle (*Trionyx sinensis*). Freshwater seed resources in Thailand come from two major sources: government and private hatcheries. Resources from the government sector include 31 inland fisheries research and development centres, 1 research institute and 27 inland fisheries stations. Most private hatcheries are found in surrounding provinces of the central part of Thailand such as Nakornpatom, Rachaburi, Phatumthane, Chachaengsoa, Samutprakan and Suphanburi. Government hatcheries were established for the purpose of supplying seed and also to demonstrate hatchery technologies. Interested farmers were given training and provided with broodstocks. The role of government hatcheries was to spur the cultivation of a species by supplying fry and fingerlings free or low cost. As private hatcheries developed, their role became provider of fry to small-holders for nursing or grow-out operations and to the government for stocking in public waters. Government hatcheries frequently concentrate on products that have broader social interest, such as broodstock, or on species that are unattractive to the private sector, such as indigenous species. These hatcheries produce fingerlings, provide some extension services and even undertake research. Since 2003, the Department of Fisheries (DOF) had implemented a programme on Good Aquaculture Practice (GAP). At the beginning of the programme, farmers and hatchery operators have to register their farms with the DOF. Farmers are required to use seed and post-larvae from hatcheries implementing GAP. Through this programme, the DOF is now able to record the number of hatcheries, their production areas and yearly production. In 2005, there are 4 673 private hatcheries, with a total area of 504 131.88 rai and yearly production of 35.9 billion fry/fingerling. Most hatcheries

apply the hormone-induced sprawning technique, commonly used hormones are Lutenizing Hormone Releasing Hormone analog (LHRHa) and Human Chorionic Gonadrotropin (HCG). Monosex tilapia seed are supplied to the market by hatcheries that use the sex reversal technique.

INTRODUCTION

Aquaculture in Thailand had developed considerably since the beginning of the century. Although freshwater aquaculture has been developed for a long time, coastal aquaculture is much more recent. Aquaculture contributes about 25 percent in volume and 45.5 percent in value of the total fisheries production in 2002. At present, it has long-term potential to increase fisheries production for both local consumption and export as well as to contribute to national economy through earnings from high value shrimp and fish species.

Aquaculture activities in Thailand can be divided in two categories, namely: freshwater aquaculture and coastal aquaculture. Freshwater aquaculture has been practiced in Thailand for more than 80 years. The development of freshwater aquaculture started in 1922 after the importation of Chinese carps for culture around Bangkok. However, the Department of Fisheries (DOF) had established the aquaculture promotion programme only in 1951. At present, more than 50 freshwater aquatic animals have been cultured.

Farming systems for freshwater aquaculture include use of ponds, paddy fields, cages and ditches. Most farms are densely located in water resources rich or irrigation areas. The central plain and coastal zones, including the vicinities of Metropolitan Bangkok, Samutprakarn, Suphanburi, Nakorn Pathom, Surat Thani, Chachoengsao and Chanthaburi are major provinces for aquaculture production. The number of fish farms in 2002 countrywide was 390 853 covering an area of approximately 131 500 ha. However, only 281 199 farms covering approximately 102 000 ha are producing. Most of these are pond farms. The number of registered farms in 2004 is more than 440 000 (Annex 1).

CULTURED SPECIES

More than 50 freshwater fish species had been cultured throughout the country. Among these, 50 percent are indigenous and the rest were imported and domesticated for a long time. Detailed freshwater aquaculture statistics by species are presented in Annex 2.

The main cultured species which contribute more than 50 percent in the total production are:

Walking catfish (*Clarias* sp.). The main cultured species is the walking catfish (*Clarias* sp.) with a production of 86 475 tonnes or 30 percent of the total production. The hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) is the most preferred species since it grows faster than the native ones. Recently, it has been reported that production per unit area of the hybrid catfish is decreasing and it was suggested that this may be due to the quality of the male African catfish which has been introduced to Thailand a long time back.

Tilapia (*Oreochromis niloticus*). The production of tilapia contributes around 29 percent (83 780 tonnes) to the total freshwater aquaculture production, second to the walking catfish. There is a trend towards standardization of size, feeds and production systems, some quality control, avoidance of off-flavors and marketing into supermarket chains. The main cultured types are hormonal sex-reversed tilapia, the Genetically Improved Farmed Tilapia or GIFT strain, Chitralada strain and Tabtim strain. This exotic species has now become very popular for freshwater aquaculture in Thailand, especially for cage culture.

Thai silver barb (*Barbodes gonionotus*). Thai silver carp or Java barb, indigenous to Thailand, ranks third in terms production and contributes around 15 percent to the total freshwater aquaculture production. The Neo-male broodstock has been produced in order to develop all female fish which has a higher yield than mix-sex culture. However, the all-female culture is not very well accepted by farmers.

Snakeskin gourami (*Trichogaster pectoralis*). Sepat siam is another indigenous species that contributes around 8 percent to the total freshwater aquaculture production. Production remains high though the culture technique is limited to extensive culture system.

Giant prawn (*Macrobrachium rosenbergii*). Freshwater giant prawn contributes around 5 percent to the total freshwater aquaculture production. The production is increasing gradually following the introduction of an improved strain, the CP strain.

River catfish (*Pangasianodon hypophthalmus*). The river catfish also contributes around 5 percent to the total freshwater aquaculture production. It is still very common in animal-fish integrated culture system in the central part of the country.

Other important freshwater species whose production is less than 5 percent of the total production are snakehead (*Channa striata*), common carp (*Cyprinus carpio*) and soft- shell turtle (*Trionyx sinensis*).

SEED RESOURCES SUPPLY

Freshwater aquaculture, as mentioned earlier, has long been established and practiced in Thailand and more than 50 species of fish and invertebrates are presently cultured. Freshwater culture consists of four main systems: pond culture, ditch culture, paddy field culture and cage culture. Total production from inland culture was 226 100 tonnes in 1998, valued at US$271.4 million, an increase of 5.6 times in volume and 10.3 times in value from production data of 1981. The major production species were walking catfish, Nile tilapia, silver barb, snakeskin gourami, giant prawn and river catfish.

There are about 27 species of commercial species being cultivated under various types of systems ranging from super-intensive farming for commercial production to extensive culture, mainly for home consumption. There are 281 199 inland farms with a total cultivated area of 101 952 ha. Over 97 percent of the total area consists of ponds and paddy field-type culture systems. The remainder consists of dammed-up ditches, swampy areas and cage culture systems. The total Thai freshwater aquaculture production for the year 2003 was estimated to be 320 402 tonnes with the top five species being Nile tilapia, hybrid walking catfish, silver barb, freshwater prawn and snakeskin gourami. Production of tilapia in Thailand is moving away from green-water fertilized systems towards pellet-fed intensified systems.This may be a reflection of the available areas for aquaculture and increasing restriction on water availability and to some extent environmental requirements. The seed resources and supplies in Thailand come from two sources: (i) government hatcheries and (ii) private hatcheries.

Government hatcheries

There are 31 inland fisheries research and development centres, one research institute and 27 inland fisheries stations being operated and managed by the Department of Fisheries (DOF). Each station/centre/institute is located in each inland province and each fiscal year they have plans and budgets for producing fish seed and seed of other aquatic animals such as the freshwater prawn, frog, soft-shell turtle, *Moina*, *Chlorella*, etc. The location of government hatcheries is shown in Figure 7.18.1 and their production in 2005 are shown in Table 7.18.1, while production data for 2006 are shown in Table 7.18.2.

FIGURE 7.18.1
Map of Thailand showing the location of government hatcheries by provinces

Private hatcheries

Most private hatcheries are found in the surrounding provinces of the central part of Thailand such as Nakornpatom, Rachaburi, Phatumthane, Chachaengsoa, Samutprakan and Suphanburi; in other parts of Thailand, fish hatcheries are spread throughout the river side area. Since 2003, the DOF implemented a programme on Good Aquaculture Practice (GAP). Under this programme, farmers and hatchery operators have to register their farms/facilities with the DOF; farmers have to use seed and post-larvae

TABLE 7.18.1
2005 Production of fish fingerlings, freshwater post-larvae, frog larvae, *Moina* sp. and *Chlorella* sp. from fisheries stations and centres (in 1 000) (C = Inland Fisheries Research and Development Centre; S = Inland Fisheries Station)

No.	Station/Centre	Fish fry/ fingerlings	Prawn post-larvae	Frog post-larvae	*Moina* sp.	*Chlorella* sp.
1	Ching Mai (C)	1 509.804	0	0	6.5	0
2	Mae Hong Son (S)	913.890	0	0	0	0
3	Lamphun (S)	1088.200	0	1.6	0	0
4	Phayao (C)	647.066	0	0	0	0
5	Ching Rai (S)	3 381.854	0	0	11.5	0
6	Lampang (S)	1 774.617	0	0	0	0
7	Phitsanulok (C)	3 800.277	0	0	39.5	0
8	Sukhothai (S)	2 400.280	2	0	269	0
9	Phichit (C)	5807.200	0	0	0	0
10	Phetchabun (S)	2 882.505	0	0	0	0
11	Mae Hong Son (S)	913.890	0	0	0	0
12	Lamphun (S)	1088.200	0	1.6	0	0
13	Phayao (C)	647.066	0	0	0	0
14	Ching Rai (S)	3 381.854	0	0	11.5	0
15	Lampang (S)	1 774.617	0	0	0	0
16	Phitsanulok (C)	3 800.277	0	0	39.5	0
17	Sukhothai (S)	2 400.280	2	0	269	0
18	Phichit (C)	5807.200	0	0	0	0
19	Phetchabun (S)	2 882.505	0	0	0	0
20	Mae Hong Son (S)	913.890	0	0	0	0
21	Lamphun (S)	1088.200	0	1.6	0	0
22	Phayao (C)	647.066	0	0	0	0
23	Ching Rai (S)	3 381.854	0	0	11.5	0
24	Lampang (S)	1 774.617	0	0	0	0
25	Phitsanulok (C)	3 800.277	0	0	39.5	0
26	Phetchaburi (C)	2 222.509	0	18.35	0	0
27	Ratchaburi (S)	1 203.820	0	0	0	0
28	Chon Buri (C)	1 027.750	69.5	19.2	352.5	0
29	Samut Prakan(S)	2 355.070	0	0	0	0
30	Sa Kaeo (C)	1 335.525	0	0	0	0
31	Trat (S)	665.600	0	0	0	0
32	Rayong (C)	1813.153	97.4	0	0	0
33	Nakhonratchasima (C)	1268.650	0	0	140.5	0
34	Loei (S)	2037.900	0	0	0	0
35	Sakon Nakhon (C)	2048.930	395	0	0	0
36	Khon Kaen (C)	3163.280	0	0	0	0
37	Mukdahan (S)	2427.890	0	0	0	0
38	Kalasin (S)	5323.912	366.4	0	117	0
39	Amnat Charoen (S)	667.700	0	0	0	0
40	Udon Thani (C)	8114.831	0	0	336.5	0
41	Nongkhai (C)	3772.075	0	0	76.5	0
42	Roi Et (C)	3558.746	51	0	65	0
43	Ubon Ratchathani (C)	1381.098	0	0	3.5	0
44	Surin (C)	3797.728	0	0	58	0
45	Yasothon (C)	1716.686	0	0	27	0
46	Chaiyaphum (S)	3633.810	0	0	0	0
47	Si Sa Ket (S)	1211.016	0	0	15	0
48	Maha Sarakham (C)	1833.300	0	0	0	0
49	Nakhon Phanom (S)	1831.325	0	7.5	0	0
50	Narathiwat (S)	104.800	0	0	0	0
51	Songkhla (C)	1404.600	0	0	0	0
52	Yala (S)	955.255	0	0	0	0
53	Suratthani (C)	2481.860	195	0	34	0
54	NakhonSiThammmarat(S)	2154.035	0	0	15	0
55	Phatthalung (C)	4910.600	523.1	0	0	0
56	Trang (C)	2762.821	625	0	0	0
57	Pattani (C)	2255.950	0	0	0	0
58	Satun (S)	528.000	22.2	0	0	0
Total		**135 153.853**	**5 942.6**	**103.4**	**3 345.9**	**374**

(PL) from GAP hatcheries to ensure that their operations follow the GAP guidelines. The DOF started to record the number of hatcheries, their production areas and yearly production. The number of private hatcheries, area and yearly production by provinces in Thailand in 2005 are shown in Table 7.18.3.

TABLE 7.18.2
Production plan for fish fry/fingerlings, prawn post-larvae, frog larvae, *Moina* sp and *Chlorella* sp.
(C = Inland Fisheries Research and Development Centre; S = Inland Fisheries Station)

No.	Stations/Centres	Aquatic animal larvae		*Moina* sp.		*Chlorella* sp.	
		# of fry	Value (Baht)	Volume (kg)	Value (Baht)	Volume (kg)	Value (Baht)
1	Chiangmai (C)	1 870 500	1 000				
2	Mae Hong Son (S)	961 150	120 000				
3	Lamphun (S)	745 000	126 000				
4	Phayao (C)	626 000	651 000				
5	Chiang Rai (S)	2 962 500	1 200 000				
6	Lampang (S)	1 400 000	265 000				
7	Phrae (C)	2 802 000	300 000				
8	Nan (S)	1 179 000	269 000				
9	Tak (C)	2 475 000	400 000				
10	Phichit 9 (C)	5 892 000	847 500				
11	Phetchabun (S)	3 090 000	430 000				
12	Phitsanulok (C)	3 332 000	714 400				
13	Sukhothai (S)	2 848 000	337 000	320	16 000		35
14	Nakhon Sawan (C)	3 300 000	450 000				
15	Kamphaeng Phet (S)	2 370 000	395 750	85	4 250		
16	Suphan Buri (C)	1 796 700	189 000				
17	Kanchanaburi (C)	1 541 000	300 400				
18	Lop Buri (C)	1 650 000	400 000				
19	Sing Buri (S)	1 700 000	255 000				
20	Phetchaburi (C)	3 500 000	350 000				
21	Ratchaburi (S)	2 070 000	319 500				
22	Chai Nat (C)	3 170 000	420 000	400	20 000		
23	Uthai Thani (S)	297 000	144 900				
24	Pathumthani (C)	2 113 250	528 850	1 023	51 150	500	20 000
25	Ang Thong (S)	2 851 000	504 000				
26	Saraburi (S)	2 200 000	440 000				
27	Chon Buri (C)	1 250 000	192 000	360	18 000		
28	Samut Prakan (S)	1 200 000	300 000				
29	Sa Kaeo (C)	1 750 000	200 000				
30	Trat (S)	801 500	178 950				
31	Rayong (C)	2 548 000	427 400				
32	Udon Thani (C)	7 546 000	1 975 000	500	25 000		
33	Sakon Nakhon (C)	3 430 000	500 000				
34	Nakhon Phanom (S)	1 683 400	1 240 280				
35	NongKhai (C)	2 820 000	673 850	123	6 150		
36	Loei (S)	2 390 000	500 000				
37	Ubon Ratchathani (C)	1 665 000	515 900				
38	Amnat Charoen(S)	1 197 600	134 760				
39	Surin (C)	2 436 000	454 200				
40	Si Sa Ket (S)	1 155 908	299 100	18	900		
41	Roi Et (C)	2 850 000	400 000				
42	Yasothon (C)	2 028 100	500 000				
43	Mukdahan (S)	1 660 000	350 000				
44	Khon Kaen (C)	4 590 000	699 000				
45	Maha Sarakham (C)	1 370 000	155 000				
46	Kalasin (S)	3 827 000	520 000				
47	Nakhonratchasima (C)	1 515 000	313 000	300	15 000		
48	Chaiyaphum (S)	2 811 500	600 050				
49	Surat Thani (C)	4 009 000	1 070 624	150	7 500		
50	Nakhon Si Thammarat (S)	2 580 000	484 000				
51	Trang (C)	2 846 000	462 600				
52	Satun (S)	700 000	100 000				
53	Songkhla (C)	625 720	195 220				
54	Yala (S)	1 445 000	201 100				
55	Pattani (C)	2 085 000	366 000				
56	Narathiwat (S)	250 000	50 000				
57	Phatthalung (C)	5 325 000	850 000				
58	Inland Aquaculture Research Institute	1 490 000	837 200				
Total		**132 622 828**	**27 102 534**	**3 279**	**163 950**	**500**	**20 000**

TABLE 7.18.3

Number of private hatcheries, area and yearly production by province in Thailand, 2005

No.	Province	No. of farms	Area (in rai)	Yearly production of fry/fingerlings
1	Bangkok	54	1 635.0000	188 258 000
2	Samutprakan	47	696.0000	1 803 792
3	Nonthaburi	6	207.0500	74 010 100
4	Pathumthani	42	425.9794	80 945 480
5	Ayutthaya	25	359.5312	225 395 005
6	Ang Thong	10	39.5000	12 232 000
7	Lop Buri	11	117.0000	1 522 053 000
8	Sing Buri	15	97.8750	48 970 000
9	Chai Nat	7	3.2500	10 004 100
10	Saraburi	25	129.6908	33 030 700
11	Chon Buri	694	2048.936	130 499 949 040
12	Rayong	157	268.0656	5 038 000 200
13	Chanthaburi	52	174.7627	1 181 343 510
14	Trat	42	212.3380	4 746 254 840
15	Chachoengsao	750	2185.4327	12 136 333 519
16	Prachin Buri	15	63.6000	23 152 000
17	Nakhon Nayok	70	423.7900	17 718 450
18	Sa Kaeo	3	5.2500	1 600 000
19	Nakhonratchasima	25	93.0500	55 742 000
20	Burirum	5	35.2500	3 100 000
21	Surin	86	467.8172	231 207 442
22	Si Sa Ket	37	27.5000	6 105 550
23	Ubon Ratchathani	202	600.2339	104 499 690
24	Yasothon	2	0	250
25	Chaiyaphum	194	280.2500	30 462 300
26	Amnat Charoen	60	898.6250	120 000 680
27	Nong Bua Lam Phu	29	247.6000	180 003 000
28	Khonkaen	81	223.4700	30 143 700
29	Udon Thani	22	147.7500	39 365 300
30	Loei	11	51.0000	7 370 000
31	Nong Khai	208	1390.4600	383 482 300
32	Maha Sarakham	267	2121.7221	1 743 589 700
33	Roi Et	293	802.4562	5 257 210 850
34	Kalasin	94	411.0000	11 303 100
35	Sakon Nakhon	12	73.5000	10 184 500
36	Nakhon Phanom	27	60.6000	7 855 700
37	Mukdahan	10	17.0000	8 001 550
38	Chiang Mai	16	786.915	22 475 000
39	Lamphun	1	0	2 000
40	Lampang	29	194.7112	3 037 100
41	Uttaradit	4	43.0000	13 001 000
42	Phrae	2	0.5000	2
43	Nan	2	6.0000	1 400 000
44	Phayao	70	306.1173	32 600 780
45	Mae Hong Son	6	8.5700	594 000
46	Nakhon Sawan	364	483016.0725	2 808 667 510
47	Uthai Thani	9	63.0000	10 069 500
48	Kamphaeng Phet	8	49.5000	162 000
49	Tak	7	17.5000	970 000
50	Sukhothai	282	301.9500	15 954 502
51	Phitsanulok	23	190.2500	79 927 000
52	Phichit	14	194.7500	102 555 000
53	Phetchabun	24	204.0000	52 085 000
54	Ratchaburi	28	352.0000	171 220 027
55	Suphan Buri	208	1798.8400	11 241 115 285
56	Nakhon Pathom	201	1075.9450	19 490 873 000
57	Samut Sakhon	73	1054.5000	73 061 760
58	Samut Songkhram	20	25.9610	103 264 000
59	Phetchaburi	24	124.5625	0
60	Prachuap Khiri Khan	171	213.8550	1 933 837 000
61	Nakhon Si Thammarat	354	1217.3150	10 679 830 193
62	Krabi	45	110.9000	1 476 568 000
63	Phangnga	166	474.4300	13 403 700 215
64	Phuket	442	1027.8581	18 327 273 051
65	Surat Thani	36	41.9030	85 410 000
66	Ranong	2	9.0000	0
67	Chumphon	7	159.0000	6 024 400 000
68	Songkhla	531	648.0200	7 446 459 520
69	Satun	183	285.2417	2 770 628 000
70	Trang	155	253.4870	21 370 982 980
71	Phatthalung	43	138.6710	187 097 000
72	Pattani	185	258.9810	1 106 018 030
73	Yala	9	2.1025	305 000
74	Narathiwat	28	47.6238	173 227 600
Total		7 462	511 745.3684	283 279 452 403

Rai: a unit of land measure equal to 1600 m^2 (about 0.4 acre)

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Aquaculture contributes around one fourth of the country's total fish production of 3.6 million tonnes. In 2003, aquaculture production was around 0.773 million tonnes and valued at US$1.91 billion. Nile tilapia contributed the highest freshwater production of 97 209 tonnes but the giant freshwater prawn shared the highest contribution in terms of value. Detailed values on freshwater aquaculture production are presented in Annex 7.18.3.

Through years of scientific research, fish breeding and culture techniques have been developed and well established in Thailand leading to the success of mass breeding of many native fish and introduced species. Many of Thai breeders are specialized in specific groups of fish such as carp, catfish, tilapia, freshwater prawn, etc. The varieties of freshwater fish species in the Thai market are more than 50 species, of which 40 species are native to Thailand.

Seed and feed are the primary source of production costs in aquaculture. There is a need to research and develop ways of decreasing production costs and disseminating existing and new technologies. Development of low phosphorus feeds to reduce environmental impacts is also recommended. Since most of the feed ingredients are imported, especially fishmeal, the government has to reduce import tax. For feed management at different stages from broodstock to fry, most hatcheries use both live food and formulated feeds. The green-water technique is still used for larval rearing in some species as a direct food source through active uptake by the larvae and as indirect source of nutrients for fish larvae through the food chain. Many kinds of formulated feeds, such as micro-particulated diet, powder feeds, etc., are normally applied for rearing fish larvae.

There are significant opportunities for research leading to improved seed quality/quantity, reproduction and early development of cultivated species. Successful research programmes in seed quality, reproduction and early development of cultivated species could enable year-round maturation and production, on demand, of gametes and fry of economically valuable species. It could also result in new markets for specialized broodstock, early life history stages and related technologies; and for technologically advanced delivery systems for chemical compounds to enhance reproductive performance.

SEED MANAGEMENT

Many hatcheries have good experiences in breeding specific fish species and freshwater fish are bred for commercial purpose. Some marine species were bred successfully only in government hatcheries. The size of the hatcheries depends on the species of fish, but in general, they are mostly small. The biggest private hatchery is Charoenpokaparn Company Ltd. (CP) which is famous for producing Ruby tilapia, freshwater prawn and seabass seed.

There are over 50 freshwater fish species, both native and exotic, found in the seed market. Local freshwater fish that can be bred are over 40 species belonging to the group of Cyprinidae, Siluiform, Bilontidae and Osphornamidae. Many species of introduced fish can also be bred successfully in Thailand such as tilapia, African sharp tooth catfish and Pacu fish. There is a current trend of increasing demand and supply for breeding exotic species or commercial species.

In addition to seed availability for certain species, the quality of seed is also an issue. Thailand have had a similar approach to the supply of seed, particularly for freshwater species such as carp, catfish, tilapia and freshwater prawn. Policy-makers recognize that the public sector, through government hatcheries, should provide seed if private hatcheries do not exist, or lack the capacity. Government hatcheries were established either for the whole country or for individual regions. Their purpose was to supply fry and fingerlings, and also to demonstrate hatchery technologies. Interested farmers were

PLATE 7.18.1
Important freshwater aquatic species in Thailand

Nile tilapia

Hybrid catfish

Thai silver barb

Snakeskin gourami

Common carp

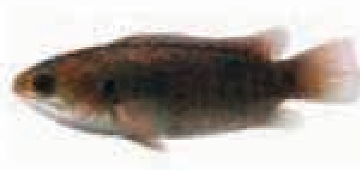
Giant gourami

given training and provided with broodstock. The role of government hatcheries was to spur the cultivation of a species by supplying fry and fingerlings free or low cost, but as private hatcheries developed their role changed to provide fry to small-holders or sell to the government for stocking in public water.

The government hatcheries frequently concentrate on products that have a broader social interest, such as broodstock, or on species that are unattractive to the private sector such as indigenous freshwater species. These hatcheries suffer from lack of funding, not enough budget for developing and are obliged to generate income by selling fish. However, they produce fingerlings, provide some extension and even undertake research.

The network of two fisheries research institutes and 58 fisheries centres/stations are mandated to produce seed for indigenous and commercial species but they also provide seed when seed demand is high. Generally, fish seed production is in private hands. In northeastern Thailand, most of the private fish farms are also involved in

PLATE 7.18.2
Important freshwater aquatic species in Thailand



Climbing perch

Gouramy

Striped catfish

Giant river prawn

Frog

Soft shell turtle

seed production of carp, rohu and tilapia and where there are shortages, these may be more attributable to poor roads than to actual shortages. Government hatcheries often concentrate on broodstock and subsidized seed supply but because they have a non-profit goal, there are concerns over lack of funding. Also, there is a potential for corruption.

A common constraint in increasing seed availability is poor linkage between seed producers and growers. Seed producers may not see the need for a central clearing house to inform growers of their closest seed supplier. As a result growers often have to rely on fry traders. To encourage better linkages in the production chain, the Thai government through the DOF has developed information centres to connect seed producers and fish growers and organizes regular private/public seed markets . This requires databases by hatcheries and species. The policies are designed to improve the market system and match hatcheries with farmers.

SEED QUALITY

The Thai Government through the DOF are now supporting the fish seed business by setting up research projects on genetics and biodiversity of cultured species through the recently established Fish and Aquatic Animal Genetics Research Institute, located in Thunyaburi District, Phatomthane Province. The DOF also plays an important role in research and development of aquaculture and seed quality control. At present, there are 59 freshwater fisheries research and development institutes/centers/stations, 26 coastal fisheries research and development centers/stations and six aquatic animal genetics research and development centers/stations throughout the country. These institutes/centers/stations carry out both basic and applied aquaculture research, they also produce fry and fingerlings. These government hatcheries has also improved farmed species by encouraging collaborative research with universities.

Traditional activities have involved selection of desirable characteristics and improvement of the breeding stocks. Today, many breeders/hatcheries are encouraged by the potential profits and have improved breeding techniques and increased the production of various fish seed. Thailand has good climate, land, water resources and manpower suitable for the fish seed production. The Thai Government through the DOF are now supporting the business by transferring new technologies through training, provision of selected broodfish and technical services on GAP and food safety.

SEED MARKETING

Because of the large size of the country, prices of aquatic products, like any other product, vary greatly across regions. In addition, for each region, they change with seasons. The lack of complete data sets on market prices of different cultured species in Thailand makes it difficult to accurately determine the financial contribution of different cultured species to aquaculture and/or to the fisheries sector. A rough estimation of this contribution is made based on prices of some aquatic products which were provided by the Thailand Fisheries Information Network which collects information from different wholesale markets at different times since 1999. For each species, the price used for the estimation is the average price from different wholesale markets in different seasons. Data are presented in Table 7.18.4.

The distribution and marketing channels for the fish seed in Thailand are relatively well developed. The wholesaler plays an important role in linking up the producers/hatcheries and consumers. The hatcheries, specialized in breeding the commercial or favoured species and the farmers who focus on producing table fish (consumable

TABLE 7.18.4
Absolute and relative contribution of major cultured freshwater species to the value of the 2002 freshwater aquaculture in Thailand

Species	Product (1000 tonnes)	Price (Baht/tonne)	Value (million Baht)	% of aquaculture value
Striped snakehead	22	59 622.73	1 311.7	8.96
Walking catfish	68.4	33 805.56	2 312.3	15.8
Common climbing perch	5.4	36 462.96	196.9	1.35
Common silver barb	83.3	30 104.44	2 507.7	17.13
Nile tilapia	113.6	28 421.65	3 228.7	22.05
Common carp	18.6	27 360.22	508.9	3.48
Snake skin gourami	18.7	37 695.19	704.9	4.82
Catfish	12.1	17 223.14	208.4	1.42
Other fish	79.3	32 571.25	2 582.9	17.64
Giant freshwater prawn	4.8	122 916.67	590.0	4.03
Shrimps	1.4	234 928.57	328.9	2.25
Others	1.6	98 250.00	157.2	1.07
Total	**429.2**	**n.s.**	**14 638.5**	**100**

Source: Fisheries Statistics of Thailand 2002. Department of Fisheries fish) usually sell their products to the wholesalers. The wholesalers could also buy the products (consumable fish) from farms in the region and distribute them to the local fish market or cold storages. Wholesalers usually sell fish seed to exporters or local retailers. Exporters would in turn sell fish seed to importers overseas, while retailers sell fish seed directly to local farmers. Hatcheries may also sell fish seed directly to farmers. Nowadays, contract farming is commonly practiced. Sometimes wholesalers have also ventured to running hatchery business to guarantee a stable supply of seed for their needs.

Thailand is regarded in the aquaculture business sector as one of the biggest exporter of fish seed. The country exports fish seed to over 20 countries worldwide with a value estimated at over US$15 million annually. The main export markets of fish seed are India, Bangladesh, Myanmar, Lao PDR, Viet Nam, Malaysia, Indonesia and Taiwan Province of China.

SEED INDUSTRY

Subsistence freshwater aquaculture, as well as inland capture fisheries, both play vital roles in food security of rural people particularly in remote areas. In contrast, intensive freshwater aquaculture and brackishwater aquaculture generally involve higher financial investment and skilled labor forces. From 10 percent of total fisheries production in the Southeast Asia region, aquaculture's share increased from 12.9 percent in 1990 and 23.2 percent by 2004. Thailand have a long-established commercial aquaculture industry and were pioneers in brackishwater cultivation. Culture of freshwater fish and prawn, marine shrimp in Thailand was encouraged by governments for food security and foreign exchange. Seed industry was also developing according to the increasing demand of seed for commercial aquaculture.

Seed production and seed quality have also been the focus of policies and regulations. In Thailand, government hatcheries undertake research, training and technology dissemination. They also produce fingerlings. Some are destined for small-scale farmers and are subsidized and oriented to particular regions. They may also concentrate on particular species deemed to have potential commercial value. These government hatcheries have become a minority in production compared with private hatcheries, which have taken over the seed industry.

The government deliberately encouraged private hatcheries by providing incentives as soft loans or tax exemptions. They can be oriented to particular species, as *Tilapia* and *Macrobrachium*. The incentives may also be available to foreign investors. Such incentives have succeeded in increasing private hatchery production of seed. To improve seed quality from the private sector, regulations and inspections are used in Thailand. Monitoring and enforcement, however, is expensive; it also requires skilled personnel.

For the seed industry, there are also preferential credit for household farmers and large-scale farms. *Tilapia*, common carp and freshwater prawn are among the species whose cultivation is constrained by seed quality. *Tilapia* and *Macrobrachium* farming are also handicapped by seed shortages in some regions and season. A serious constraint for certain species is seed availability and quality. To increase seed availability other policies have been adopted. The goverment allows the import of equipments, material supplies and the employment of foreign technicians. To increase availability of seed and to lower the price of seed, the DOF have strict prohibitions on the export of broodstock. The government allows the export of fish seed to other countries and also imports from other countries. However, the seed has to pass strict quarantine and quality controls.

The private sector has a network of hatcheries and nurseries for their freshwater aquaculture that supplies fry and fingerlings preferred by farmers. Nursing farms also need to be developed. Fish seed production is highly segmented with farmers specialized in breeding and production of larvae and young fry which are sold to others who grow them to a larger size.

Even more significant of Thailand's freshwater seed industry is the employment in freshwater fish farming. In 1992, Thailand's employment in freshwater aquaculture was estimated at 239 684. Since 1992, output of freshwater fish in Thailand has almost tripled, so employment would also have increased. A conservative estimate would suggest that at least 500 000 people are currently employed in freshwater aquaculture with 600 000 employed in total. Data on household income suggest that aquaculture was a lucrative activity. In 1992, except for carp culture, households earned on average more than US$1 000 growing freshwater fish. Fresh water prawn farming was even more lucrative with household incomes approaching US$12 000.

SUPPORT SERVICES

The DOF, under the Ministry of Agriculture and Cooperatives, plays an important role in aquaculture development planning and implementation in Thailand. These include aquaculture extension services and transfer of fish culture technologies. Administration of the DOF is divided into two parts: the central administrative and the regional administrative sections. The central administrative part includes five bureaus and nine divisions; whereas the regional administrative part includes 75 provincial fisheries offices. The organizations within DOF that share responsibility for aquaculture management and development include three bureaus (Inland Fisheries Research and Development Bureau, Coastal Fisheries Research and Development Bureau and Fisheries Development and Technology Transfer Bureau), three divisions (Aquatic Animal Genetics Research and Development Institute, Fishery Technological Development Division and Fish Inspection and Quality Control Division, 31 inland fisheries research and development centers, 15 coastal fisheries research and development centers and 75 provincial fisheries offices.

There are at least 16 universities around the country that offer aquaculture and related courses from diploma to post-graduate (e.g. PhD) degrees. These universities also carry out research on aquaculture and offer training courses on several aspects of aquaculture. New technologies have been transferred to farmers and private hatcheries through training and other mass media services such as radio/television broadcast, internet and websites, etc.

There are many educational institutes that provide courses on aquaculture or bioscience from vocational to university levels. The areas of aquaculture research and development are also established in both the academic field and within the DOF. All these research and development bodies need linkages, strengthening and budget support. The DOF's budgetary allocation for fisheries research steadily increased from 1992 to 1998 valued between 2 400 to 3 800 million Baht (US$96-152 million). The private sectors dealing with aquaculture business should also play their roles in supporting research and extension works.

SEED CERTIFICATION

There have been great concerns in aquaculture products' quality worldwide. Recently, the DOF developed guidelines on aquaculture farm standardization to ensure that aquaculture products are safe and produced through farm-to-table approaches. These guidelines are presently on a voluntary basis but will become mandatory in the near future. At present, three guidelines are available as follows:

- Code of Conduct for Responsible Aquaculture (CoC) has been developed for the marine shrimp beginning from hatchery, farm, aquaculture business (feed, therapeutic agents and chemicals), product distributor and processor. The DOF audits and certifies hatcheries, farms, distributors and processing plants in order to issue the label CoC product.

- Good Aquaculture Practice (GAP) emphasizes an aquaculture product that is fresh, clean, free of therapeutic agents and chemicals and non-contaminated with disease. GAP is a fundamental practice to be implemented by farmers in order to achieve successful implementation of CoC in the future.
- Safety Level is only for freshwater aquaculture product used for domestic consumption.

The DOF targets 30 000 hatcheries and farms to be certified for CoC and GAP for the year 2004. Farms/hatcheries are regularly monitored for hygiene and GAP with emphasis on the use of feed and therapeutants. Therapeutants such as oxytetracycline, oxolinic acid, chloramphenical and nitrofurans in raw materials are monitored by DOF laboratories. DOF officers randomly sample seed, feeds, water and end-products or prior to harvesting products at farms through analyses using HPLC, ELISA or LC/MS/MS techniques depending on the chemical substances involved.

The Inland Fisheries Reseach and Development Bureau is the main government institute providing support to the industry by transferring new technologies to farmers/hatchery operators through training, provision of selected broodfish and other technical services. The policy of the bureau is to present useful and up-to-date information in suitable form to farmers, hatcheries and other stakeholders involved in fish seed production. Another activity of the DOF is to create an accreditation scheme for hatcheries. The use of the scheme is to ensure that strict control is consistenly exercised so that only high quality fish seed are produced and sold. Hatcheries need to have a dedicated warehouse with adequate breeding tank and nursing facilities, reservoir tank for water suppling, polluted water treatment system and footbaths at entrance to the farmgate, etc. Under the scheme, the bureau routinely (i) collects samples of water, fish seed and other aquatic animals produced from these hatcheries for laboratory examination for pathogens and (ii) restrict the use of drugs and chemicals. The bureau confirms the absence of certain kinds of pathogens, restricted use of chemicals and drugs by the hatcheries.

LEGAL AND POLICY FRAMEWORKS

Many legislation/regulations have been applied as management tools of the government in order to effectively manage and monitor the aquaculture industry in Thailand. These include:

- Fisheries Act 2490;
- DOF Regulation on the Application and Certification on Live Black Tiger Shrimp (*Penaeus monodon*) Exportation, BE. 2547;
- DOF Regulation on the Application and Certification on the Importation of Aquatic Animals for Broodstock, BE. 2547;
- Organic Aquaculture Standard;
- DOF Regulation on the Importation and Registration of Hatchery and Farms for Breeding and Genetic Improvement of Pacific White Shrimp (*Penaeus vannamei*);
- DOF Regulation on the Certification of Marine Shrimp Hatchery Performing the Code of Conduct Production;
- DOF Regulation on the Certification of Marine Shrimp Grow-out farm Performing the Code of Conduct Production;
- DOF Regulation on the Certification of Marine Shrimp Production with Good Aquaculture Practice BE. 2546;
- Animal Epidemic Act 2547/2499;
- Food Act 2542.

ECONOMICS

In Thailand, aquaculture makes an important contribution to the national GDP. In 2002, aquaculture accounted for 2.07 percent of the total GDP (Sugiyama, Staples and

Funge-Smith, 2004). Aquaculture also plays a substantial role in providing vital income generation opportunities to the people. In 2001, aquaculture offered full-time or part-time jobs to 80 704 households while capture fisheries offered employment to around 50 198 households.

The aquaculture industry generates many other related businesses. Among the important ones are fish seed, fish feed, chemicals suppliers, storage, processing, marketing, etc. Since fish seed is a key factor to the success of the aquaculture industry, seed production needs to be developed before expandinf existing national aquaculture production plan.

INFORMATION OR KNOWLEDGE GAPS

The increasing importance of aquaculture strongly argues for government to give priority to developing clear, well-formulated, implementable and realistic national and local policies for aquaculture development, based on financial, social and environmental sustainability. As the private sector is the key to successful land sustainable aquaculture development, the views of the industry should be taken into account with respect to policy formulation, research and development.

Aquaculture in Thailand will retain its increasingly crucial function to maintain the importance of low-input aquaculture as a protein food supplier for domestic consumption as well as to develop a highly competitive, sustainable aquaculture industry in Thailand to meet consumer demand for cultivated aquatic foods and products that are of high quality, safe, competitively-priced and nutritious and are produced in an environmentally responsible manner with maximum opportunity for profitability in all sectors of the export industry.

FUTURE PROSPECTS AND RECOMMENDATIONS

Since capture fisheries are being harvested at or above their maximum sustainable yield, aquaculture is playing an increasing role as a protein food supplier to the world population. Thailand has proved to be a country of high potential and success in aquaculture for decades. The increasing contribution of aquaculture, in brackishwater or freshwater, has become a substantial part of the country's economic development. Further development of aquaculture is, therefore, of great national interest. A consensus has been developed that a dramatic increase in aquaculture is needed to supply both domestic and foreign growing aquatic food needs.

The continued growth and competitive position of the Thai aquaculture industry in the global market place will be directly related to the resources invested in research and technology development. The diversity of species cultured, seed quantity and quality and the production systems employed present added challenges for aquaculture's future research agenda.

An expanded research and technology development programme for aquaculture will offer significant benefits to both producers and consumers of aquatic products by enhancing production efficiency and quality of aquatic organisms cultivated for both food and non-food purposes. It will also help assure environmental compatibility of aquaculture systems, enhance understanding of biological systems and processes, lead to development of new or improved aquatic products and processes and contribute to conservation, enhancement, or utilization of important genetic resources.

There are opportunities to substantially improve production efficiency through research in the areas of genetics and seed quality development, i.e. improving traditional aquatic animals breeding, broodstock development; aquatic animal health, i.e. population health management, pathogen-free and disease-resistant broodstock; healthy reproduction and early-stage larvae development, i.e. year-round maturation and production and growth, development and nutrition, i.e. increased survival, faster growth rates, better feed conversion rates, improved environmental tolerances, etc.

There are also significant opportunities for research and technology development to improve the sustainability and environmental compatibility of aquaculture systems. Of primary concern is the protection and conservation of the nation's water resources. Beneficial results could include improved water utilization, reduced waste output from aquaculture systems, improved waste management, development of economically viable uses of waste byproducts and reduced costs of waste treatment. Additionally, new markets for innovative water re-use systems and waste management technologies should be developed.

The development of improved means to assure safety and quality of aquaculture products through innovative processing technologies and new product development represent important opportunities for aquaculture. Research can lead to new techniques to improve the freshness, color, flavor, texture, taste, nutritional characteristics and shelf-life of cultivated aquatic animals. Practical technologies can be developed to detect, assay and reduce toxins, contaminants and residues in aquacultural products. Development and adoption of uniform quality standards throughout the aquaculture industry and assurance of product safety and high quality will improve consumer confidence in domestically cultivated aquatic animals.

There is considerable pressure on aquaculture to reduce its reliance on feeds containing fish meal and also to increase the efficiency of its current usage of this resource. There is no doubt that the high value sector of aquaculture is growing and this sector is the most reliant on feeds containing fish meal and fish oil. Within the aquaculture sector, there is likely to be shifts in feeding and feed composition since the freshwater aquaculture sector has a greater opportunity to use non-marine sourced feed ingredients, particularly slaughterhouse wastes, brewery wastes and agricultural mill by-products.

There is a need for expanded and improved extension educational programmes, incorporation with industry and researchers, to communicate promising research results to demonstrate profitable technologies and to educate consumers and the public. There is also a need for other support services of the aquaculture industry including public information access and retrieval systems, aquatic plant and animal health services, marketing services, statistical and economic support services, etc.

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ANNEX 7.18.1

Number of farms, area under culture by type of culture and province (2002) - Area :ha

Province	Total		Pond		Paddy cum Fish		Ditch		Cage	
	No.of farm	Area	No.of farm	Area	No.of farm	Area	No.of farm	Area	No.of farm	Area
Buri Ram	8 964	1 527	8 618	1 334	345	193	1	-	-	-
Maha Sarakham	4 513	2 290	3 608	1 070	905	1 220	-	-	-	-
Yasothon	4 970	975	4 503	537	436	416	30	22	1	-
Roi et	1 808	472	1 464	265	344	207	-	-	-	-
Loei	4 959	1 534	4 828	1 528	8	5	4	1	119	1
Si Sa Ket	10 753	1 480	10 102	923	651	557	-	-	-	-
Sakon Nakorn	1 496	427	1 482	414	14	12	-	-	-	-
Surin	17 112	2 233	16 667	1 635	415	588	17	5	13	5
Udon Thani	16 964	4 304	16 949	4 293	15	11	-	-	-	-
Ubon Ratchathani	9 281	1 548	8 361	1 062	856	485	1	-	63	-
Mukdahan	4 931	821	4 879	815	19	5	2	-	31	-
Nong Bua Lum Phu	3 279	561	3 235	538	40	22	4	1	-	-
Amnat Charoen	3 620	585	3 197	349	392	235	2	1	29	-
Central Plain	52 494	58 646	45 475	38 478	4 025	18 257	2 691	1 900	303	11
Bangkok Metropolis	1 082	2 372	1 044	2 311	15	56	8	6	15	-
Kanchaburi	991	545	886	511	9	10	27	24	69	1
Chantaburi	1 021	259	1 021	259	-	-	-	-	-	-
Chachoengsao	4 455	5 466	3 585	1 320	677	4 009	192	137	1	-
Chonburi	757	1 158	709	1 072	43	81	5	5	-	-
Chai Nat	1 575	214	1 551	213	-	-	16	1	8	-
Trat	537	131	537	131	-	-	-	-	-	-
Nakhon Nayok	1 305	592	1 303	590	1	2	1	-	-	-
Nakhon Pathom	5 117	4 947	5 061	4 921	1	3	54	23	1	-
Nonthaburi	1 536	899	812	226	48	250	667	424	9	-
Pathum Thani	2 078	1 527	1 083	1 306	-	-	247	219	28	2
Prachuap Khiri Khan	1 359	315	312	1	3	-	-	1	-	-
Prachin Buri	1 170	619	1 147	618	1	1	1	-	21	-
Ayutthaya	3 374	2 138	3 018	1 821	3	9	327	307	26	1
Phetchaburi	851	381	848	374	-	-	3	6	-	-
Rayong	1 229	387	1 228	387	1	-	-	-	-	-
Ratchaburi	2 687	3 069	2 573	2 948	23	39	91	83	-	-
Lop Buri	1 204	352	1 170	320	20	24	10	7	4	-
Samut Prakan	5 567	20 553	3 897	11 692	1 669	8 859	-	-	1	2
Samut SomgKharm	509	776	29	16	200	708	274	51	6	-
Samuy Sakhon	3 046	7 058	1 688	2 692	961	3 932	396	433	1	-
Saraburi	1 237	491	1 173	441	10	3	54	47	-	-
Sing Buri	1 128	236	1 040	218	3	5	78	13	7	-
Suphan Buri	3 473	2 732	3 331	2 616	35	84	64	32	43	-
Sa Kaeo	4 582	1 182	4 197	952	301	175	62	50	22	4
Ang Thong	624	247	467	210	3	3	114	33	40	1
Southern	26 611	2 599	25 845	2 466	29	8	706	123	31	2
Krabi	746	99	746	99	-	-	-	-	-	-
Chumphon	873	109	873	109	-	-	-	-	-	-
Trang	2 350	223	2 349	221	1	1	-	-	-	-
Nakhon Si Thammarat	3 049	384	2 911	326	12	6	120	53	-	-
Yala	1 155	88	1 149	87	3	1	3	-	-	-
Pattani	1 308	96	1 253	93	-	-	37	3	18	-
Phangnga	557	87	556	82	-	-	1	5	-	-
Phatthalung	4 668	369	4 377	336	-	-	285	33	6	-
Phuket	235	26	234	26	-	-	1	-	-	-
Narathiwat	1 947	155	1 929	153	-	-	18	2	-	-
Ranong	467	37	466	37	-	-	1	-	-	-
Songkhla	3 065	298	2 860	275	4	-	196	22	5	-
Satun	845	76	843	75	1	-	1	1	-	-
Surat Thani	5 352	553	5 299	548	8	-	43	3	2	2

ANNEX 7.18.2

Quantity of main freshwater species produced

Species	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total	**177 759**	**200 663**	**229 120**	**239 760**	**226 772**	**252 553**	**270 974**	**279 654**	**294 465**	**320 402**
Nile tilapia	59 397	76 054	90 416	91 112	73 427	76 460	82 363	84 480	83 780	97 209
Catfish, hybrid	34 170	44 120	47 711	60 759	57 466	72 289	76 000	77 905	86 475	90 248
Thai silver barb	24 133	27 432	37 615	35 100	38 951	41 289	46 276	42 152	44 242	48 844
Giant river prawn	10 124	7 792	8 000	7 856	4 764	8 494	9 917	13 310	15 393	35 102
Snakeskin gourami	16 993	16 714	14 200	17 230	17 214	21 989	21 577	22 519	24 179	13 590
Striped catfish	13 189	12 000	10 300	6 860	11 200	11 339	13 226	14 638	14 837	8 887
Common carp	3 419	3 556	3 887	4 209	7 093	5 811	5 539	4 773	5 046	6 861
Freshwater fishes	1 154	2 178	2 720	1 661	2 059	2 831	5 318	5 019	5 381	5 851
Striped snakehead	6 500	5 790	7 750	6 921	5 336	4 005	4 447	6 830	5 483	5 773
Roh labeo	2 899	1 481	2 590	2 736	1 876	1 704	1 172	1 595	2 125	1 960
Mrigal carp	444	478	680	670	1 620	1 285	1 057	798	985	1 543
Frogs	353	137	439	440	1 132	1 010	1 033	1 046	835	1 326
Climbing perch	1 944	949	1 189	910	763	760	470	403	519	1 049
Silver carp	2 059	654	402	1 032	565	481	438	202	202	581
Giant gourami	15	349	30	1 160	1 475	1 709	1 487	1 182	1 555	526
Soft-shell turtle	70	80	117	150	324	342	367	2 523	3 143	487
freshwater eel	<0.5	1	<0.5	12	16	539	38	38	25	240
Gouramis	58	259	374	349	93	97	169	154	165	220

ANNEX 7.18.3

Value of main freshwater fish species

US$ "1000										
Species	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total	177 540.20	216 439.40	236 128.10	233 643.70	167 719.40	226 885.30	245 800.20	208 569.90	255 658.20	347 097.50
Giant river prawn	37 881.90	33 684.60	31 972.10	25 108.40	14 168.80	28 343.10	32 518.30	35 727.90	41 335.40	124 874.90
Nile tilapia	35 191.70	53 789.10	66 111.60	58 705.20	45 963.00	53 457.20	57 775.50	51 088.10	62 615.20	75 201.60
Catfish, hybrid	32 446.60	45 477.50	47 029.20	63 394.30	37 111.20	52 318.80	52 494.80	45 744.40	56 935.90	60 060.50
Thai silver barb	21 994.60	26 139.90	32 832.40	30 154.10	26 303.30	32 197.30	40 504.50	25 187.30	32 766.60	39 895.80
Snakeskin gourami	19 338.80	24 621.40	20 177.60	23 037.00	15 878.00	28 962.30	28 755.20	20 216.80	25 611.10	15 645.40
Striped snakehead	12 421.90	12 303.50	16 104.20	14 639.60	7 441.50	6 585.10	7 214.20	7 778.00	7 854.80	8 593.60
Common carp	3 273.80	4 363.40	4 313.10	4 192.10	5 655.90	5 190.60	4 801.10	3 301.10	3 828.80	6 183.50
Striped catfish	6 676.20	6 228.00	5 913.70	3 610.60	4 608.90	5 954.80	6 919.40	4 856.00	6 541.30	4 589.10
Soft-shell turtle	1 432.40	1 689.00	2 428.40	1 988.60	2 212.50	4 847.10	5 497.00	6 132.00	9 390.90	3 238.10
Freshwater fishes nei	544.70	3 030.10	3 875.70	1 360.30	1 351.60	2 032.50	3 610.70	4 269.80	2 629.30	2 668.40
Frogs	705.80	321.00	877.80	771.80	1 421.80	1 494.50	1 450.80	893.40	975.30	1 556.60
Roho labeo	1 935.50	1 569.40	2 155.40	2 292.40	984.30	1 165.70	786.70	992.60	1 301.10	1 382.00
Climbing perch	2 143.60	1 447.90	1 346.50	1 080.40	1 512.50	882.80	540.80	369.80	592.70	1 267.60
Mrigal carp	423.20	417.90	536.90	481.90	864.80	713.60	581.50	382.70	673.30	985.2.00
Giant gourami	41.40	894.70	74.90	2 358.70	1 936.10	2 485.50	2 119.70	1 490.20	2 471.70	553.40
Silver carp	1 088.10	462.00	378.60	468.30	305.20	254.40	230.00	139.80	134.80	401.80

7.19 Freshwater fish seed resources in Uganda

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ABSTRACT

The aquaculture sector in Uganda has started to grow very rapidly during recent years with the commercialization approach taken by the government. Aquaculture is now seen not only as source of dietary protein but also as a means of generating income through improved productivity and managing aquaculture production as a business venture. This has attracted a new class of farmers.The issues of fish seed availability and quality have become a major challenge. This new trend has made the government to turn to private sector for improved supply of the required quality and to meet the needed quantity of fish seed. Fish seed propagation in Uganda was, until the late 1990s, a remit of the public sector. Currently there are nearly 50 private fish hatcheries ranging from small- to medium-scale with a few large commercial operation. The country's projection for meeting the aquaculture and stock enhancement seed requirements is about 450 million fingerlings annually. The general plan is to meet this demand through privately-owned and operated fish hatcheries. Use of the private sector calls for trained manpower and exposure to appropriate technology. There is also urgent need to improve broodstock management skills and to initiate breeding programmes for improvement of the productivity of key aquaculture species. Although government has established some regulations under the "Fish (Aquaculture) Rules 2003" to regulate fish seed production and distribution, there is still a need for technical assistance to review and develop clear and implementable standards and guidelines for the private fish hatchery owners and operators in Uganda.

INTRODUCTION

Characteristics, structure and resources of the aquaculture sector

Fish farmers in Uganda, characterized as largely poor, practice aquaculture for subsistence. Uganda produces up to 15 000 tonnes of aquacultured fish, including production from small-scale fish farmers, emerging commercial fish farmers and stocked community water reservoirs and minor lakes. There are an estimated 20 000 ponds throughout the country with an average size of 500 m^2 of surface area per pond and production ranging between 1 500 kg/ha subsistence farmers to 15 000 kg/ha for emerging commercial fish farmers. With improved market prices, government intervention, quest for profitable production and stagnant supply from the capture fisheries, the aquaculture sector in Uganda has started to attract more entrepreneurial farmers that are seeking to exploit the business opportunity provided by the prevailing fish demand. This latest upsurge in aquaculture development has also resulted in transformation of a number of small-scale fish farmers both in management and size of production.

The current estimate is that 20 to 30 percent of the smallholder subsistence ponds have been transformed into profitable small-scale production units. In total, it is estimated there are nearly 5 000 ponds owned by nearly 2 000 farmers practicing at this level with an average pond size of 1 500 m^2/per pond. New entrants comprising of Ugandan "middle" or working class plus a few businessmen have adopted improved production systems with more technical management and more deliberate planning, closely working with private technical experts and growing fish for targeted and established markets. Pond surface is in the range of 5 000 m^2 to 50 000 m^2 numbering 500 and having an estimated 20 to 30 percent of active pond surface. This category includes commercial hatchery operators and a number of grow-out farmers that are already exporting fish to regional markets in the Democratic Republic of Congo, Kenya and Rwanda. Industrial and/or more intensified fish culture in Uganda is only beginning to take route and this is mainly driven by foreign direct investments or as joint ventures between local firms and foreign companies. Most farms/companies at this level are either in the stage of putting infrastructure in place or at the beginning of the production process. The targeted market of those companies is the regional market and the unutilized fish processing capacity in the country targeting international markets.

HISTORY AND GENERAL OVERVIEW

Aquaculture in Uganda is recorded to have started in 1941 after importing carp. Fish farming was officially proposed for the country in 1947 by colonial officers with the establishment of the Kajjansi Fish Experimental Station. Because of controversies surrounding carp in the early years of introduction in Uganda, officers then chose to use tilapia for stocking purposes. A vigorous fish farming extension programme resulting in 1 500 ponds constructed by 1956 followed with most ponds made in the central region (Buganda) and southwest most part (Kigezi) of the country. Support from FAO was sought and received in 1959 to 1960 to evaluate the use of carp alongside with tilapia as culture species. This technical assistance endorsed the use of carp and further expansion of aquaculture in Uganda. With additional FAO support, aquaculture was promoted in Uganda under the rural development program and the Department of fisheries recorded up to 11 000 ponds by the late 1968 producing fish largely for subsistence. Fish farming was based largely on "farmer to farmer" supply of seed and/or from the government stations that greatly limited the expansion of the sector. With changed policies under successive governments, Uganda's progress was short-lived and farmers abandoned the ponds due to lack of stocking materials, limited technical guidance and excessive government regulatory regimes. In 1999, at the time of the Fisheries Master Plan study, it was established that Uganda had only 4 500 functioning ponds with only a portion stocked producing 285 tonnes of fish annually. With the government's strategic intervention and support from development partners including FAO, aquaculture picked up once again reaching 15 000 tonnes of fish produced out of 20 000 ponds with an average size of 500 m^2 by year 2003. Due to the limited fish seed, carp has overtime fallen out of favour and instead the African catfish alongside Nile tilapia took its place. Fish farming in Uganda has up to date been pond culture-based but with the urge to engage in profitable and commercial aquaculture undertaking there has been an expressed move and planning toward cage culture-based aquaculture.

Human resources

The aquaculture subsector had by year 2004 an estimated 12 000 farmers with about 150 service providers or extension workers employed by local governments. Fifty districts out of 56 have an officer employed by the local government who is in-charge of technical guidance and management of the aquaculture sector. Another estimated 100 technical persons with basic training on fisheries and aquaculture are working as private service providers under the privatized, demand-driven and farmer-managed extension and advisory system. At the Department of Fisheries Resources, there is an Aquaculture Unit headed by a Principal Fisheries Officer under which are five Senior Fisheries Officers and four support staff. The Aquaculture Unit reports to the Assistant Commissioner for Fisheries in charge of the Production Division of the Department of Fisheries Resources. There are additional 100 persons working as managers for the upcoming commercial fish farms, some of whom have attained formal training in fisheries and aquaculture. Under each of these farm managers, an average of three persons are employed as labourers that support the manager in the farm. In addition, there are an estimated 20 000 people who provide specialized manual labour during construction of ponds, water and diversion channels, site clearing, stocking and seining during harvest, largely on a part-time basis. However, some youth have organized themselves into specialized groups for pond construction, which they do for their livelihood/occupation on a contract basis.

Farming systems distribution and characteristics

Of the 56 districts as of 2003, the Ministry of Agriculture, Animal Industry and Fisheries has identified 31 as suitable for fisheries and aquaculture development based on both natural and socio-economic factors. The districts zoned are found around the country's major water systems including Lake Victoria Crescent, Lake Kyoga Basin, River Nile catchment, Edward-George complex and Koki Lakes. These districts are: Mayuge, Jinja, Bugiri, Busia, Mukono, Mpigi, Wakiso, Masaka, Rakai, Mbarara, Bushenyi,Ntungamo, Kasese, Hoima, Masindi, Nebbi, Gulu, Adjumani, Arua, , Kamuli, Soroti, Lira, Iganga, Tororo, Pallisa, Mbale, Apac, Kabiramaido, Kabarole, Kamwenge and Kyenjojo. Table 1 provides production data and other information for each of the districts listed. Annex 7.19.1 gives information on production, systems of production, area under production and the value of production for each of the listed districts.

CULTURE PRACTICES

In Uganda, there are currently eight species that are cultured, composed of six finfish [*Oreochromis niloticus* (Nile tilapia), *Clarias gariepinus* (African catfish), *Tilapia zilli* (Zilli's tilapia), *Oreochromis leucostictus* (Mbiru), *Cyprinus carpio* (Carp), *Labeo victorianus* (Ningu)], one freshwater prawn (*Macrobrachium rosenbergii*) and one reptile - crocodiles. Nile tilapia is the most commonly farmed species. It was previously naturally restricted to the Nile system for which Lake Albert, the Uganda-Democratic Republic of Congo shared lake, is part of, and from where it was transplanted and introduced in most of the Ugandan water bodies including the major lakes (i.e. Victoria, Kyoga, George and Nabugabo). With good quality growth characteristics, easy production of seed and good taste across the country, Nile tilapia has become the number one cultured species. The only reservation is the prolific reproduction and seemingly resultant stuntedness.

African catfish (*Clarias gariepinus*) has recently emerged as the most favoured species for aquaculture in the country. Rural farmers have grown fond of it and the regional market has started to grow for this species. The main characteristics of this species are fast growth, ability to literally feed on any household organic waste. The technology for its reproduction and seed propagation has been perfected even at the very small-scale level of hatcheries. This species has wide distribution in all waters of

TABLE 7.19.1
Potential fish production from stocking/re-stocking of minor lakes

Lake Name	District	Area in sq. km.	Number of seed required	Cost of seed (in million UGX)	Expected production (tonnes)	Expected value (in million UGX)
Nyamusinigire	Bushenyi	4	880 000	44	440	440
Kyamiga	Bushenyi	3	640 000	32	320	320
Mishora	Mbarara	2	420 000	21	210	210
Nakivale	Mbarara	38	7 600 000	380	3 800	3 800
Karunga	Rakai	2	480 000	24	240	240
Kijanebalola	Rakai	40	8 000 000	400	4 000	4 000
Kachera	Rakai	44	8 800 000	440	4 400	4 400
Mutanda	Kisoro	26	5 220 000	261	2 610	2 610
Mulehe	Kisoro	4	860 000	43	430	430
Bunyonyi	Kabale	49	9 800 000	490	4 900	4 900
Karenge	Bushenyi	4	720 000	36	360	360
Kojweri	Soroti	95	19 000 000	950	9 500	9 500
Kowidi	Soroti	30	6 000 000	300	3 000	3 000
Kihodo	Soroti	12	2 400 000	120	1 200	1 200
Maragaga	Soroti	5	1 020 000	51	510	510
Pacolo	Soroti	3	680 000	34	340	340
Ajama	Kumi	9	1 800 000	90	900	900
Gigati	Pallisa	12	2 400 000	120	1 200	1 200
Kawi	Pallisa	10	2 000 000	100	1 000	1 000
20 Game	Pallisa	2	480 000	24	240	240
Komumwi	Pallisa	3	520 000	26	260	260
Kaditi	Pallisa	19	3 800 000	190	1 900	1 900
Nyasali	Pallisa/Kumi	23	4 600 000	230	2 300	2 300
Adois	Kumi/Soroti	43	8 600 000	430	4 300	4 300
Nyagoa	Kumi/Pallisa	25	5 000 000	250	2 500	2 500
Gawa	Kumi	3	600 000	30	300	300
Kwania	Apach/Lira	497	99 400 000	4 970	49 700	49 700
Lemwa	Pallisa	10	2 000 000	100	1 000	1 000
Kochobo	Kumi	4	800 000	40	400	400
30 Opare	Soroti	5	1 000 000	50	500	500
Kasago	Kumi	2	460 000	23	230	230
Semere	Soroti/Kumi	5	1 000 000	50	500	500
Bisina	Soroti/Kumi	179	35 800 000	790	17 900	17 900
Aibapet	Soroti	6	1 240 000	62	620	620
Opeta	Soroti	61	12 200 000	610	6 100	6 100
Abokat	Soroti	3	680 000	34	340	340
Nawampasa	Kamuli	5	1 060 000	53	530	530
Nakiwa	Kamuli/Iganga	112	22 400 000	1 120	11 200	11 200
Muilu	Kamuli/Pallisa	2	400 000	20	200	200
40 Namasajeri	Kamuli/Pallisa	18	3 600 000	180	1 800	1 800
Nabigaga	Kamuli	12	2 400 000	120	1 200	1 200
Owapet	Soroti	5	1 080 000	54	540	540
Rubi	Gulu	40	7 900 000	395	3 950	3 950
Total			**295 740 000**	**14 787**	**147 870**	**147 870**

Uganda especially those linked to swamps and has been traditionally a primary target for a large segment of the fishing community traditionally.

Other species such as the introduced carp, *Tilapia zilli*, *T. rendalli*, black bass and trout, have remained insignificant as cultured species largely because of the lack of appeal to consumers, lack of quality fish seed and/or inadequate knowledge of appropriate technologies and conditions to propagate those species and their seed. However, when ranked, common carp is the favoured by farmers especially in the relatively cold regions of the country.

New on-farm species is the *Labeo victorianus* which is now being cultured in an effort to save the species from extinction. The hatchery technology of this species, however, is still only available to government research institutes (Kajjansi Aquaculture Research and Development Centre) and seed production from the centre is still very limited. Of increasing interest as an quaculture species is the Nile perch (*Lates niloticus*) which is good for processing for export to premium markets. Trials are underway at the Kajjansi Aquaculture Research and Development Centre to propagate this species. A few farmers are already growing Nile perch in the ponds with success. However, there has been no breakthrough yet with artificial seed propagation. Both the research centre and farmers growing Nile perch are still getting their seed from the wild.

The most common system of culture in the country is pond culture. Other forms of fish culture such as cage culture are only starting to be discussed especially by the emerging commercial fish farmers. Previously, 99 percent of subsistence fish farmers had ponds ranging from 50 m^2 to 200 m^2. With the drive to commercialize aquaculture production, efforts are being made to increase the pond surface and pond numbers. The average pond size currently stands at 400 m^2/pond, with an estimated total of 20 000 ponds countrywide.

PRODUCTION

Current estimates are based on fish seed production capacity, stocking record, size of stocked water bodies, number and size of farmer ponds. The Department of Fisheries Resources had projected an annual production of 15 000 tonnes for 2005. This includes production expected out of stocked community dams and reservoirs projected at 9 500 tonnes. Out of subsistence farmers, 2 500 tonnes are expected from 17 000 ponds owned by 11 000 farmers and another 3 000 tonnes produced by 200 emerging commercial farmers whose production is targeted for the regional market. The total pond surface area is estimated at about 6.5 km^2 (650 ha) with over 80 percent of the farmed fish production as African catfish in 2004. Details of the production for the 31 districts zoned for fisheries and aquaculture production are given in Annex 7.19.1.

Aquaculture production, species, values

With the growing demand for fish locally, regionally and internationally, Uganda has increased her efforts to develop the aquaculture sector as an alternative to increasingly stressed natural stocks. According to the Department of Fisheries, Uganda will have to produce up to 320 000 tonnes annually out of aquaculture by 2015 if it is to avoid becoming a net importer of fish products. There is already a visible trend of intensification of fish farming systems including adoption of larger pond sizes and numbers, use of higher stocking rates, search for better quality fish species both in growth performance and marketability, use of formulated feeds and turning to more intensive fish culture systems such as cages and tanks. Over the last five years fish production has grown from under 500 tonnes to 15 000 tonnes and is fast transforming from subsistence-base to a profit-orientated and export-driven farming. In addition, aquaculture is attracting partnerships with external firms and individuals who wanted to take advantage of existing markets.

Fish remains the only animal protein Uganda has been able to supply to the external markets (both regional and international) and is by far the most available and adequately distributed animal protein throughout the country. It remains comparatively affordable to the majority of Ugandans. Fish production is nearly three times that of beef production and many times higher than chicken production.

Uganda's non-food aquatic species production through aquaculture is limited to the upcoming ornamental fish farming industry and the baitfish farming targeting the Nile perch fishery. Uganda currently produces 3 million catfish fingerlings annually for the bait annually. The most significant contribution to the national economy is indirect through the Nile perch fishery. Over 20 private hatcheries have been set-up and currently supplying bait for the Nile perch fishery. There is one crocodile farm found in Masaka District in Central Uganda. The crocodiles are reared mainly for the skin. A few courtyard undertakings have sprung up for the production of ornamental fish. All these undertakings are however still very insignificant when compared to the table fish species cultured both in value and quantity.

Aquaculture in Uganda is currently predominantly land-based with an estimated 650 ha of pond surface utilized for aquatic production. Much of this land surface has been brought for aquaculture purposes with the coming on board of the emerging commercial fish farmers. Of increasing importance also are the community water reservoirs and minor lakes, which are regularly stocked for the surrounding communities. The stocked water bodies are estimated to produce up to 9 500 tonnes of fish annually while pond-based production generates over 5 500 tonnes of farmed fish/year.

The key species used in aquaculture are Nile tilapia and African catfish. Other species include *Tilapia zilli*, *T. rendalli*, *O. leucostictus*, *C. carpio*, *M. rosenbergi*, koi carp and other native species used in ornamental fish farming. Freshwater prawns, *M. rosenbergi*, for food fish production, koi carp for ornamental purposes and red tilapia for aquaculture research and development have been introduced into the country for aquaculture during the last ten years.

SEED RESOURCES/SUPPLY

Until five years, over 95 percent of the fish seed supply for aquaculture came from government-operated hatcheries while the other 5 percent came from "farmer to farmer" supply system. Seed in most cases were of poor quality and were basically tilapia seed. Currently over 90 percent of the seed are supplied from private sector-owned and operated hatcheries with a growing choice of species and strains propagated for seed supply to farmers. Annex 7.19.2 gives the details of the seed resources in the country.

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Annex 7.19.2 gives the details on existing hatcheries for freshwater fish seed production including location, production figures, the number of species, available technologies (e.g. breeding, hatching, rearing) and gene banks. Currently most of the hatcheries are pond-based with some sort of wet room that contains incubation troughs supplied with running water or some sort of improvisation.

SEED QUALITY

Trained hatchery operators are conversant with issues of seed quality especially the need to sort fish seed by sizes and age. Most hatcheries reported having separate ponds or containments areas *hapas* for separation of the different batches of tilapia fish seed both by sizes and age – a factor that is strongly demanded by grow-out farmers. Catfish farmers reported that cannibalism is the result of non-sorting of fish seed according to sizes.

SEED MARKETING

Grow-out farmers buying small quantities have to pick up the fish seed. However, for large orders or supply to a good number of farmers in the same area, hatchery operators are willing to delivery fish seed. Some medium-scale hatcheries reportedly have their own farm trucks and oxygen cylinders for transporting fish seed in large quantities and over long distances (see Annex 3). Prices for nearly all the hatcheries were negotiable and varied greatly even for hatcheries within the same locality. A number of small hatchery operators and grow-out farmers have been organized, as groups or associations, with the help of the local governments as a means to guarantee market and in order to work together among themselves to ensure that seed are available in good quality whenever needed and hatchery operator has ready market for any seed produced. Some of the large- and medium-scale hatcheries have put up sign posts and advertised their companies in the media.

PLATE 7.19

Facilities at Tukundane fish farm in Ugandas

Tukundane fish farm hapas holding Nile tilapia fingerlings ready for dispatch to grow-out farmers

Farm visits at Tukundane Fish Farm by aquaculture students of Makerere University

Tukundane fish farm proprietor with catfish brood

SEED INDUSTRY

Uganda's current seed production industry can be categorized into three groups: small-scale, medium-scale and large-scale. Small-scale hatcheries produce largely for rural communities and are usually limited in their capacity to supply seed to the district in which they occur. Small-scale hatcheries are those considered to produce less than 200 000 fingerlings of any one species a year or those producing not more than 300 000 fingerlings in total in a year. The medium-scale hatcheries target emerging commercial grow-out farmers, and produce seed that can be sold beyond the district of production. Many medium-scale producers came up during the government's programme of stocking and restocking of water bodies and have since transformed into commercial hatcheries. Medium-scale hatcheries produce between 300 000 to 1 million fingerlings a year. The large-scale hatcheries are only starting to come up and they are categorized as those that produce over 1 million fingerlings a year.

Small-scale hatcheries are limited in technical capacity and resources. Normally these category of hatcheries which are rural-based are credited for bringing quality fish seed for rural fish farmers. However, this category has the risk of not providing rural farmers with a quality product given the limited resources and remoteness of hatcheries for effective monitoring by the regulatory agencies. Medium-scale hatcheries are always careful to keep up the quality of their products as they largely dependent on commercial fish farmers coming back to buy more seed from them. There is a tendency with this category of hatcheries to over-produce seed to meet either the market demand and to meet deadlines. In so doing, this category of hatcheries is likely to lead to increased fish escapees, over-fertilization and failure to adhere to guidelines to ensure quality fish seed production. Large-scale hatcheries are normally well-planned and well-designed. Previously there was only one public aquaculture research centre (KARDC) and these now are growing to meet and ensure provision of quality fish all the time. Many of the large-scale hatcheries are clearly around the central administrative districts and supply fish seed only to large-scale farms. One such hatchery (SUNGENOR) is specialized in improved tilapia seed from the GIFT strain of Nile tilapia and supplies seed under a contract growing scheme where farmers sell back the fish to the company's fish processing and export partner (NGEGE Ltd).

On the whole, fish farming remains an alien practice a situation that was not helped by the manner in which aquaculture was first considered and introduced into the country. The practice was considered to be non-income generating and only for fish protein provision for the rural communities who did it at subsistence level with little or no input other than the fish seed. However, with time the practice has began to attract profits and generated income for fish farmers who have started to invest commercially and expand production targeting local, regional and international markets. This level of farmers have better-constructed production units, have designed measures against predators (small reptiles and birds) and are using formulated fish feeds either bought from feed firms or manufactured on farm. These fish farms are also better located and are employing technically trained persons or seeking advice from competent aquaculture service providers.

SUPPORT SERVICES

Delivery of agriculture advisory services had been legally changed since 2002 from public delivery to private delivery with gradual shift from public-funded to private-funded delivery of advisory services (extension). As a result, many public agencies and institutions responsible for aquaculture extension have been either dismantled or realigned to fit the new government service delivery system. The services, unlike in the past, have to be popularly demanded by farmers. This is a point of contention for aquaculture as it is still minor in popularity compared to other sectors under agriculture which means that there are only a few places which stand to benefit from this new arrangement of service delivery. However, the government has started generating information such as aquaculture practice manuals, guidelines for the seed propagation for the respective farmed species provided through the Department of Fisheries Resources by both the central and local governments, the National Agricultural Advisory Services and the KARDC.

SEED CERTIFICATION

All fish seed producing, supplying and fingerling raising farms and companies have to be certified by law. This is in accordance with the provisions of the statutory instrument regulating aquaculture activities under the FISH ACT (1964) known as the Fish (Aquaculture) Rules 2003 instrument number 31. The operator has to apply using a required application form, submit it to the Chief Fisheries Officer or to a person designated by the Chief Fisheries Officer to work ON his or her behalf. Inspectors are then dispatched to the aquaculture establishment to inspect and ensure that all requirements and plans are in place to ensure responsible production of quality fish seed. Based on the report of the inspectors, the Chief Fisheries Officer then issues a Fish Seed Production Certificate. This process is aimed at ensuring that farmers get quality fish seed and to prevent ecosystem alteration and ecological and genetic disruption from either escapees of farmed fish or entry of unwanted fish into the production system. In essence, no one is not allowed to produce or pass on fish seed without certification. This provides the legal and policy framework for fish seed production in the country.

ECONOMIC ASPECTS OF HATCHERY OPERATIONS

Below are some of the conclusions regarding tilapia seed production that were arrived at by an expert under the Technical Cooperation among Developing Countries (TCDC) programme provided by the FAO Technical Cooperation Project (TCP) to guide hatchery operators.

The main technical standards developed in terms of documented simple and sustainable technologies that fit the current level of production in Uganda and which have been applied in the project zones include the following:

- Nursing tilapia from the size of 0.15-0.2 g per fish can reach 4.1 g with the survival rate of 87.1 percent for 40 days of nursing and productivity of 23-27 fish /m^2
- Nursing catfish from the size of six to eight days old (0.5g-30g per fish) to reach 4.4 g per fish with a survival rate of 43.0 percent for 40 days of nursing and productivity of 26-29 fish/m^2
- Preliminary calculation of producing 545 fish per 1 kg of broodstock 50 fry/ month/m^2 pond area for 30 days with the cost of fry at UGX5.2-8.1/fish seed with 3 day fry brought from a commercial fish farm.
- Transportation of larvae, fry and fingerling of both tilapia and catfish using oxygenated plastic bags with a survival rate ranging from 92-100 percent traveling a distance of 60-280 km for 4-8 hrs. Transportation of tilapia broodstock in a crest tank supplied with oxygen can get a survival rate of 99-100 percent with the similar distance and time. The simple transportation method of transporting in a container with oxygen air can be used for the short distance of approximately 15 km with same results.

INFORMATION OR KNOWLEDGE GAPS

Gaps exist in the information needed for planning and operation of commercial or medium- to large-scale hatcheries in the country. There has been some work done at the technical level by local institutions and international agencies including FAO and DFID to generate information especially for the small-scale hatcheries. However, attempts to get the actual economics involved in running rural hatcheries by local institutions and by these international agencies were not conclusive, there has not been any attempt in the country to review the economics of hatchery operations at any other level of hatchery production and operation. Serious consideration of economics is needed to provide information to the operators required for appropriate investment and planning.

STAKEHOLDERS INVOLVED WITH FISH SEED PRODUCTION

There are many stakeholders involved in seed production with the seed producers and the fish farmers as the primary stakeholders. There are nearly 60 fish seed producing agencies and/or individuals in the country and about 12 000 grow-out fish farmers. This is followed by the government which is interested in promoting aquaculture for both for food and bridging the gap between the current fish supply and fast increasing demand for fish for trade at local, regional, and international levels. The government is also interested in fish seed as management tool for existing fisheries through routine stocking and restocking of fishery exploited water bodies. Other key stakeholders include the aquaculture research centres and fish fry centres as part of government institutions in place to promote the adoption of aquaculture and development and provision of needed technologies for aquaculture practice. Aquaculture currently provides employment to an estimated 35 000 people in the country.

Producers/farmers: Of the 35 000 people, 12 000 are engaged in aquaculture as owners of the production units producing an estimated 5 500 metric tonnes of fish annually and employing another 23 000 upfront from farm labourers to extension workers, technicians and managers.

Local institutions and farmers associations: Key non-government organizations and institutions involved in the promotion of the use of quality fish are mainly fish farmers' organizations and processing and exporting factories and firms. There are about 20 district-based fish farmers' organizations and five other organizations that have a national coverage. About four factories are currently interested in buying fish from aquaculture for processing for export – and this require that the seed used are of good quality and produces fish that meets the market requirement.

Small hatcheries: Many of the hatcheries in the country remain small- to medium-scale seed production hatcheries that have come up during the last three to five years with increasing importance of fish in the country and which are supported by a number of government and other non-government agencies to ensure availability of quality fish seed to farmers especially in the rural areas. There are currently more than over 50 small- to medium-sized hatcheries in the country.

Larger hatcheries: Until two to three years back, there were only two large hatcheries, one managed and operated by the government at KARDC and a private one known as Sunfish Farm. Another three private ones were until recently only at the planning stage. All the three are now in full operation and an additional five have come up as a result of expansion of the originally small hatcheries with the expanded market and improved quality of their seed.

Government institutions: The key institutions of government in seed production are the Department of Fisheries Resources that provides the legal and policy framework for all activities related to seed production, including support and promotion. The Department of Fisheries Resources is central and works with local governments departments responsible for fisheries in carrying out its mandate. However, local government fisheries officers handling aquaculture may also be engaged in extension. The other government institution involved in seed production is the KARDC which is mandated to generate information through research for improved aquaculture production. Specifically, KARDC is involved in the development of better performing seed and strains of fish species that are demanded by the market. Along with this are three government regional fry centers(Aquaculture Development Centres – Nkoma, Bushenyi and Laliya), which although dilapidated, are scheduled for rehabilitation under the current fisheries development project funded by African Development Bank Loan facility. In addition, there are three districts with hatcheries that are owned and operated by the local government mandated to propagate seed to supply rural fish farmers.

Delivery of advisory services to farmers (extension) under the country's Plan for Modernization of Agriculture (PMA) has been transformed to private and farmer-demanded extension service system. This new approach is mandated by law. This includes and applies to aquaculture practice as well. This is a move towards empowering farmers to demand and pay for extension services from private service providers and getting the government out of directly providing extension services to farmers. The national agency responsible for this arrangement is known as the National Agriculture Advisory Services (NAADS) that is currently a semi-autonomous body.

Researchers: Research on fish seed issues that had public funding was a remit of KARDC – and the institute was responsible for generation of information, knowledge and technologies on fish seed production and propagation, as well as improving the quality and performance of the fish seed. Other institutions such national university known as Makerere University and the Fisheries Training Institute at Entebbe conducted some limited research concerning seed issues for academic purposes. However, with the new National Agriculture Research System Bill, research has been made open and competitive with funding from the World Bank. It is therefore anticipated that other key players may come in to do research on fish seed issues.

Donors: A number of projects have been funded by donor agencies over the last five years: These include the following:

i. Small Scale Fish Farming Project – largely for rural livelihood supported by DFID – started 1999 and ended 2004;
ii. Support to Fisheries Management aimed at bolstering production of quality fish seed and setting of large commercial fish farms supported by the government – started 2003 ended 2004;
iii. Support to Aquaculture – Fish Fry meant for provision of seed to the rural poor farmers supported by the government, started 2001 ended 2004;
iv. Support to Fisheries Development Project – in which support for aquaculture has been earmarked for rehabilitation of infrastructure for Research and Regional Fry Centres. It also will have a minor component for support directly to fish farmers at all levels including provision of credit. This has been supported with a loan from ADB – started 2003 and to end 2008;
v. Assistance to fish farmers in eastern Uganda – which has supported the creation of model commercial small-scale private hatcheries in three zones in eastern Uganda. This has been through an FAO TCP project – started 2002 and ended 2004;
vi. Lake Victoria Environment Management Project that supports aquaculture activities – largely involved in training, sensitization and awareness campaigns on good aquaculture production practices in 13 districts of Uganda Lake Victoria Basin. This project is also supporting the setting up of commercial private small-scale hatcheries in six of the thirteen districts, supported through a loan and grant from the World Bank, started 1999 until 2005;
vii. Fisheries Development Project in which there is limited support to fish farmers to improve their facilities and commercialize their production, funded by a Government Loan Facility from African Development Bank starting from 2003 to 2008. The project will also support the renovation and rehabilitation of the government regional fry centres and KARDC.

FUTURE PROSPECTS AND RECOMMENDATIONS

Freshwater fish seed resources demand in the country is going to significantly increase in the coming five years as Uganda strives to transform her production from rural subsistence to commercial or profit-oriented aquaculture production. The national plan is to produce 50 000 tonnes of fish by end of 2007 and 120 000 tonnes by year 2011. This, according to the government plans, will mainly from both the medium-scale and the few large commercial fish farmers. By projection, including the government's intention to continue with the restocking exercise, and the bait demand by the long line fishery of Nile perch the National demand for seed is estimated at over 450 million fingerlings of quality fish seed per annum. Given the quite ambitious plan for aquaculture, Uganda needs to continue emphasizing the promotion of private sector intervention and leadership to achieve her aim. There is a need for continued and renewed research to improve local strains so as to reduce on challenges such as over proliferation of Nile tilapia and subsequent stunting of grow-out fish, cannibalism and marked size differences in grow-out facilities of African catfish, low performance of the limited genetic base of carp and limited choice of species and their strains for aquaculture. Table 1 is the Department of Fisheries Resources estimate for fish seed needed to stock minor lakes in the country. This estimate does not take into consideration the requirements for augmenting depleted larger lakes such as Lakes Edward and George. Also shown in Tables 7.19.2 to 7.19.4 are the estimated production and requirements as Uganda strives to develop her aquaculture potential. These figures are projection and can only be realized if the right situations prevail and required resources are made available to support development of the sector.

TABLE 7.19.2

Potential fish production from cage culture systems in major crater lakes. All crater lakes over 20 m deep are targeted for cages. The cage systems in crater lakes will produce 4 500 tonnes/km^2. The cage system in major lakes will produce 4 500 tonnes in a 500 km^2

Crater lakes	Number of districts	Target species	Area in sq. km.	Number of systems	Production (tonnes)	Value (in millions of Ugandan Shilling UGX) US$1 = UGX 1 170
Lake Victoria	Lake basin (11)	Nile tilapia	30 720	61	276 480	414 720
Lake Edward	Lake basin (3)	Edward tilapia	663	1	5 967	8 951
Lake Albert	Lake basin (5)	Nile tilapia	2 114	4	19 026	28 539
Kanyegeya	Kabarole	Nile tilapia	0.01	1	11	17
Katanda	Kabarole	Nile tilapia	0.35	1	788	1 181
Mwegenyi	Kabarole	Nile tilapia	0.30	1	675	1 013
Kifuruka	Kabarole	Nile tilapia	0.15	1	338	506
Mwamba	Kabarole	Nile tilapia	0.48	1	1 080	1 620
Lugembe	Kabarole	Nile tilapia	0.08	1	169	253
Nyungu	Bushenyi	Nile tilapia	0.20	1	450	675
Kamweru	Bushenyi	Nile tilapia	0.34	1	754	1 131
Nkugute	Bushenyi	Nile tilapia	0.58	1	1 305	1 958
Opeta	Soroti	Nile tilapia, Catfish	42.00	21	94 500	141 750
Mutanda	Kisoro	Black bass	23.00	12	51 750	77 625
Bunyonyi	Kabale	Catfish, Black bass	57.00	29	128 250	192 375
Kabarole Lakes	Kabarole	Nile tilapia	11.00	6	24 750	37 125
Kasese Lakes	Kasese	Nile tilapia	10.42	5	23 445	35 168
Total			**146**	**81**	**328 264**	**944 605**

TABLE 7.19.3

Potential fish production from river cage culture systems

River Name	Target species	River lengths	Number of systems	Production (tonnes)	Value (in millions of UGX)
Victoria Nile	Nile tilapia	390	98	97 500	146 250
Albert Nile	Nile tilapia	215	54	53 750	80 625
Turkwel	Mirror carp trout	40	10	10 000	15 000
Aswa	Nile tilapia and Catfish	200	50	50 000	75 000
Semliki River	Trout mirror carp	8	2	2 000	3 000
Kagera	Catfish	20	10	10 000	15 000
Kazinga Channel	Nile tilapia	25	6	6 250	9 375
Mayanja	Nile tilapia and Catfish	30	8	7 500	11 250
Sezibwa	Nile tilapia and Catfish	28	7	7 000	10 500
Total				**244 000**	**366 000**

(Note: One cage system per 4 km is expected to produce 1 000 tonnes with an average price of UGX1 500/kg)

TABLE 7.19.4

Potential fish production from stocking of dams and valley tanks

Region	Number of Dams Valley Tank	Capacity in million liters	Estimated area in millions of sq. m.	No, of seed required in millions	Cost of seed (in million UGX)	Expected production (tonnes)	Expected value (in millions UGX)
Acholi	85	847	169	34	339	16 940	16 940
Ankole	93	6 780	1 356	271	2 712	135 610	135 610
Mengo	65	2 166	433	87	867	43 329	43 329
Masaka	67	7 979	1 596	319	3 192	159 581	159 581
Toro	11	252	50	10	101	5 036	5 036
Kalamoja	123	4 453	891	178	1 781	89 062	89 062
Busoga	43	738	148	30	295	14 753	14 753
Bukedi	42	137	27	5	55	2 743	2 743
Total	**529**	**23 353**	**4 671**	**934**	**9 341**	**467 054**	**467 054**

(Note: The dam list used is from old statistics and estimate assumes the following: stocking rate of 1 fish/5 m^2; the dams are assumed to have an average depth of 5 m).

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ANNEX 7.19.1
Aquaculture Production Information for the 31 Districts of Uganda zoned for Fisheries and Aquaculture Production for 2004

	Districts	System of culture	Number of production units	Farms surface in hectares	Species cultured	Fish production metric tonnes
01	Bugiri	Pond culture	352	15.84	Catfish	79.2
					Nile tilapia	61.8
02	Busia	Pond culture	160	6.4	Catfish	32.0
					Nile tilapia	16.0
03	Iganga	Pond culture	408	28.56	Catfish	171.4
					Nile tilapia	71.4
04	Jinja	Pond culture	246	12.3	Catfish	61.5
					Nile tilapia	40.0
					Freshwater Prawns	1.5
05	Kaberamaido	Pond culture	260	5.2	Catfish	28.1
					Nile tilapia	14.0
					Carp	1.2
06	Kamuli	Pond culture	366	23.79	Catfish	119.0
					Nile tilapia	59.5
07	Mayuge	Pond culture	166	4.98	Catfish	22.4
					Nile tilapia	9.0
09	Mbale	Pond culture	248	7.44	Catfish	37.2
					Nile tilapia	11.2
					Carp	15.0
10	Pallisa	Pond culture	280	11.2	Catfish	67.2
					Nile tilapia	22.4
					Carp	5.4
11	Soroti	Pond culture	352	10.56	Catfish	52.8
					Nile tilapia	35.6
12	Tororo	Pond culture	600	36	Catfish	180.0
					Nile tilapia	108.0
13	Masaka	Pond culture	1024	51.2	Catfish	460.8
					Nile tilapia	102.4
14	Mpigi	Pond culture	288	10.08	Catfish	50.4
					Nile tilapia	25.2
15	Mukono	Pond culture	516	25.8	Catfish	193.5
					Nile tilapia	77.4
16	Wakiso	Pond culture	916	45.8	Catfish	961.8
					Nile tilapia	274.8
		Cage culture	20	0.004	Nile tilapia	15.3
17	Bushenyi	Pond culture	1 048	20.96	Catfish	104.8
					Nile tilapia	37.7
					Carp	0.5
18	Hoima	Pond culture	130	2.6	Catfish	13.0
					Nile tilapia	5.2
19	Kabarole	Pond culture	252	5.04	Catfish	25.2
					Nile tilapia	7.6
20	Kamwenge	Pond culture	352	8.8	Catfish	44.0
					Nile tilapia	13.2
21	Kasese	Pond culture	714	17.14	Catfish	85.7
					Nile tilapia	42.8
22	Kyenjojo	Pond culture	646	6.46	Catfish	32.3
					Nile tilapia	16.2
23	Ntungamo	Pond culture	352	5.28	Catfish	26.4
					Nile tilapia	13.2
24	Masindi	Pond culture	152	2.28	Catfish	11.4
					Nile tilapia	5.7
25	Mbarara	Pond culture	524	13.1	Catfish	65.5
					Nile tilapia	32.8
26	Adjumani	Pond culture	159	3.18	Catfish	15.9
					Nile tilapia	8.0
27	Apac	Pond culture	178	3.56	Catfish	17.8
					Nile tilapia	10.7
28	Arua	Pond culture	726	14.52	Catfish	72.6
					Nile tilapia	43.6
29	Gulu	Pond culture	972	43.74	Catfish	218.7
					Nile tilapia	109.4
30	Lira	Pond culture	1068	42.72	Catfish	213.6
					Nile tilapia	149.5
31	Nebbi	Pond culture	352	8.8	catfish	21.1

ANNEX 7.19.2
Details on existing hatcheries for freshwater fish seed

No.	Source of seed	Operators name	Location of establishment	Species propagated	Purpose for seed production	Gene bank	Annual seed production capacity
A	Wild capture	Department of Fisheries Resources	Natural water bodies	Tilapiines Bagrus species African Catfish Nile perch	Growout, Breeding, Research Growout, Research Growout, Broodstock, Bait Growout, Research	Natural Species repository	400 000 20 000 4 500 000 150 000
B1	Artificial propagation	Sun fish Farm	Wakiso District	African Catfish Nile tilapia	Growout, Bait Growout	N/A	15 000 000 3 000 000
B2	Artificial propagation	Bushenyi Aquaculture Development Center	Bushenyi District	Nile tilapia	Growout, Research, Training	N/A	480 000
B3	Artificial propagation	Sisa Fish Farm	Wakiso District	African catfish	Growout, Bait	N/A	6 000 000
B8	Artificial propagation	MOSO4 Enterprise	Iganga District	African catfish Nile tilapia	Growout Growout	N/A	2 400 000 1 200 000
B5	Artificial propagation	Kikkati Fish Farm	Mukono District	African catfish	Growout, Bait	N/A	3 600 000
B6	Artificial propagation	Bamukwasi Rock Valley Fish Farm	Tororo District	African Catfish Common Carp Nile tilapia	Growout Growout Growout	N/A	1 200 000 240 000 600 000
B7	Artificial propagation	Butande Integrated Fish Farm	Busia District	African catfish Nile tilapia	Growout Growout	N/A	300 000 1 200 000
B8	Artificial propagation	Salama Integrated Fish Farm	Busia District	African catfish Nile tilapia	Growout, Bait Growout	N/A	600 000 840 000
B9	Artificial propagation	Banga Fish Farm	Mayuge District	Nile tilapia	Growout	N/A	240 000
B10	Artificial propagation	Namasere Fish Farmers Association	Bugiri District	African Catfish Nile tilapia	Growout, Bait Growout	N/A	600 000 480 000
B11	Artificial propagation	Mpigi Fish Farm	Mpigi District	African catfish Nile tilapia	Growout, Bait Growout	N/A	1 200 000 600 000
B12	Artificial propagation	Interglobe Aquaculture Fish Farm	Kampala	African catfish	Growout	N/A	600 000
B13	Artificial propagation	Sisa Integrated Fish Farming Ltd	Wakiso District	African catfish Nile tilapia	Growout, Bait Growout	N/A	1 200 000 600 000
B15	Artificial propagation	Ruta Fish Farm	Wakiso District	African Catfish	Growout, Training of extension workers	N/A	360 000
B16	Artificial propagation	Mutungo Kitiko Fish Farm	Wakiso District	Nile tilapia	Growout	N/A	240 000
B17	Artificial propagation	JAMS aquaculture and Fish Farm	Wakiso District	African catfish Nile tilapia	Growout, Bait Growout	N/A	1 500 000 960 000
B18	Artificial propagation	SIBCO Ltd	Nakaseke District	African catfish Nile tilapia	Growout Growout	N/A	480 000 360 000
B19	Artificial propagation	Lean on Systems (U) ltd.	Wakiso District	African catfish Nile tilapia	Growout, Bait Growout	N/A	1 500 000 1 800 000
B20	Artificial propagation	The Pearl Group	Wakiso District	Nile tilapia	Growout	N/A	960 000
B21	Artificial propagation	Kampala Fish Farmers Ltd.	Wakiso District	African Catfish Nile tilapia	Growout, Bait Growout	N/A	1 800 000 960 000
B22	Artificial propagation	Umoja Fish Farm	Wakiso District	African catfish	Growout, Bait	N/A	12 000 000
B24	Artificial propagation	Kakunyu Agricultural Farm	Luwero District	Nile tilapia	Growout	N/A	600 000
B25	Artificial propagation	Kabali Farm	Mukono District	African catfish Nile tilapia	Growout, Bait Growout	N/A	360 000 480 000

No.	Source of seed	Operators Name	Location of establishment	Species propagated	Purpose for seed production	Gene bank	Annual seed production capacity
B26	Artificial propagation	Nalubowa Lusembo & Co. Estates	Masaka District	African catfish Nile tilapia	Growout, Breeding Growout, Breeding	N/A	15 000 000 2 400 000
B27	Artificial propagation	Kyankuzi Fish Farm	Iganga District	African catfish	Growout	N/A	600 000
B28	Artificial propagation	Kabeihura Farm	Bushenyi District	African catfish Nile tilapia	Growout Growout	N/A	1 200 000 2 400 000
B29	Artificial propagation	Kigezi Fish Industry Project	Kabale District	African catfish Nile tilapia	Growout Growout	N/A	480 000 360 000
B30	Artificial propagation	Kabumba Fish Farmers	Isingiro District	Nile tilapia	Growout	N/A	1 500 000
B31	Artificial propagation	Gisoro Community Developers Farm	Kisoro District	Nile tilapia Common Carp	Growout Growout	N/A	600 000 240 000
B32	Artificial propagation	Aquafarm Consult Ltd.	Wakiso District	African catfish	Growout, Bait	N/A	2 400 000
B33	Artificial propagation	Tukundane Fish Farm	Isingiro District	Nile tilapia Tilapia zilli	Growout Growout	N/A	2 400 000 600 000
B34	Artificial propagation	Tochi Heights & Aqua Ltd	Gulu District	African catfish Nile tilapia	Growout Growout	N/A	600 000 12 000 000
B35	Artificial propagation	306A Mixed Farm	Apac District	Nile tilapia	Growout	N/A	8 400 000
B36	Artificial propagation	Pukure Orphan Care Integrated Farm	Gulu District	African catfish Nile tilapia	Growout Growout	N/A	240 000 360 000
B37	74	Ogur Fish Farms Ltd.	Lira District	African catfish Nile tilapia	Growout Growout	N/A	240 000 360 000
B38	80	Braj Fry Centre	Hioma District	African catfish Nile tilapia	Growout, Bait Growout	N/A	480 000 720 000
B39	84	Erisotto Aquafarm	Wakiso District	African catfish Nile tilapia	Growout, Bait Growout	N/A	480 000 720 000
B40	86	Katfereza Fish Farming	Wakiso District	African catfish Nile tilapia	Growout Growout	N/A	240 000 360 000
B41	89	Namuyenje Mixed Farmers Ltd	Mukono District	African catfish	Growout, Bait	N/A	1 200 000
B42	90	Naluvule Farm	Wakiso District	African catfish Nile tilapia	Growout, Bait Growout	N/A	480 000 720 000
B43		Nkoma Aquaculture Development Centre	Mbale District	Nile tilapia Common Carp	Growout, Research, Training Growout, Research, Training	Strain repository	600 000 240 000
B44		SCAPA Limited	Kamuli District	African Catfish Common carp Nile tilapia	Growout Growout Growout	N/A	1 200 000 120 000 720 000
B45		Magogo Integrated Farm Dealers in Fish	Kamuli District	African catfish Nile tilapia	Growout Growout	N/A	600 000 720 000
B46		Kajjansi Aquaculture Research and Development Centre	Wakiso District	African catfish Common carp Labeo victorianus Bagrus sp Nile perch	Growout, Research, Breeding Growout Growout, Research Research Research	Strain repository	960 000 360 000 840 000 120 000 60 000
B47		Son of the Nile Fish Farm	Mukono District	Nile tilapia	Growout, Breeding	N/A	18 000 000

7.20 Freshwater fish seed resources in Viet Nam

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ABSTRACT

This review provides the current status of freshwater fish seed resources for aquaculture development in Viet Nam. There are a total of nineteen indigenous and exotic fish species commonly cultured in freshwater aquaculture. Chinese and Indian major carps, Mekong catfish and tilapia are the most popularly cultured species. Fish culture based on hatchery seed began in early 1960s. Many of the estimated 420 hatcheries currently in operation in the country produce annually an estimated 15 billion freshwater fish hatchlings. Most of the existing hatcheries are being managed as private business. The Chinese-style circular spawning and incubators are dominant hatchery technologies used throughout the country.

This document also describes a summary of technical parameters for seed production, seed quality management and marketing of the main farmed freshwater fish species in Viet Nam. Finally future prospects and recommendations on several issues related to further development of freshwater fish seed production in the country are provided.

INTRODUCTION

According to the Ministry of Fisheries (MOFI), the total aquaculture area and production in Viet Nam in 2004 were 902 900 ha and 1.15 million tonnes, respectively, of which around 639 700 ha and 0.640 million tonnes came from freshwater aquaculture, respectively (MOFI, 2005). Freshwater fish were estimated as providing nearly 35 percent of the total animal protein intake of the nation. There are nineteen indigenous and exotic fish species commonly cultured in freshwater systems. These are listed in Table 7.20.1. Carps, catfish, and tilapia are the most popularly cultured species. Mekong catfish account for about 40 percent of cultured freshwater fish production followed by major carp species (i.e. grass carp, mrigal, common carp) and tilapia.

SEED RESOURCES AND SUPPLY

Aquaculture in both northern and southern Viet Nam has its roots in the collection and stocking of fish seed caught from the wild. In the north, Vietnamese silver carp, grass carp, mud carp were collected as hatchlings from the Red River. In the south, Mekong catfish, snakehead and silver barb have also been caught as wild fry.

TABLE 7.20.1
List of commonly cultured freshwater fish species in Viet Nam

English name	Local name	Scientific name
Common carp	Ca chep	*Cyprinus carpio* L.
Chinese Silver carp	Ca Me trang Trung Quoc	*Hypophthalmichthys molitrix* (C.&V.)
Vietnamese Silver carp	Ca Me trang VietNam	*Hypophthalmichthys harmandi* Sauvage
Bighead carp	Ca Me hoa	*Aristichthys nobilis* (Rich)
Grass carp	Ca Tram co	*Ctenopharyngodon idellus* (C.&V.)
Rohu	Ca Troi An	*Labeo rohita* Hamilton
Mrigal	Ca Mrigal	*Cirrhinus cirrhosus* Hamilton
Mud carp	Ca Troi ta	*Cirrhinus molitorella* (C.&V.)
Black carp	Ca Tram den	*Mylopharyngodon piceus* (Rich)
Spinibarbus	Ca Bong	*Spinibarbus denticulatus* Oshima
Gold Fish	Ca Diec	*Carassius auratus* (L.)
Silver barb	Ca Me Vinh	*Barbodes gonionotus* Bleeker
Nile Tilapia	Ca Ro Phi van	*Oreochromis niloticus*
Mekong Stripped Catfish	Ca Tra	*Pangasius hypophthalmus*
Hybrid Catfish	Ca Tre lai	*Clarias macrocephalus x C. gariepinus*
Notopterus	Ca That lat	*Notopterus notopterus*
Climping perch	Ca Ro dong	*Anabas testudineus (*Bloch*)*
Sand goby	Ca Bong tuong	*Oxyeleotris marmoratus* (Rleeker)
Snakehead	Ca loc bong	*Ophiocephalus micropeltes* C. & V.

Fish culture based on hatchery seed began in early 1960s. The introduction of induced breeding of fish can be traced to a group of technicians from north Viet Nam who travelled to the People's Republic of China between 1957 and 1960 to learn the techniques. Government hatcheries were subsequently built all over north Viet Nam between 1965 and 1975, and thereafter technicians were sent to the central highlands and south between 1975 and 1990.

Almost all of the commonly cultured freshwater fish seed are currently produced from hatcheries. Large variations in aquaculture environment, particularly in minimum temperatures between north and south Viet Nam are largely responsible for the differences in popularly cultured species in the two regions. Significance of aquaculture importance and existing hatchery seed production of different major freshwater fish in northern and southern provinces of the country are presented in Table 7.20.2.

Plate 7.20.1 illustrates the different freshwater fish species produced in hatcheries in Viet Nam.

TABLE 7.20.2
Hatchery seed production of freshwater fish species in Viet Nam

Species	Northern Provinces	Southern Provinces
Silver carp	+++	++
Bighead carp	++	+
Mud Carp	+	
Common carp	++++	+++
Grass carp	++++	+++
Rohu	++++	++
Mrigal	++++	+++
Black carp	+	
Spinibarbus	+	
Nile tilapia	++	+++
Silver barb	+	+++
Hybrid catfish	++	+++
Mekong stripped catfish	+	++++
Climbing perch	+	+++

Aquaculture importance and hatchery seed production: + ++++

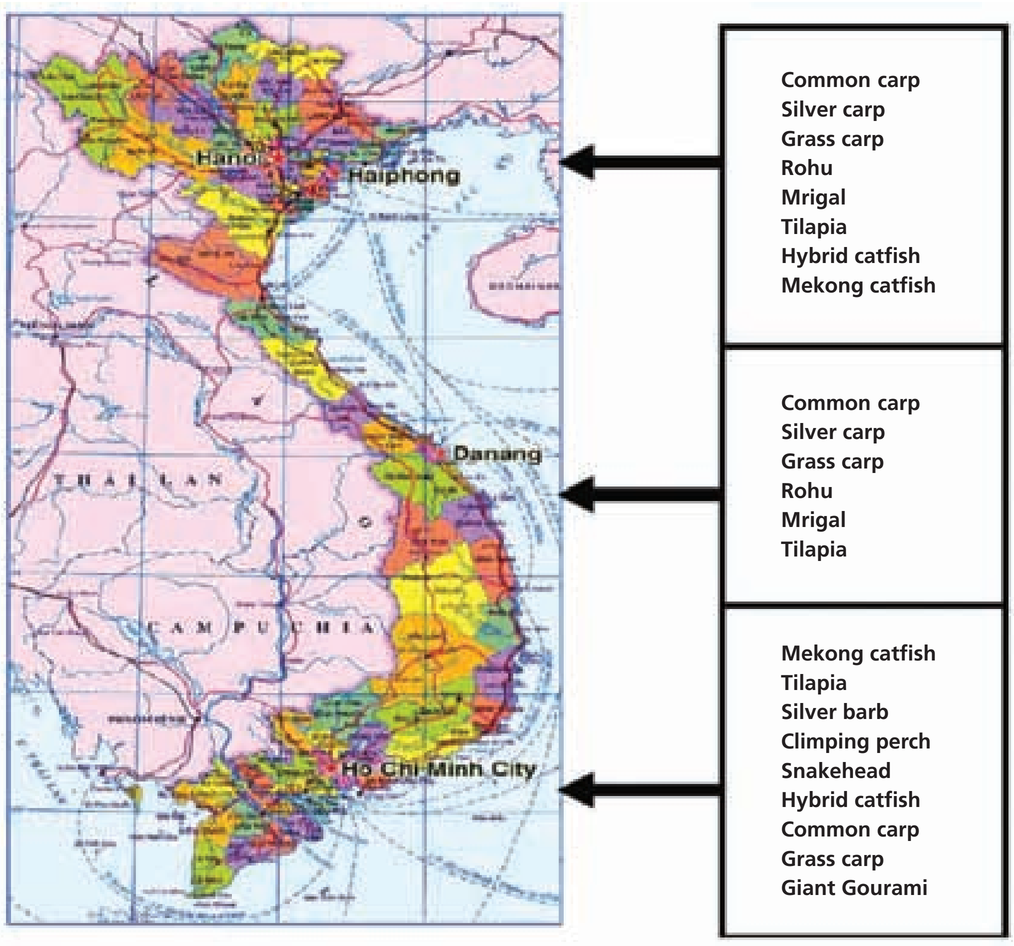


FIGURE 7.20.1
Location of commonly cultured freshwater fish species in Viet Nam

SEED PRODUCTION FACILITIES AND SEED TECHNOLOGY

Many of the estimated 420 hatcheries are currently in operation in the country. According to MOFI, in 2004 there were a total of 15 billion freshwater fish hatchlings produced from hatcheries. Out of these, 3 billion were Mekong stripped catfish hatchlings. Hatcheries used to be nominally under the Central Government, provincial administration or commune control. But most of existing hatcheries are now effectively being managed as private businesses. Private entrepreneurs are active in hatchery development and dominate the nursing and trading sectors in both north and south Viet Nam. Currently, only 43 hatcheries are government supported, although the level of support is variable and low. Financial support for government hatcheries are limited to management salaries and occasional investment in infrastructure. Most of the hatchery operation costs are met from seed sales and revenues are retained after payment of tax. Private hatcheries have evolved from farmer cooperatives and local government operations, but many started after implementation of the market reform policy. Most government hatcheries have larger pond areas than that of private operations.

The dominant hatchery technology throughout the country is the Chinese-style circular spawning and incubation systems (Figure 7.20.2) introduced from the People's Republic of China 40 years ago. Using low water head and large flow rates, these systems are eminently suitable for the water-rich delta areas of north and south Viet Nam where they are concentrated.

PLATE 7.20.1

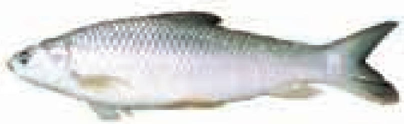
Illustration of freshwater fish species produced in hatcheries in Viet Nam

Common carp

Vietnamese Silver carp

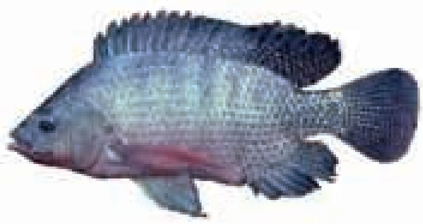
Chinese Silver carp

Rohu



Mrigal

Grass carp



Nile Tilapia

Black carp

FIGURE 7.20.2
Chinese-style spawning and incubation system

FIGURE 7.20.3
Careful selection of broodfish for spawning

Careful broodfish management and natural spawning, rather than stripping is the normal practice (Figure 7.20.3). Two types of hormone are commonly used in induced breeding of fish under hatchery conditions. These are preserved pituitary gland (PG) and gonadotropic releasing hormone (LH-RH). Most hatcheries spawn broodfish more than once in a season depending on species and seed demand. Major carp broodfish spawn two to three times in a season as is commonly practiced in hatcheries.

Chinese-style hatcheries suit Chinese and Indian major carps (grass carp, silver carp, bighead carp, rohu, and mrigal) including the *Spinibarbus* and silver barb. Common carp is an important species in both north and south Viet Nam, but appears to suffer significant hatchery constraints. Spawned naturally in hatchery cisterns, fertilized eggs attached to water hyacinth roots can be incubated out of water early in the season or in water as the temperatures increase. Stripping and 'dry' fertilization followed by removal of the egg stickiness before incubation in the normal way has also been found to improve hatchery efficiency of this fish considerably. These techniques were practised in producing common carp seed in a few hatcheries of the Research Institute for Aquaculture No. I (RIA 1), National Broodstock Centres (NBCs) and some provincial fish seed centres. The stripping technique and 'dry' fertilization are also commonly applied in production of hybrid catfish (*Clarias macrocephalus x C. gariepinus)* and Mekong stripped catfish.

Plate 7.20.2 shows some examples of the different types of incubation systems for different species used in Viet Nam.

Five to seven day old hatchlings are the main seed produced in hatcheries. Most hatcheries nurse some fry but the majority of hatchlings are sold to nursing operators. There are several concentrated areas of specialized nursery operators. Nursery operations are based on stocking a single species of hatchlings in fertilized earthen ponds at high densities. The fish are raised as a batch for a few weeks or months before harvesting.

Live gene banking of freshwater fish species was initiated at the three Research Institute for Aquaculture (RIAs), priority given to commonly cultured species/strains and seriously threatened indigenous freshwater species. Three NBCs have been built in the northern, central and southern regions providing *ex-situ* gene banking of commonly

PLATE 7.20.2

Examples of different types of incubation systems for different species

Incubation jars for common carps and catfish seed

Experimental and small-sized incubation jars for common carp and catfish hatcheries

Incubation for tilapia seed

Incubation for local river catfish seed

cultured freshwater fish species/strains and are responsible for dissemination and maintenance of genetic quality of existing and improved aquaculture breeds. They also have a role in genetic improvement for different stocks of major cultured freshwater fish. Recently, frozen gene bank have been developed, starting with the cryopreservation of common carp, grass carp, silver carp and Mekong stripped catfish.

SEED MANAGEMENT

A summary of technical parameters for seed production of some common freshwater fish species in Viet Nam is given in Table 7.20.3.

Most of the major carps (i.e. grass carp, silver carp, rohu, mrigal) with very high fecundity have the advantage for mass production of seed using the Chinese-style hatcheries with low head supply tank, supplied by water pumped from an irrigation canal.

The relatively low fecundity of common carp is a fundamental constraint to mass production of seed but production is further restricted by reliance on natural spawning in tanks or hapas with egg collection and incubation on aquatic weeds.

Despite the very recent history of hatchery development, hatchery operators have rapidly gained experience in managing broodfish and adapted quickly to the high demand for their products. Year-round spawning rapidly developed once it was realized that fish could be maintained in mature condition year round. Demand for seed exceeding supply has further stimulated output and operators have overcome constraints of small land areas by specialization into hatchling or fingerling production. Intensification of broodfish management through intensive feeding and multiple spawning became essential.

TABLE 7.20.3
Technical parameters of fish seed production in Viet Nam

Species	Age of maturity (year)	Average weight of spawner (kg)	Number of spawning per year	Introduction	Effective interval (hour)	Fecundity (1 000/kg Female)	Hatching time (hour)	Hatching rate (%)
Silver barb	1	0.15-0.2	4	1.5-3 doses of pituitary gland Water current	4-6	500-700	6-9	50-90
Silver carp	2	1-2	2	1 000-3 000 I.U. HCG/kg female	8-10	80-200	12-18	50-80
Indian carp	1-2	1-3	3	2.5-3 doses of pituitary glands 0.1 mg RLH/kg 500 I.U. HCG/kg	8-10	120-300	15-20	65-90
Common carp	1	0.3-1	6	1 dose of pituitary glands Water current	6-12	80-100	36-48	70-90
Hybrid catfish	1	0.1-0.25	3-4	3.5 mg of pituitary glands/kg 2 500-3 000 I.U. HCG/kg	14-18	50-70	22-26	60-90
Tilapia	3-6 mo	0.03-0.1	5-6	Natural spawning		6.3-18.5		

Tilapia seed production is part of a diversified sub-urban agriculture system concentrated in the peri-urban areas of Hanoi and Ho Chi Minh cities where the main sewage canal drains through these areas and mixed-sex tilapia are produced in shallow earthen ponds fertilized with sewage. Pond preparation involves draining, sun drying (one day) and application of pesticide before refilling. Quicklime is used at a rate of 7-10 kg/100 m^2 and pig dung or ammonium nitrate-based NPK fertilizers as basal fertilizers. Sewage varies in strength seasonally where dry season sewage is stronger and needs settlement before use. Approximately three weeks after stocking, young fry are evident and the brooders are removed by seining. The seed are then nursed on in the same pond for a further 10-30 days after which all the seed are harvested by seining, draining of the ponds and final fish harvest. The pond is then re-prepared over a ten day period. Seed are graded at harvest and the ratio of seed sizes harvested depends on the nursery period. The duration of the cycles varies with demand. If demand is low, the operator tends to lengthen the nursery period resulting in larger seed. A total of four to five cycles per year are normal. The system is efficient with respect to broodfish use because fish removed from one pond can be stocked in another. Usually, sewage is added during a culture cycle by gravity and pumping. Broodfish are also fed supplementarily with rice bran. The earthen pond hatcheries around Hanoi and Ho Chi Minh cities that have long produced poorly documented tilapia hybrids are now in decline because of urban development and there is a widening demand by public and private hatcheries for pure strains of Nile tilapia, with certified breeding histories.

Recently, demand of all-male tilapia seed is increasing in Viet Nam. Most of all-male tilapia are normally produced by sex-reversal treatment using hormone diets. Oral administration of hormone-treated diets, with a dosage of 17α-methyltestosterone ranging from 45 to 60 mg/kg^{-1} diet, starts from first feeding and continues for a duration of four weeks. Details of hatcheries and production of sex-reversed tilapia in Viet Nam in 2003 are shown in Table 7.20.4.

There are two methods of spawning catfish: natural spawning and artificial spawning. But now, artificial spawning is popular and necessary for catfish. Simply stated, artificial spawning involves administering the potential breeders with two shots of gonadotrophic hormones and then manually spawning the fish. Broodstocks are separated by sex three to four mos in advance of breeding. Females will have a soft belly and an enlarged, red genital pore. Males will display a small genital pore and flat belly. Broodstock are fed with a mixture of animal and vegetable protein at about 5 percent of their body weight per day.

TABLE 7.20.4
Production of sex-reversed tilapia fry (millions) in 2003

Hatchery and Province	Production by strain, where known		
	GIFT	Thailand	Total
Research Institute for Aquaculture No. 1, Bac Ninh	4.8	1.2	6.0
AG Aquacultural Research and Hatchery Production Center, An Giang	3.5	1	3.5
Do Luong Hatchery, Nghe An	—	—	2.0
Yen Ly Hatchery, Nghe An	1.9		1.9
Fish Seed Center, ThuaThien, Hue	—	—	0.7
Dong Son Hatchery/ Thanh Hoa	—	0.7	0.7
Fish Seed Center, Hung Yen	0.2	0.2	0.4
Fish Seed Company, Son La	—	—	0.2
Fish Seed Center, Hai Phong	1.8	1.2	3.0
Hai Thanh Company, Ho Chi Minh City	25.0	—	25.0
Phu Huu Company, Ho Chi Minh City	1.2	10.8[a]	12.0
Vinh Hung Company, Vinh Long	—	—	8.0
Fish Seed Center, DongThap	1.5	—	1.5
Total (where strains are known)	**39.9**	**14.1**	**64.9**

— = no data available by strain

The final stages of maturation of the female's eggs are induced by injection of hormones, a combination of dried pituitary glands and HCG. The hormones are grinded, dissolved in distilled water and administered as a single injection in the evening which allows the ripe eggs to be manually stripped from the fish the following morning. Sperms are obtained from testes removed from a male African catfish by dissection and the eggs are fertilized by carefully mixing eggs and sperm together in a bowl. The number of eggs produced per female depends on the time of year. In the early part of the season (February - April), 1 kg of females will produce around 5 000-7 000 hatchlings but this rises to over 20 000 later in the season. A single male will produce enough sperms to fertilize 0.5 kg of eggs.

SEED QUALITY

MOFI (2000) has issued criteria for seed quality of the most commonly cultured fish species. These include specific requirements for size and age of brooders and growth performance and health status of fish seed such as growth rate, survival, uniformity of size at harvesting. However, the government guidelines for standard broodfish age and weight are not clearly observed in many hatcheries. And there are no clear criteria for selection of quality broodfish.

Fish seed quality is an important concern by different aquaculture stakeholders. Little and Tuan (1998) reported more than 60 percent of fish farmers in the north perceived fish seed quality to be "good" or "very good", only a minority (< 7 percent) thought they were "bad". However, there presently is a widespread opinion that seed quality of most of commonly cultured fish species such as Chinese and Indian major carps, tilapias, etc. is poor. There are several reasons that can explain the existing poor quality of fish seed in Viet Nam. These are: (i) most hatcheries's broodstocks came from same sources, i.e. one founder stock and (ii) hatcheries have retained their own fish, only a few purchased extra from different sources, suggesting inbreeding is likely a problem and (iii) poor management of broodfish due to limited pond area and intensively multiple spawning.

In order to improve quality of fish seed, there have been several selective breeding programmes of freshwater fish. These genetic improvement programmes involved common carp (Thien *et al.*, 1993), tilapia (Dan, Luan and Quy, 2001), Mekong stripped catfish (Hao *et al.*, 2004), grass carp and mrigal (Tuan *et al.*, 2003, 2005). Awareness of genetic issues has also increased among hatchery operators during the last decade, largely due to training programmes and extension conducted in the country. These have lead to many hatchery operators changing their broodstock management practices and broodstock. The impacts of these are hard to measure but likely to be fairly widespread.

The Ministry of Fisheries promulgates and implements fish quarantine regulations in Viet Nam, the responsibility for disease screening is allocated to the National Office for Fisheries Quality and Aquatic Health. The RIAs have responsibilities for assessment of environmental and economic impacts of fish introductions and transfers. However, these institutes currently lack sufficient resources to implement biosecurity measures effectively. Illegal and unquarantined introductions of alien aquatic species are continuing, posing threats to biodiversity and to aquaculture and fisheries.

SEED MARKETING

Seed traders are obviously playing important roles in freshwater fish seed marketing and distribution in Viet Nam. The specialized nature of the hatchery, nursery and food fish operations have resulted in the emergence of traders or middlemen as key actors in fish seed marketing. However, many farmers buy fish seed directly from hatchery and nursing operators. Most farmers buy and stock fish seed in early part of the year when seed are considered as being "good quality" and having a longer period to grow.

Recently, tilapia aquaculture is expanding in Viet Nam. Demand for tilapia seed, particularly all-male tilapia in the northern provinces during the early months of the year is very high. Large numbers of tilapia seed produced in the south and China are imported to the north during February-May.

Trading fry and fingerlings is a seasonal activity peaking between February and May. Nursed seed are purchased and distributed mainly by young, otherwise underemployed, men in the village. Working in pairs, they travel long distances by bicycle with the fish seed carried in basket panniers lined with plastic sheeting. Typically only two baskets will be carried and the traders alternate the load between them. Seed may be traded locally but longer distance marketing, where fry are carried for several days, is also common.

Traders may extend their range by using a bus or truck for part of the journey to reach the furthest destinations which are often areas with few hatcheries and where there is a high demand for fish seed. Fish are conditioned in hapas prior to moving them and mortalities are generally very low during transportation. Water is regularly exchanged from ponds, rivers and the ricefields *en route* and the movement of the bicycle aids in aeration. The numbers of seed varies with the size rather than the season. Table 7.20.5 presents live transportation details of some freshwater fish seed in northern Viet Nam.

In order to promote sales, the nursing operators and traders often provide accommodation, and other services including provision of credit, guaranteed replacement of fish mortalities to seed buyers. The nursing operators also attract and maintain customers by ensuring that a variety of fish seed species are available during the sales season and guaranteeing both quality and quantity of the fish seed sold.

SEED INDUSTRY

Most of freshwater fish seed producers and suppliers in the country are small-scale operators. Fish hatcheries often have a total of pond water areas from 1 to 10 ha, with annual seed production capacity varying from 5 to 200 million hatchlings. Household nursing operators with limited pond areas ranging from 500 m^2 to 5 000 m^2 per household are common. They nursed fry and fingerlings to sell the majority of seed to nearby growers.

There are differences in weather conditions between the north and the south. Warm temperature all-round year in the southern provinces are favourable for fish seed production; the cold winter during December-March in the north is unfavourable weather for fish seed production. Fish seed have to be overwintered in ponds with

TABLE 7.20.5
Trading of freshwater fish seed in northern Viet Nam

Species	Size (cm)	Price (VND/fish)		Transportation			Notes
		Buy	Sell	Container	Containers/trip	Fish/container	
Grass carp	hatchling	2	3	Plastic bag	2	0.6 million	Bottled oxygen Motorbike
Rohu	hatchling	2		Plastic bag	1	50-70 000	Local nursery operator Air-inflated, bicycle, bottled oxygen, motorbike
	hatchling	2		Plastic bag	1	1.0 million	Up to 6 hrs
Mrigal	1-2			basket	2	8 000	Bicycle, 2.5-4 kg weight, 80 km journey
Grass carp	2	15	18	Basket	2	7 500	Bicycle
Mrigal	2-3			Basket	2	2 700	Bicycle, on ferry
Common carp	2-3			Canvans	1	200-300 000	By truck to northwest highlands; nurse themselves
	4			Tank	1	150 000	
Common carp	4	20	40-100	Basket	2	750	Bicycle < 100 Km 10 kg weight (depends on distance)
Rohu	8	36	50-100	Basket	2	300	Bicycle Nursing for 1 mo before sale (depends on season)

high water depth, even in green house facilities. There are often shortages of fish seed at early months of every year. Shortage and high demand of seed at early months lead to higher price of fish seed during these months.

Most seed suppliers are close to the markets. However, there is less development of hatcheries and nursing operations in the northern mountains, thus, a huge number of fish seed particularly fry and small fingerlings are being transported long distances from the suppliers located in the delta to markets in the mountainous areas.

Ho Chi Minh City is a concentrated area for tilapia seed production, most of its production are supplied to seed markets in the Mekong Delta and in the central highlands and even to northern provinces during February-May.

Women have actively involved in freshwater fish seed production. They are working in fish hatcheries, fry and fingerling nursing, i.e conditioning broodfish, pond preparation, feeding, and managing incubators. Only a few women are involved in fish seed trading.

A number of traditional knowledge of farmers exists in the freshwater fish seed industry in the country. Fish nursing farmers believe that preparation of seed prior to sale is very important and that which affects the quality of fish seed. Various techniques are commonly used including stopping feeding for one or two days before packing. Fish fry and fingerlings are trained in pond before harvest by seining or other forms of disturbance to acclimatize them to stress and eliminate weaker individuals. Hatchery operators report that well-fed and fully-mature broodfish produced high quality eggs and inappropriate use of hormones was also implicated in the production of poor quality seed in early breeding season.

SUPPORT SERVICES

There are good support services to freshwater fish seed industry in Viet Nam. Every year MOFI have aquaculture extension and technical training programmes, many of them related to freshwater fish seed production. These included:

- short-term training courses on hatchery and broodstock management of Chinese and Indian major carps, common carp, tilapia; sex-reversal tilapia techniques; improved common carp seed production and broodstock management;

- distribution of improved tilapia and common carp to different local hatcheries; and
- production of technical extension manuals on fish seed production, fish nursing, live fish transportation and others.

In order to promote aquaculture development in remote regions, there are annual budgetary allocations from local governments to subsidize fish seed transportation to fish farmers in the remote mountainous areas. Funds for each mountainous province usually range between VND50-200 million/year.

There are credit schemes available for farmers. Fish seed producers (hatchery, nursing operators) have access to credit from different banks where they can have a loan of VND50 million maximum for their seed business with very low interest.

SEED CERTIFICATION

There is no seed certification system existing in the country.

ECONOMICS

There are several factors that determine the price of freshwater fish seed. These depend on the balance between supply and demand, seasonality, species and quality of seed.

Seed production of most Chinese and Indian major carps are beyond the demand therefore these seed often are relatively cheap. However, the seed produced during the early months of the breeding seasons can be sold at higher price due to high demand of fish seed as fish producers are very keen in getting early seed for longer period of growth.

The price of the improved quality seed is normally high. The improved tilapia and the selected common carp can normally sell at 50 percent higher than that of normal ones.

PLATE 7.20.3
Freshwater fish seed transportation methods used in Viet Nam

STAKEHOLDERS

There are various stakeholders involved in freshwater fish seed production. These are as follows:

Producers/Farmers. There are a total of 420 freshwater fish hatchery operators and thousands of fish nursing farmers.

Fishery extension services. There are national networks of fishery extension services in the country. The National Fishery Extension Centre (NAFEC) under MOFI is responsible for fishery extension services at the national level. In every coastal province, there is a Provincial Centre for Fishery Extension Services under the Provincial Department of Fisheries, whereas in each inland province, fishery extension services are included in the activities of the Provincial Centre for Agriculture Extension Services under the Provincial Department of Agriculture and Rural Development.

Research Institute for Aquaculture (RIA) and National Broodstock Centres (NBC). There are three RIAs in the country (RIA No. 1, RIA No. 2 and RIA No. 3) who are responsible for aquaculture research and development in the north, south and the central regions of the country, respectively. Recently, three NBCs have been established under these RIAs. The RIAs and NBCs are responsible for development of new varieties/strains or innovations in freshwater fish seed production.

Government Institutions. The Department of Aquaculture under MOFI is responsible for providing the legal and policy frameworks for the seed industry.

Education and Training Institutions. There are seven universities in the country providing a degree on Bachelor of Science in Aquaculture. Aquaculture technicians have also been trained from three Fisheries Colleges.

Donors. There are a several existing donor-funded projects on freshwater fish seed research, development. These are:

- DANIDA: provided Support to Freshwater Aquaculture (SUFA).
- MOFI: provided support to the following research projects and activities:
  - Investigation into genetic improvement of grass carp and mrigal
  - Selective breeding for growth improvement of Mekong stripped catfish
  - Induced breeding and hatchery technique of *Hemibagrus elongatus* (Grinther)
  - Gene bank of freshwater fish species
  - Induced breeding and hatchery technique of *Semilabeo notabilis* Peters
  - Seed dissemination and technology transfer projects:
    - dissemination of improved common carp and tilapia strains
    - technology transfer of all-male tilapia production
- AUSAID: improved breeding of common carp for small-scale farmers (002/04VIE). A research project under the Collaboration for Agriculture & Rural Development Program (CARD).
- NORAD: selective breeding for growth improvement of tilapia, a component under the NORAD-funded project on Building up Research, Education and Extension Capacity of RIA-I.
- ADB: achieving greater food security and eliminating poverty by dissemination of improved carp strains to fish farmers (ADB-RETA 6136).

FUTURE PROSPECTS AND RECOMMENDATIONS

The Government of Viet Nam has considered freshwater aquaculture as an important means to ensure food security of the Vietnamese people in the future. Production of enough quantity of quality fish seed is an essential factor to sustain development of freshwater aquaculture in the country. The government had approved a national program of aquaculture development for the period of 1999-2010 which projected 2 million of aquaculture products by the year 2010, of which 0.87 million tonnes will come from freshwater aquaculture. It has also estimated that a total of 9 200 million freshwater fish seed of major cultured species (Major chinese and Indian carps, Mekong stripped catfish, tilapia) are needed.

There are several issues related to freshwater fish seed production in Viet Nam, these are:

- development of appropriate methods for field-level identification of fish seed quality is obviously needed;

- improving quality of fish seed is essential, plans for developing improved genetic quality of fish seed should involve private hatcheries, as well as appropriate approaches of improved seed dissemination;
- further training in both technical and management of seed production for stakeholder's are needed; and
- certification of seed quality should be developed.

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7.21 Freshwater fish seed resources in Zimbabwe

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ABSTRACT

Nile tilapia and rainbow trout are both farmed in Zimbabwe. Nile tilapia seed was introduced to Zimbabwe from Kenya, Zambia and Scotland in the 1970s for aquaculture farming purposes. Trout was introduced in the early 1900 for sport fishing. Nile tilapia seed is difficult to find in Zimbabwe due to low demand, restriction of Nile tilapia seed movement from hatcheries and possible inbreeding. Tilapia is popular as it can be dried, smoked or salted which improves storage life. Trout is less popular as it is not as well known or readily available and refrigeration is needed for storage. Although Zimbabweans prefer red meat and chicken, demand for farm raised and wild caught tilapia is strong and growing.

Currently, two private hatcheries in Zimbabwe grow 19 million tilapia seed per annum. Seed are for private use and transportation is restricted, as moving seed requires a permit from the Government's National Parks and Wildlife and such permits are very difficult to get. There is one government trout hatchery in Nyanga, which provides seed to dams for recreational fishing. Inbreeding reduces overall performance of a fish. As no new introduction of seed had been made since their initial introduction to Zimbabwe, it is likely that inbreeding is affecting the overall growth and reproductive vigour of both Nile tilapia and trout stocks. National Parks and Wildlife is being consulted for permission to import fresh Nile tilapia genes.

Warm water temperatures in northern Zimbabwe are ideal for tilapia production, just as the cooler temperatures in the eastern highlands are for trout farming. Although Zimbabwe has a natural competitive advantage for seed production, the economic situation and lack of legal framework is not conducive to investment. Positive investment incentives and duty free import of equipment need to be developed in order attract sector investment.

INTRODUCTION

Only Nile tilapia (*Oreochromis niloticus*) and rainbow trout (*Onchorynchus mykiss*) are farmed commercially in Zimbabwe. African catfish and Indian carps are also

FIGURE 7.21.1
Map showing the location of aquaculture farms in Zimbabwe

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present in the country, but are not farmed commercially. Nile tilapia is not indigenous in Zimbabwe but was introduced, probably in the 1970s, for fish farming purposes. It is not authorised for farming outside the Zambezi valley, which includes Lake Kariba in the north of the country. This species is known to be present in many farm dams and natural water bodies across the country, following unofficial introductions that have been made over several decades. Carp has been introduced to Lake Chivero, near Harare, to try and control prolific weed growth but is not farmed commercially in Zimbabwe. Environmental conditions in the Zambezi Valley and Lake Kariba are acceptable for commercial tilapia farming outdoors as water temperatures are warm (above 24 °C) for most of the year and water quality is good. Water temperatures south of the Zambezi Valley, or on the Highveld, are probably too cold for too long for outdoor commercial tilapia farming.

There are three known tilapia farms in Zimbabwe (Figure 7.21.1):

- 'Lake Harvest Aquaculture (Pvt.) Ltd. (LHA), established in 1997 in Kariba (365 km northwest of Harare) and producing around 3 000 tonnes per annum of whole fish;
- 'The Bream Farm', established in the early 1980s in Kariba and producing less than 100 tonnes per annum, mainly on a recreational put and take basis); and
- 'Mazvikadei Fish Farm' near Banket (90 km northwest of Harare), established in the 1970s and currently producing around 50 tonnes per annum of tilapia, mainly on a recreational put and take basis.

There are three known small trout farms in Zimbabwe (Figure 7.21.1). All are located in the Nyanga area, in Zimbabwe's Eastern Highlands, where colder water temperatures enable trout production. There is also a government trout hatchery in Nyanga that produces small numbers. Trout were introduced into the eastern highlands in the early part of the 20th century from Europe, for sport fishing.

- 'Clairmont Trout Farm', established in the 1970s or earlier and producing no more than 50 tonnes per annum;
- The Trout Farm, established in the 1970s or earlier and producing less than 5 tonnes per annum; and
- 'Inn on Ruparara' trout farm, established in the 1990s and producing less than 20 tonnes per annum.

Zimbabweans generally prefer red meat and chicken to fish but demand for farmed and wild tilapia is strong. Tilapia is known as 'bream' in Zimbabwe. Farmed fish is preferred to wild as wild-caught tends to be associated with quality problems (off-flavours, spoilage, presentation and traceability). LHA sells the equivalent of around 800 tonnes per annum of whole farmed fish in Zimbabwe in the form of frozen fillets and frozen whole fish. There is also strong demand for the cheaper by-products (heads and belly flaps). Other by-products of tilapia are sold to crocodile farms.

Trout is less popular than tilapia as it is less well-known and not readily available, being an introduced species from Europe and only farmed in the Eastern Highlands. It is also more expensive than tilapia. Trout is only available in up-scale supermarkets and restaurants in cities, whereas tilapia is found in salted and dried forms (wild-caught) and in frozen form in butcheries and supermarkets across the country.

Cages are separated and kept in deep water which ensures that the environmental impact if positive

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SEED RESOURCES AND SUPPLY

Farmed tilapia seed is available from private hatcheries: LHA and The Bream Farm, both in Kariba. LHA produces around 2 million fry per month for 9 months of the year (i.e. when water temperatures are warm enough to breed outdoors). The Bream Farm produces around 1 million fry per annum. Both farms produce tilapia seed almost exclusively for their own use. Little to no seed is sold to third parties because firstly, demand is low and secondly, Nile tilapia, the only tilapia seed produced in hatcheries in Zimbabwe, is not supposed to be moved out of the Zambezi Valley (including Lake Kariba), except by way of permit from the Government's Parks and Wildlife Authority. Such permits are difficult to obtain.

There are no operational government hatcheries for tilapia in Zimbabwe, although the authors understand that attempts are being made by the government to resuscitate one or two of the Government hatcheries.

Each of the three trout farms has its own small hatchery for on-farm use. The government hatchery in Nyanga produces seed for local dam stocking. This is for recreational put and take fishing.

SEED MANAGEMENT

The Nile tilapia in Zimbabwe was introduced from Kenya, Zambia and Scotland (through the University of Stirling) in the 1970s and 1980s. There have been no subsequent introductions and the author believes that inbreeding is a serious problem in the Zimbabwean stocks. Permission from the Parks and Wildlife Authority is currently being sought for bringing in fresh genes. Inbreeding is likely to be a problem in the trout stocks also.

Tilapia broodstock are kept in earthen ponds in Kariba. There has been some hybridization with other tilapias, including *O. mossambicus* and *O. mortimeri*. LHA has an active selective breeding programme, which commenced in 2004. This was designed with the assistance from the Worldfish Centre (WFC). Spawning is mainly by way of batch culture, supported by newly (2004) introduced hapa spawning and egg incubation. LHA holds around 15 tonnes of broodstock, of various ages and parent groups.

Fish feed is produced by one large scale commercial animal feeds supplier. Most of the smaller fish farms make their own feed as cost, availability and logistics are often prohibitive. Obtaining quality fish feed in large volumes is difficult in Zimbabwe because the raw materials have become scarce (mostly imported since around 2002) and expensive and there has never been any serious investment in aquafeed equipment. Extrusion is of poor quality. This makes intensive tilapia aquaculture inefficient. High crude protein (45 percent) fry food is available and is of reasonable

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Lake Harvest tilapias are transferred to floating cages once they reach the juvenile stage.

quality (as extrusion is not required), but is expensive due to high imported fishmeal inclusion.

Trout feed is expensive because of its high fishmeal percentage, which is expensive to import. Pigment additives are also difficult to obtain because they involve foreign currency. Fish oil is expensive to import and difficult to obtain.

SEED QUALITY

Tilapia seed quality is probably poor in Zimbabwe due to likely inbreeding of existing Nile tilapia broodstocks. Fresh genes are needed for improved growth performance although LHA has its own selective breeding programme, which is beginning to produce positive results. The Zimbabwean authorities are reluctant to allow the introduction of new genes at the present time, although they are considering LHA's request for an import of the Genetically Improved Farmed Tilapia (GIFT) fish from Malaysia.

Water quality is high in Lake Kariba and no serious health or disease problems in tilapia are known of by the author, although there have been one or two low level incidents of treatable bacterial infection.

Growth rates are site-specific, being heavily dependent on temperatures and feed quality in particular. With good (> 24 °C) water temperatures for nine months of the year, reasonable quality feed and year-round feed availability, growth rates from fry to market size (750 g) of 14 to 16 months can be expected. Fresh genes, selective breeding and improved feeds are needed to improve growth rates.

Good hatchery hygiene is practiced in LHA but not throughout Zimbabwe.

There are no set criteria for seed quality in Zimbabwe.

There is a high degree of variability in fish sizes at harvest and this is mainly due to feed quality, irregular fed supplies, sub-optimal husbandry practices and a likely high incidence of inbreeding.

SEED MARKETING

There is no formal seed marketing in Zimbabwe.

SEED INDUSTRY

Aquaculture is a small industry in Zimbabwe with only a handful of farms. Thus the fish seed industry is also on a small-scale, with the exception except of LHA, which produces around 18 million tilapia fry per annum for own consumption.

SUPPORT SERVICES

The Government of Zimbabwe has established a small aquaculture extension service within the Department of Agriculture and Rural Extension services (AREX). Its main role is small water body stock enhancement. It has been responsible, since 1992, for stocking dams and small water bodies with *O. mossambicus* tilapia. The seed have been collected from the wild. Species such as *O. macrochir*, *Tilapia rendali* and *T. sparrmanni* have also been stocked in small dams across the country.

FAO is currently sponsoring a small water body stock enhancement programme that is managed through the Parks and Wildlife Authority. No dams have yet been stocked under this programme.

There is no meaningful public sector research being conducted on aquaculture and its development in Zimbabwe.

SEED CERTIFICATION

There is no seed certification in Zimbabwe.

LEGAL AND POLICY FRAMEWORKS

There is no legislation covering aquaculture seed specifically in Zimbabwe.

ECONOMICS

In the authors, view, Zimbabwe offers good natural competitive advantages for commercial tilapia and catfish aquaculture. However, the economic environment and lack of legal framework for this sector are not conducive to investment. The current costs of aquaculture production in Zimbabwe (especially feed) are high. Changes in the macro-economic fundamentals are needed before any significant further investment is likely to take place in this sector. Fish seed are not sold on a formal basis in Zimbabwe and any informal trade is very small scale. However, LHA would be able to ramp up its fry production very significantly if there was demand.

STAKEHOLDERS

The main stakeholders are the five existing fish farms in Zimbabwe (commercial producers with own hatcheries), as well as the Parks and Wildlife Authority of Zimbabwe (license operators, control fish movements, lease water bodies for aquaculture) and AREX (described above).

The Department of Livestock and Veterinary Services is also a key stakeholder as they prescribe and manage the administration of chemicals for use in aquaculture. They are also the designated 'Competent Authority' for the export of farmed fish products from Zimbabwe to Europe.

There are no NGOs currently involved in aquaculture in Zimbabwe at present.

There is no association of aquaculture producers in Zimbabwe at present. A regional association rather than a Zimbabwean one would be more appropriate in the authors' opinion, at this stage of the industry's development. It is unlikely that a local association would have any significant impact in Zimbabwe at present, as fisheries/aquaculture is not an important sector as far as the overall economy is concerned, and there are too few producers in Zimbabwe.

Research should target improved seed (genetics, growth rates) and feed (using locally available materials), disease risks and management, as well as on mapping areas suitable for commercial aquaculture.

Government may need assistance in developing a policy and legal framework for aquaculture. Aquaculture investment zones should be established.

There are no donor funded projects in aquaculture in Zimbabwe at present.

FUTURE PROSPECTS AND RECOMMENDATIONS

In the authors' opinion, Zimbabwe could be a major low-cost producer of tilapia

Harvesting of tilapia from Lake Harvest Aquaculture Ltd

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and catfish for regional and export markets. LHA is already perhaps the largest tilapia fish farm in Africa and produces high quality fish products, intensively. It has demonstrated that commercial industrial scale aquaculture is viable in Zimbabwe, under difficult economic conditions. However, the macroeconomic fundamentals need to change before any further investment in this sector will take place.

An enabling legal framework for aquaculture also needs to be established, to make it easier for potential investors in this sector. Policy management of the sector may need to be reviewed as currently this is not sensitive enough to the needs of an investor.

Improved growth strains of Nile tilapia need to be brought in so that growth rates can be improved. In the author's opinion, this is important for Africa generally because Africa is being left behind Asia and Latin America in the race for efficient and low cost tilapia commercial aquaculture.

There needs to be a focus on selective breeding in Zimbabwe.

A package of attractive investment incentives should be designed specifically for aquaculture, including duty free import of equipment.

Support for private sector initiatives, rather than government-led development of this sector, is recommended.

Training (theory and hands-on) and focused research at agricultural college and university level is needed.

Credit lines for commercial aquaculture development need to be established, although aquaculture is a long-term investment risk and is suited more to equity type investment rather than to debt.

The actual distribution of Nile tilapia across Zimbabwe should be mapped and, in the light of this, policies reviewed on movement/stocking of this species across the country.

8. Thematic reviews and contributed papers

8.1 Seed quality in freshwater fish production

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ABSTRACT

Aquaculture is the fastest growing food production sector, globally. The old adage of "what you sow is what you reap" certainly holds true. Quality seed is a fundamental pre-requisite for sustainable and successful aquaculture. In many countries including Asia, the issue of seed availability has always attracted the attention of aquaculturists, developers and policy makers and the response has been to produce enough quantities of seed locally. Wherever this has not been possible, introduction of seed or broodstock from other sources (e.g. import) has been the norm. As the quantity and availability of fish seed have improved in Asia, the quality issue has come to the forefront. This has received special attention in recent years when poor performance indicators (e.g. growth, production, survival, disease) have consistently been attributed to seed quality. However, it must be remembered that in all aquaculture systems, stocking quality seed does not necessarily ensure a successful crop. The success does depend on a range of other factors including post-stocking management practices (e.g. water quality, feed and disease management). There is a need to very clearly understand the relationship between quality seed and post stocking success on a species by species basis for important cultured species. Otherwise there is a danger of all crop failures (e.g. poor growth, mortality, low survival) being attributed to seed and seed quality alone.

Seed which are active, healthy in appearance, uniform in size, potential for high survival, better growth, less/or no disease usually fit the definition of good quality seed, irrespective of the species. Some of the important factors which are perceived to have a significant impact on seed quality include broodstock health and genetic make-up and husbandry (hatchery and nursery) practices. Most quality assessment criteria include gross examination, activity evaluations, stress tests and screening for specific pathogens. In high value species, such assessments would be scored and used to make informed decisions.

Seed producers and suppliers have a major responsibility to ensure production and delivery of quality seed to the farmers. Farmers should make an attempt to understand the concept of seed quality, select the right kind of seed and follow better management practices (BMPs) to give the stocked seed the ideal conditions to grow. National governments should endeavor to develop and implement mechanisms (e.g. development and promotion of BMPs, seed certification, domestication, brood stock banks) that will ensure supply of quality seed to farmers. Compliance to global instruments, standards, codes of practice and guidelines will help to minimize the risks due to pathogens/diseases

associated with transboundary movement of seed and broodstock. Only through strong resolve and commitment among stakeholders, can production and supply of quality seed be assured.

INTRODUCTION

Aquaculture is the fastest growing food production sector, globally. The Asia-Pacific region is the biggest contributor to aquaculture production, producing over 90 percent of total volume. The recent regional review of status and trends in aquaculture development in Asia-Pacific conducted by FAO in collaboration with NACA (NACA, 2006) identified five major trends for aquaculture, namely: (i) increasing intensification driven by restrictions and limits to aquaculture expansion, (ii) continued diversification of species and need for their responsible use, (iii) continued diversification of production systems, (iv) increasing influence of markets, trade and consumption and (v) enhanced regulation and better governance. These five trends will have positive and negative impacts on producers, consumers, governments and most importantly on the environment. The challenge would be to promote the good impacts and mitigate the negative impacts. This challenge will therefore create a drive for better management in aquaculture in many parts of the world. Better management has different meanings and connotations for different stakeholders. In simple words, better management could mean efficient production systems which meet the expectations of the producers, requirements of consumers and ensure sustainability of the environment. The goal of the primary producer is to increase yields and maximize returns and at the same time implement sound management measures that help to sustain the practice. With more stringent demands coming from domestic and export markets for safe and higher quality fish, aquaculture operators will be under severe pressure. The success of farmers, especially the small-scale ones will depend on the efficiency of their production systems.

IS SEED QUALITY AN ISSUE?

The old adage of "what you sow is what you reap" certainly holds true. Quality seed is a fundamental pre-requisite for sustainable and successful aquaculture, be it small-scale or commercial farming. Inadequate supply of quality seed is often suggested as a major constraint for aquaculture in many parts of the world (Little *et al*., 2002a). Availability (quantity) and quality are often confused or mixed when discussions center around crop performance or aquaculture development. There is a need to very clearly and carefully distinguish between seed availability (quantity) and quality arguments.

For example, Kongkeo (2001) emphasized that one of the technical constraints in Asian aquaculture is the inadequate and unreliable supply of quality fish seed, while Machena and Moehl (2001) identified the lack of fish seed as a serious restriction to aquaculture development in sub-Saharan African region. Little *et al.* (2002a) interestingly suggests that as the quantity and availability of fish seed have improved in Asia, the quality issue has come to the forefront. The following two questions need to be carefully understood before discussions on seed quality can proceed.

1. Is there enough seed available (quantity) to meet the demands of the growing aquaculture industry?
2. Is there enough quality seed to ensure sustainable and profitable aquaculture enterprise?

In many countries including Asia, the first question has always attracted the attention of aquaculturists, developers and policy makers. If one considers the development of aquaculture practices, it becomes apparent that the first response has been to produce enough quantities of seed locally (within the country) to meet the requirements of the industry. Wherever this has not been possible, introduction of seed or broodstock from other sources (e.g. import) has been the norm. This has happened in the past and is still happening with shrimp, freshwater prawn, carps, catfish and tilapia. The issue of quality comes to the attention of producers only after a certain period of time when performance indicators (e.g. growth, production, survival, disease) consistently point a finger towards seed quality. Very often this is too late. Factors which contribute to production of poor quality seed would have become established as a normal practice in the system.

Now we are in a stage where the emphasis is slowly shifting from quantity to quality. Only in very recent years have farmers began to realize the importance of quality seed (e.g. uniform sized seed, pathogen-free seed) to the success of a crop. It may not be entirely wrong to say that this shift in emphasis (attitude) to seed quality has come about largely because of the recurrent disease problems that has besieged the aquaculture industry especially shrimp and freshwater prawn.

Production of quality seed should be examined from two perspectives, i.e. existing seed production systems and new seed production systems. Existing seed production systems have mastered the hatchery technology for most of the widely cultivated species (shrimp, prawn, carps, catfish, tilapia), but the industry is yet to perfect the art of producing seed of desired quality. The task ahead in the seed production sector is to understand the factors that contribute to poor quality seed and develop interventions (better management practices [BMPs]) to address the problems. If we consider the cyprinid, freshwater prawn or tilapia industries, the challenge is to promote BMPs at every stage of the seed production chain and rectify the problems or minimize the risk factors which contribute to production of poor quality seed. Such management interventions come at a cost and therefore quality seed will be more expensive. This is different to setting up of a new culture system in a region or country. While setting up of new seed production systems, every effort should be made to use the available knowledge and learn from the past mistakes of the sector. Relevant authorities should ensure that the new systems adhere to standards and guidelines and produce quality seed.

Aquaculture development in many parts of the globe has been based on the ready availability of seed to farmers. Although seed of key cultured species (e.g. cyprinids, catfishes, tilapia, shrimp and prawn) are now produced in large quantities, poor quality is increasingly seen as a major impediment to the success of aquaculture. However, it must be remembered that in all aquaculture systems, stocking quality seed does not necessarily ensure a successful crop. The success does depend on a number of other factors including post-stocking management practices (e.g. water quality, feed and disease management). There is a need to very clearly understand the relationship between quality seed and post-stocking success on a species by species level for important cultured species. Otherwise there is a danger of all crop failures (e.g. poor growth, mortality, low survival) being attributed to seed and seed quality alone. Such a misconstrued approach might limit opportunities to look for post-stocking management interventions that could contribute to a successful crop.

It is very difficult for quantity and quality to go hand in hand. Aquaculture development plans should be based on availability of quality seed and not merely on availability of seed. The shift in emphasis to quality brings in several questions:

- What is quality seed?
- What factors contribute to poor quality seed?
- What practices are necessary to ensure production and supply of quality seed to growers?
- What tools are there to assess quality of seed?
- What mechanisms are in place to ensure supply of quality seed to farmers?
- How to ensure compliance to quality standard by seed production sector?
- How to monitor post-stocking performance of the seed and its relation to quality?

- How to ensure that the grow-out sector implements better post-stocking husbandry practices to achieve success with good quality seed?

The present thematic review attempts to address some of the above issues. This review describes factors that might contribute to poor quality seed, identifies some of the seed quality assessment criteria followed in the sector, highlights the roles and responsibilities of different stakeholders in the seed production and supply chain, suggests some approaches based on case studies, discusses regional and international standards and instruments that contribute towards quality seed, and finally raises some issues for discussions during the workshop for developing recommendations and action plans.

SEED QUALITY – DETERMINING FACTORS

As stressed in the earlier section, it is still not always clear whether poor performance of fish seed are due to the fish seed quality itself or results from inadequate management by grow-out farmers (Little *et al*., 2002a, b). However, for the purpose of this paper, a good quality seed is defined as one that benefits the hatcheries, nurseries, intermediaries in the seed supply network and finally the producers. Seed which are active, healthy in appearance, uniform in size, with potential for high survival, better growth, less or no disease usually fit this definition of good quality seed, irrespective of the species. There are several factors which could contribute to the quality of seed. Some of the important ones which are perceived to have a significant impact on quality include:

- broodstock
- husbandry (hatchery and nursery)
- seed movements and availability (transport, holding and distribution, trans-boundary movements)
- pathogens and diseases (important parasitic, bacterial, fungal and viral diseases)

Broodstock

Management of broodstock has critical impacts on the health status and subsequent performance of seed (Mair, 2002). Broodstock source (wild or domesticated), health, genetic make-up, maintenance and spawning methods have often been linked to poor quality seed and subsequent poor performance. Husbandry of broodstock during maturation of the gonads is likely to affect seed quality. Increased frequency of spawning and out-of -season production may also result in poor quality seed. If seed quality is identified as a problem, it is not always easy to attribute the problem to broodstock-related issues. For ascertaining this with some degree of confidence in any cultured species, there is need for strong population-based research accompanied with good record keeping and traceability system by the seed producers and farmers. The potential negative impacts of genetics-related broodstock management issues such as inbreeding, genetic drift, introgressive hybridization and unconscious selection on the quality of seed is beyond the scope of this review. Broodstock health status is important to consider as some of the dangerous pathogens are known to be transmitted both vertically and horizontally to the progeny. In the case of shrimp and freshwater prawn, it is becoming increasingly common to screen broodstock for selected pathogens and choose those which test negative. Individual spawning is now being promoted in shrimp and prawn hatcheries to prevent cross contaminations which are common in mass spawning systems. Use of genetic tools and domestication programs to improve quality in terms of growth and disease resistance is another area which is seen increasingly important towards contributing to quality seed. Specific pathogen free (SPF) and specific pathogen resistant (SPR) programmes are making a significant positive impact in enhancing the quality of seed in shrimp farming. Compared to high value shrimp, screening and selecting brood stock which are negative for pathogens is yet to become a practical and feasible management option in carp, catfish or tilapia farming.

Husbandry

Poor husbandry practices during production, nursing, holding or transportation are believed to negatively affect the quality of seed and later performance. There could be innumerable husbandry-related factors that could have a bearing on the quality of seed that is finally produced from a hatchery or seed rearing facility (e.g. nursery systems). In principle, this could apply to a simple backyard hatchery or a sophisticated commercial hatchery of any species. In this paper, no attempt is made to list all the potential factors that could compromise the quality of the seed instead, some key issues are highlighted and generic approaches which could improve quality of seed have been suggested.

Spawning and hatching techniques that promote production of high quality, disease-free eggs and larvae (e.g. disinfection strategies, separation of dead and unfertilized eggs, separation of spawning and hatching units, individual spawning) should be of priority consideration in any hatchery. Use of same facility for seed production of different species could encourage transfer of pathogens between species. For example, shrimp hatcheries are routinely used in some countries for freshwater prawn. It is well known that pathogens which are harmless in one species could become highly pathogenic in another species. Similar practices also exist in freshwater fish hatcheries (e.g. cyprinids, catfishes, tilapia).

The design of the hatcheries and nurseries should consider biosecurity, efficiency and cost-effectiveness. For example, hatcheries using water directly from the source water could introduce infectious agents (e.g. spores, larval stages of parasites, other carriers of pathogens). Water for the hatchery should be filtered and treated to prevent entry of disease carrying organisms and any pathogens present in the source water. Hatcheries without biosecurity measures in place could easily end up producing infected or poor quality seed. Diseases which can affect one tank (indoor or outdoor) of larvae can be easily spread to other tanks or rearing systems through contamination of hands or equipment, if it is used for more than one tank. Similarly, poorly prepared outdoor rearing/nursing systems could infect good quality seed produced in a biosecure hatchery. Procedures for disinfection of hands, feet and equipment should be strictly followed to prevent cross contamination. To reduce disease and stress levels for the growing larvae, it is important to stock the correct number of larvae and maintain optimum water quality conditions throughout the larval rearing process.

Routine health monitoring is an important component of good husbandry to ensure that any potential problems are recognized early and interventions employed to rectify the underlying causes and prevent further spread. Diseases in hatcheries and early larval rearing (nurseries) systems could lead to mortality and production of inferior quality seed. Oftentimes seed coming out of systems that have a history of disease might look clinically healthy but in fact could be carriers of pathogens. Such seed, when get transported and stocked in grow-out systems, could result in immediate post-stocking mortalities or growth loss thereby affecting productivity.

The growth and survival of seed, and the water quality of the larval rearing systems (indoor or outdoor) depend to a large extent on the quality and quantity of food offered to the larvae. Use of good quality feed of right kind and optimizing feeding regimes help maintain good water quality, whilst promoting growth and high survival, thus, resulting in production of good quality seed from the hatchery.

Chemicals used in the seed production systems could affect the final quality of seed. Many of the chemicals routinely used in hatcheries and seed rearing facilities are often ineffective for major disease problems. Indiscriminate use of chemicals (e.g. antibiotics) can lead to bacterial drug resistance, induce slow growth and suppress immunity in the seed. It is now well recognized that seed exposed to these banned chemicals can retain very low traces of the chemicals in the tissue for long time. Stringent food safety requirements in many countries will make it very difficult for aquaculture products with low levels of banned chemicals to be marketed. From this perspective, it is worth considering tissue residues as criteria for seed quality assessment.

Seed production systems which have a comprehensive system of documentation and record keeping will be in a better position to determine the cause of any problems and take remedial actions. Such in-house practices will contribute towards producing good quality seed.

In order to ensure production and supply of quality seed to grow-out farmers, it is necessary to establish a set of BMPs which underpin an effective hatchery production system. These include the presence of essential infrastructure, the development of biosecurity system, the provision of adequate amounts of clean water, the responsible use of chemicals, correct feeding practices, and the assurance of the health status of stocks through in-house and laboratory testing. Similar BMPs should also be developed for broodstock (collection, handling and maintenance), seed transportation, etc. Stakeholders in the chain should be encouraged to follow BMPs, otherwise the impact on quality could be compromised. Implementing simple science-based BMPs by all stakeholders could go a long way in producing and delivering large numbers of high quality seed. BMP information for most cultured species is available in one form or the other. Developing simple and easy to understand BMP manuals for important cultured species is very useful. BMP manual developed under the NACA/support to brackishwater and marine aquaculture (SUMA) project for *P. monodon* hatcheries in Vietnam is a good example in this direction (www.enaca.org/modules/mydownloads/viewcat.php?cid=169).

Seed movements and availability

Harvest and transport of seed should be done with great care and with minimum stress. This will ensure good survival rate of seed on stocking into the grow-out ponds. It is well known that seed are moved (transported) within a locality, province, and country and between countries both legally and illegally. In most parts of the world this movement is mainly driven by demand. Bringing quality assurance along the movement chain is a very difficult challenge. The seed transport and distribution chain can be short or long. Whereever the time and chain is short, delivery from the seed production center to the grow-out system may not significantly diminish the quality of seed. Farmers may be assured of the same quality that originates at the seed production centre. However, if the time and the distribution chain is long, then the probability of quality deterioration is high. There can be several reasons for it. Mode of transportation, awareness levels of seed handlers and intermediaries, local conditions and constraints, experience of entrepreneurs are all important.

Many actors (e.g. farmers, traders/distributors, nursery and hatchery operators) handle fish seed from its source of production to delivery; poor management may occur at any stage. The nature of seed supply networks predisposes fish to disease. Handling of seed occurs frequently and in environments prone to change and extremes. These increase the stress and the likelihood of disease. Poor quality may also undermine the livelihoods of actors in the supply network. Understanding the stakeholders, their current practices, the constraints they face, and the experience gained as entrepreneurs in fish seed production, distribution and use are important to develop system-specific strategies to improve quality (Little *et al.*, 2002a). Development of simple BMPs (e.g. transport during cool hours of the day, proper aeration, acclimatization before stocking, minimum handling) for actors in the seed distribution chain can be of significant value.

Seasonality and availability of seed have indirect bearing on the quality of seed a farmer receives. For many species, breeding is done only during certain seasons and this makes availability of seed throughout the year difficult. Development of local specific interventions to tackle the issue of availability has led to some innovative practices, which have contributed to considerable improvements in quality (Box 8.1.1).

BOX 8.1.1

Stunted yearlings

To overcome the problem of seasonality and availability, carp farmers of Andhra Pradesh, India started the system of producing "stunted yearlings", which has now become very popular (Veerina, Nandeesha and Rao, 1993; Mohan and Bhatta, 2002). In this innovative approach, farmers would buy seed during the carp breeding season (e.g. monsoon months) and stock at very high densities (50 000-100 000/ha), feed at 1-2 percent body weight and rear for 6-12 mo. The surviving fish at the end of the holding period would be approximately 100-200 g in size and stunted. It is widely believed (circumstantial evidence) that the weak and sick fry would die and the healthy ones will become stunted. These stunted yearlings when stocked into grow-out ponds (3 000/ha) would grow to 1.5-2.5 kg in 8-12 months with survival rates of 85-95 percent. In commercial carp culture systems in many parts of India, this practice has completely replaced the conventional system of stocking fingerlings, and there is considerable improvement in health, survival and production.

Widespread trans-boundary movements of seed are a cause for serious concern.

Globally, aquaculture is expanding to new areas, intensifying and diversifying. So are trade in aquaculture species, products and services. These includes seed and broodstocks. Trade in seed and broodstocks usually carries some inherent risk of moving aquatic animal pathogens. Majority of the seed and broodstock (e.g. shrimp, freshwater prawn, tilapia, cyprinid) movements have been intentional and primarily for the purpose of aquaculture (Briggs *et al*., 2004). Irresponsible movements still constitutes the major reason for the spread of infectious pathogens. Important trans-boundary diseases in the Asia-Pacific region including the epizootic ulcerative syndrome (EUS) in fresh and brackishwater fishes, white spot disease (WSD) and Taura syndrome virus (TSV) in cultured penaeid shrimp, koi herpes virus (KHV) among koi and common carp and white tail disease (WTD) in freshwater prawn are in one way or the other associated with movement of seed and broodstock. Stakeholders in importing and exporting countries must respond to such inherent risk by developing and implementing strategies to reduce that risk to an acceptable level.

Global standards, codes of practice and guidelines (voluntary or obligatory) exist and provide certain level of protection against pathogen/disease risks associated with transboundary movement of live aquatic animals and their products. These regional and international agreements are specifically directed at health management and include provisions to minimize risks associated with introduction of aquatic animal pathogens. International and regional organizations have been supporting national governments in their efforts to comply with global instruments and guidelines. One good example in the Asia-Pacific region is the development and adoption of regional guiding documents which take into full consideration the provisions of the WTO's Sanitary and Phytosanitary Agreement (SPS Agreement), the OIE Aquatic Animal Health Standards, as well as the FAO Code of Conduct for Responsible Fisheries (CCRF). The Asia Regional Technical Guidelines (FAO/NACA, 2000) provide the most comprehensive framework available for development and implementation of national strategies to address aquatic animal health issues at different levels-national, provincial and local.

Pathogen risk analysis is increasingly being used as a decision making tool to determine risk associated with movement of live aquatic animals, including seed and broodstock. The principal components of pathogen risk analysis are hazard identification, risk assessment, risk management and risk communication (Arthur *et al.*, 2004). When applied to aquatic animal diseases, hazard identification involves the process of identifying pathogenic agents that may be introduced along with seed and broodstocks. Risk assessment (quantitative or qualitative), through a structured process attempts to assess the risks (likelihood/possibility of occurrence of undesired outcomes and the severity/magnitude of consequences) resulting from an identified hazard (pathogen). International (e.g. OIE) and regional (e.g. NACA) disease reports provide regular and updated information on diseases of concern to support the risk analysis process in order to minimize introduction of pathogens with host movements. The risk analysis process appears to put more responsibility on the importing countries. However, exporters also have a responsibility to minimize the risks of pathogen introduction. Responsible trading, with partnership and responsibilities shared between importing and exporting countries, is a major task that will reduce the risks of serious aquatic animal pathogen introduction and spread. Stakeholders intending to move seed of exotic aquatic animals need to adopt more effective risk management measures, resulting from the risk analysis process. Known and unknown risks need to be considered. Irresponsible or ill-considered movements of seed of exotic animals can impact aquaculture and seriously affect the livelihoods of the small-scale farmers. Guidance on risk analysis can be found in manuals (Arthur *et al.*, 2004; OIE, 2004a, b; Rodgers, 2001) and few of the published risk analysis case studies (AQIS, 1999; Kahn *et al*., 1999; Arthur *et al*., 2004; Bondad-Reantaso *et al*., 2004).

DISEASES

Early developmental stages (spawn, fry and fingerlings in the case of fish; nauplii, mysis and post-larvae [PL] in the case of prawn) of most cultured species are susceptible to a variety of pathogens. Hatchery, nursery and early rearing systems offer an ideal environment for infection and disease outbreak, because such systems usually stress the host and favour the proliferation of virulent pathogens. In addition, the various components of the immune system (both innate and specific) are known to become structurally and functionally competent only after four to eight weeks post-hatching depending on the fish species. This makes early developmental stages of most cultured species more susceptible to diseases. Depending on the nature and severity, the disease may cause mass mortality of the affected seed in a short time, produce protracted small-scale mortality, reduce growth and result in poor quality seed. In addition, seed coming out of infected hatcheries could be infected and carry the pathogens to grow-out systems, where disease can manifest and result in mortality of stocked seed. Diseases caused by parasites, bacteria, viruses and fungi are common in freshwater seed production systems.

Little *et al. (*2002b) provided an interesting discussion on health management issues in freshwater fish hatcheries, nurseries and fry distribution networks with emphasis in Asia. Freshwater fish seed supply in Asia is largely based on networks of small farmers that produce and deliver seed to farmers. As the quantity and availability of fish seed have improved, the quality issue has been increasingly questioned. Factors affecting the health status of fish seed available to farmers are complex and relate to both the knowledge of the various “actors” in seed networks and the broader environment. Hasan and Ahmed (2002) have provided considerable information on issues in carp hatcheries and nurseries in Bangladesh, with special reference to health management. Diseases were found to be less prevalent in indoor hatcheries compared to outdoor earthen nursery ponds. The following section provides a brief insight into some of the common diseases encountered in seed production systems of freshwater fish and prawn.

Cyprinids, catfishes and tilapias

Parasitic diseases in nurseries are one of the most important factors limiting the growth and survival of fry and fingerlings. Protozoan ciliates (*Ichthyopthirius multifiliis, Trichodina* sp.) and flagellates (*Ichthyobodo necator, Cryptobia* sp.) are some of the common ectoparasites affecting the performance of freshwater fish hatcheries and seed rearing farms. Certain ectocommensal ciliates (*Epistylis* sp., *Vorticella* sp. and *Zoothamnium* sp.) attach to the external surface leading to fouling. These ectoparasitic protozoans are often associated with mortalities of younger stages of cultured fish. The situation becomes worst in waters with low oxygen and high organic matter as most of these have simple and direct life cycle enabling them to multiply rapidly in such conditions.

Diseases caused by endoparasitic sporozoans are a serious concern in fish seed farms. These spores present in the pond soil are normally ingested by the early feeding stages of fish. The infective element of the spore (sporoplasm) is released in the gut. The sporoplasm reaches the target tissue using the vascular route. Once inside the target tissue, the vegetative trophozoites cause massive destruction of the target tissue and produce large spore containing cysts. The period from ingestion of spore to expression of clinical disease may take anywhere between a month to several months. Indian major carp fingerlings coming out of contaminated earthen nursery/rearing ponds carry the infection to grow-out ponds and result in severe post-stocking mortalities (Mohan and Shankar, 1999).

Monogenetic trematodes like *Dactylogyrus* spp. (gill flukes) and *Gyrodactylus* spp. (skin flukes) with their well-developed attachment haptor and feeding apparatus can cause extensive pathology and mortality in early developmental stages of fish. Larval stages of digenetic trematodes (e.g. cercaria and metacercaria) are capable of causing mass mortalities in nursery systems (Mohan, Shankar and Ramesh, 1999). Larger crustacean ectoparasites like *Argulus* sp. (fish lice) and *Lernaea* sp. (anchor worm) with their well-developed attachment organs and mouth parts inflict considerable damage at the site of attachment and feeding thereby predisposing the fish to secondary systemic bacterial and fungal infections.

Several bacterial pathogens causing morbidity and mortality in fish seed have been reported from hatcheries and nurseries. Common and major diseases are due to motile aeromonads, vibrios and pseudomonas. Bacteria can cause disease either as primary pathogens or as secondary opportunistic invaders. Surface ulcerative types of diseases (e.g. fin rot, tail rot, ulcer disease) are characterized by haemorrhagic surface ulcers and are caused by species of *Aeromonas, Pseudomonas*, *Vibrios, Flexibacteria* and *Myxobacteria*. Surface ulcerative disease conditions at times develop to acute systemic disease. Acute systemic disease are characterized by the presence and proliferation of bacteria in internal organs like kidney, heart, spleen, blood and other visceral organs. These diseases produce significant necrotic changes in all affected organs and can cause mortality in a short time scale. Bacterial haemorrhagic septicaemia caused by *Aeromonas hydrophila* is a major problem in carp seed production facilities. Poor water quality, organic pollution, temperature fluctuations and extremes, wild fish reservoir, overcrowding, poor nutritional status and trauma could easily predispose early developmental stages to bacterial infections.

The ability of aquatic fungi to cause disease in fish seed is well known. Potentially, incubated eggs and early development stages of all freshwater fishes are susceptible to external fungal infections. Majority of the aquatic fungi are saprophytic and derive their nourishment by decomposing organic matter. Aquatic fungi can cause disease either as primary pathogens or as secondary invaders. External fungal infection is also a problem in hatcheries during incubation of eggs. The fungus first establishes on dead and unfertilized eggs and gradually spread to healthy developing eggs destroying the entire batch of incubated eggs. Egg washing and removal of necrotic substances such as unfertilized and damaged eggs helps to minimize fungal infection in hatcheries (e.g. *Saprolegnia* infection or cotton wool disease).

Virus is a highly obligatory intracellular parasite. Virus replication is invariably at the cost of the host cell, either the cell is affected partly or fully. At the host level, virus affects target organ partially damaging and impairing its function or fully destroying it leading to morbidity and death of the host. There is limited information on the impact of viral pathogens in the early development stages of carps, tilapia and catfishes. Grass carp hemorrhagic virus (GCHV) since its first description in 1980s has been associated with mortalities of early developmental stages of Chinese carps (Yulin, 2005). Among salmonids, the impact of infectious pancreatic necrosis (IPN) virus has been well studied. Vertical transmission of viral pathogens from the mother to the progeny is a cause for serious concern in many cultured species.

Freshwater prawn

Both larval stages and adults of the giant freshwater prawn, *Macrobrachium rosenbergii* are prone to diseases caused by viruses, bacteria, fungi and parasites (New, 2003). Early larval stages are susceptible to vibriosis caused by V*ibrio harveyi*. The unique clinical sign of this disease is the luminescence of infected larvae which can be observed at night. Infected larvae also show fouling, opacity, slow swimming, aggregation and mortality. Mortalities may reach 100 percent. Chitinolytic bacterial diseases (e.g. shell disease, brown spot disease, black spot disease and rust disease) in the larval stages are caused by bacteria such as *Vibrio* spp*., Pseudomonas* spp., *Aeromonas* spp*. and Flavobacterium* spp. In severe cases, infection may spread to the epithelium, muscle and viscera, resulting in septicaemia and mortalities. Poor water quality and high organic load are usually associated with shell lesions. Larval mid-cycle disease generally occurs in early larval stages. The etiological agent is unknown but *Enterobacter* sp. is suspected. Clinical signs with high larval mortality include, reduced food intake, bluish grey colour, weak spiralling swimming behaviour, possible cannibalism, atrophy of hepatopancreas epithelium. Larvae lose their appetite and moribund ones are eaten by the healthier larvae.

Macrobrachium muscle virus (MMV) affects PL with an epizootic disease similar to idiopathic muscle necrosis virus (IMNV). Affected prawns exhibit white, opaque areas in the abdominal segments accompanied by progressive weakening of feeding and swimming habits (Tung, Wang and Chen, 1999; Arcier *et al*., 1999). MMV is known to infect freshwater prawn within 10 days of moving PL to outdoor ponds. A mortality of 50-75 percent is seen within two weeks after transporting to grow out ponds. Since late 2001, a new disease widely known as white tail disease (WTD) or white muscle disease (WMD) has been observed in larvae and PL of *Macrobrachium rosenbergii* in the hatcheries and nursery ponds in some parts of the world (Sahul Hameed *et al*., 2004; Widada *et al*., 2003). Mortality due to this disease has been estimated up to 100 percent within two or three days. Clinical signs of WTD include milky or whitish appearance of muscles particularly in tail region. The causative organisms have been identified as *Macrobrachium rosenbergii* nodavirus (*Mr*NV) and extra small virus (XSV) (Widada *et al*., 2004; Bonami *et al*., 2005). Considering the economic impact and potential to spread, WTD of *M. rosenbergii* has been included in the FAO/NACA/OIE regional quarterly aquatic animal disease (QAAD) reporting list, effective for reporting from the first quarter of 2005 (FAO/NACA, 2005).

There are few diseases of uncertain etiology impacting seed production. Idiopathic muscle necrosis is known by various names, such as, white muscle disease, muscle opacity or milky prawn disease. It causes massive larval mortalities in hatcheries and the mortalities can be sudden. The disease appears as multi-focal diffuse opacity of striated muscle. Idiopathic muscle necrosis of *M. rosenbergii* is considered to be associated with stresses including salinity and temperature fluctuation, hypoxia, hyperactivity and over crowding. Mortalities are associated with extensive necrosis of muscle fibres. Exuvia entrapment disease (EED) affects late stage larvae and early PL. It is also known as metamorphosis moult syndrome. Affected larvae are unable to free appendages, eyes or rostrum from the exuvia in which they become entrapped. Mortalities caused by EED are not usually severe. The cause of the disease is unknown but it is thought that poor water quality, external fouling and nutritional deficiency may be responsible.

Microbial fouling caused by epibionts is commonly observed in larval stages. Epibiont fouling organisms include filamentous and non-filamentous bacteria, algae or protozoa common to the aquatic environment. Severe fouling affects respiration, feeding, moulting and preening activities of the larvae.

QUALITY ASSESSMENT

As a first step, improved understanding of the importance of stocking quality seed should come about in the farmers. Only then can farmers demand/insist for quality seed and make an attempt to assess the quality of the seed before purchase. Commercial farmers tend to be better aware of the need to select quality seed. Farmers culturing high value species (e.g. shrimp, prawn) also tend to attach significant importance to assessment of seed quality before making a purchase. It is also in the interest of seed producers that they must understand quality assessment criteria so that they can aim to produce quality seed. Competition between producers can stimulate the interest of hatcheries to improve quality. Seed producers assuring consistent supply of quality seed can demand premium price from grow-out farmers.

There is also concern on the quality of seed stocked in community water bodies. In culture-based fisheries, government and contracted private hatcheries produce vast numbers of seed for stocking systems ranging from small community tanks, reservoirs to open-water floodplains. The overall outcome of such stocking programmes is determined by a combination of natural, socio-economic and institutional conditions (Lorenzen and Garaway, 1998), as is the quality of the seed alone. Non-availability of large-sized fingerlings has often been suggested as the reason for limited success of such stocking programmes in many of the developing countries.

Quality assessment criteria

Several quality assessment criteria have been developed for different cultured species. Most quality assessment criteria would include gross examination (color, pigmentation, fin quality), activity evaluations (swimming, phototaxis), stress tests (formalin or salinity) and screening for specific pathogens (e.g. WSD in shrimp, MrNV and XSV in prawn). In high value species, such assessments would be scored and the final score would be used to make decisions.

Quality assessment schemes developed for shrimp seed selection are widely used by the farmers. Similar models are being applied to freshwater prawn in some of the countries. Chanratchakool *et al*. (1998) provided a very detailed account of PL selection criteria and this has helped to set some standards in the industry. Over the years, these selection criteria have either been simplified or further refined to suit the requirements of the small-scale extensive as well as commercial intensive farmers.

The aim of larval selection is to try and predict which PL will have the best survival and growth in the pond (Fegan, 1992). It is not always easy to say which criteria should be considered. Parameters that reflect the health of the PL at the time of the examination do not necessarily reflect the subsequent performance in the ponds. In many instances it may not be possible to buy the desired seed and it may be necessary to take whatever PL are available. Generally PL quality assessment involves five main areas: gross examination, microscopic examination, stress test, V*ibrio* test and screening by polymerase chain reaction (PCR).

Gross examination of PL is made to assess size distribution (PL 15 minimum length of 12 mm for *P. monodon*), behavior (respond rapidly to external stimuli), activity (swim with straight bodies), colour (clear or dark, not red/white), fouling (minimum or no external fouling with protozoa or bacteria) and feeding (gut fullness). Microscopic examination of a sample of 20-30 PL is suggested for scoring the quality of the PL based on appearance of the hepatopancreas, gut condition, fouling, deformity, and muscle:gut ratio.

Stress testing involves exposure of the PL to 50 percent of the ambient salinity or 100-200 ppm formalin for 30 min followed by estimation of survival. A survival of over 75 percent is regarded as ideal.

Vibrio examination is done following standard bacteriological procedures to assess the bacterial load in the larvae and the proportion of good and bad bacteria. Through simple hepatopancreas smear preparations, PL are also checked for the presence of Monodon baculovirus (MBV) occlusion bodies. Post-larvae with large numbers of occlusion bodies are thought to perform poorly post-stocking. Testing by PCR for important viral pathogens (e.g. WSD, TSV) can help reduce the risk of crop loss due to diseases. In many countries, PCR screening of each batch of PL stocked has become a routine practice amongst commercial shrimp farmers. For example in India, there are over 90 PCR laboratories operated by both the government and private sectors offering the screening service to farmers. Normally a sample of 150 shrimp (preferably the weakest out of a larger batch of salinity/formalin-stressed shrimp) are taken from each tank and preserved in 90 percent alcohol and then sent to a PCR laboratory for analysis using a two-step, or nested PCR technique. PCR-negative seed are widely believed to perform well in grow out ponds. However, although widely used in several shrimp farming countries of the world, PCR screening is highly susceptible to error for various reasons. Screening by PCR is effective only if conducted by well trained technicians in properly designed and equipped laboratories applying strict quality control and high ethical standards.

Quality assessment criteria similar to that followed for shrimp seed selection are also followed for selection of *M. rosenbergii* seed. Since the last one year, considering the importance of white tail disease and the risk of introduction of the pathogen with the seed, farmers in many countries (e.g. Thailand, Vietnam, India) have started to select seed that has been screened for the presence of MrNV and XSV, the causative agents of white tail disease.

Compared to shrimp and prawn, rigorous selection criteria for quality assessment in freshwater fish seed (cyprinids, catfish, tilapia) is unheard of. However, in Atlantic salmon smolt selection, several criteria have been established to select quality smolts. Salinity stress tests, growth, morphological changes and body composition (Dickhoff *et al*., 1995), fin quality (Davidson, Swan and Hayward, 19955), behavior (Ola *et al*., 1994), and color changes are also suggested as valuable quality indicators. There are limited studies on quality indicators in cyprinids and other freshwater species like catfishes and tilapias. Scale loss and tail damage of cyprinids after transportation have been used as quality indicators in India and Bangladesh. Ingthamjitr (1998) developed salinity challenge test for use with hybrid *Clarius* catfish hatchlings. Simple field keys that use visual assessment of species and quality could educate fish seed buyers and reduce cheating on species and quality that are prevalent in trading of the commonly cultured fish species in Asia (Little *et al*., 2002a).

Elimination of weak seed is becoming an important intervention in some cultured species. Post-stocking mortality of seed can be high, especially if farmers can only access poor quality seed. Since good quality seed are often scarce, farmers resort to stocking more seed than required, to compensate for post-stocking mortality. This practice can have serious management implications. Elimination of weak seed before stocking, so that only strong and active seed are stocked into the pond, can give farmers better control over feed and water management. Elimination of weak PL is followed as a routine practice by shrimp farmers in many countries in Asia (Thailand, India, Vietnam, Indonesia). The method involves exposing the PL to formalin bath of 100-200 ppm for up to one hr. After exposure, only actively swimming PLs are separated and stocked. Detailed procedure is provided by Chanratchakool *et al.* (1998).

Use of nursery systems to produce better quality (larger and uniform size) seed are practiced in some of the countries. In the case of shrimp and prawn, such nursing systems are used to produce juveniles, which are larger, of uniform size and much stronger. In the case of fish, nurseries produce fingerlings and advanced fingerlings. However, there is a need to make a distinction between commercial nurseries and farmer-owned nurseries. Procurement of seed from commercial nurseries may still present the same level of risks concerning pathogens to farmers. Many commercial seed nurseries (both shrimp and fish) have a short turn-around time and hence, resort to continuous stocking and repeated harvesting. This practice prevents adoption of BMPs (e.g. pond drying and liming before stoking) thereby increasing the risk of harvesting infected seed. To overcome this, farmer-owned nurseries are being increasingly suggested as a management intervention to improve quality of seed meant for stocking. Use of nursery impoundments within a pond is becoming popular among shrimp farmers. The main advantage is that it concentrates the PL and allows them to be more accurately monitored and easily fed. It also enables more effective exclusion of predators and easier water quality management. Healthy juveniles from a good nursery system usually result in good post-stocking survival and production (Chanratchakool *et al*., 1998). The concept of Aquaclub nurseries (promoted under the MPEDA/NACA/ACIAR shrimp disease management project in India), where groups of farmers collectively nurse shrimp PL and share the juveniles for stocking are becoming popular in India (Padiyar *et al.*, 2005).

Close proximity of sales outlets can allow knowledgeable farmers to select for quality and price, increasing pressure on vendors to maintain quality. Clusters of enterprises are also characterized by specialization in knowledge and activity that can enhance consistency and quality of fish seed (Barman *et al.,* 2002). A good example of farmer organizations (Aquaclubs) putting pressure on hatcheries to produce quality seed is demonstrated under the MPEDA/NACA/ACIAR shrimp disease control project in India (Box 8.1.2).

From the above discussion it becomes clear that it is possible to apply certain criteria to select quality seed and at the same time use strategies to improve the quality of the seed (e.g. on farm nurseries). The developments and lessons learned in shrimp seed selection should enable stakeholders to develop good seed selection criteria for commercially important freshwater fish seed.

Research into seed quality issues

There has been limited research focused exclusively on seed quality issues. The project "Fish Seed Quality in Asia" funded by Department for International Development (DFID) involving Asian Institute of Technology (AIT) and partner institutions in four countries (Viet Nam, Bangladesh, Lao PDR, Thailand) has done some pioneering work in this area using a structured approach (AIT/DOF, 2001, AIT/RIA1, 2000, AIT/CAF, 2000; AIT/DOF 1, 2000). Surveys in four areas of Asia included all actors in the seed supply network (problem recognition and definition), stakeholder workshops lead to identification of researchable issues and policy recommendations (participatory methodology for problem understanding and system description), reports produced in different languages (state of the system reports) and research issues addressed by partner institutions (researchable issues). The project was successful in identifying and characterizing the nature of quality constraints in carp and tilapia seed production systems in five countries of Asia and developed templates for strategies to deliver quality fish seed. Some of the key issues identified include:

- perception that state-produced seed was of better quality than private hatchery seed;
- seed production of high demand species does not fill the demand, such demand may be fueled by perceptions of quality in relation to production as well as market forces;

BOX 8.1.2

Contract hatchery system for better quality seed: lessons from MPEDA/NACA/ACIAR project

Stocking high quality and healthy seed is fundamental to success of a crop in shrimp farming. Small-scale farmers find it a daunting task to procure good quality seed. At present, to select small quantity of clean seed for their individual requirement, they visit several hatcheries, spend considerable cash on testing the seed batches and still are uncertain of the seed quality, they finally get. This process of seed selection is time consuming, expensive and still has the risk of farmers not being able to get quality seed at the right time. To proactively address this serious problem, the MPEDA/NACA/ACIAR programme in West Godavari district in Andhra Pradesh introduced "Contract hatchery seed production system" to meet the seed requirements of Aquaclub farmers and to avoid the difficulties in procurement of good quality seed.

Under this system, Aquaclub farmers (farmer associations/self-help groups) place bulk orders to a hatchery 45-60 days in advance of planned stocking date, for production of required quantity of seed. Through a consultative process, often facilitated by the project team, mutual agreement is formed between selected hatcheries and Aquaclubs for follow-up of better management practices in hatcheries and other terms and conditions for production and procurement of quality seed.

About 45-60 days before the stocking date, farmer leaders of Aquaclubs visit four to five hatcheries. They observe the hatchery facilities and discuss the quality requirements and production procedures with the hatchery owners and technicians. Once the farmers are satisfied with hatchery facilities, production processes, qualification and experience of technicians and if the hatchery owner agrees with the terms and conditions laid down by the farmers, then farmers place the order for supply of seed in bulk quantities (e.g. may be up to 5-10 million PLs). In addition, they also offer an additional five to ten percent price premium for such seed produced according to their requirements.

Since 2004 (the last three to four crops), several contract hatchery systems are functioning in Andhra Pradesh, India. Aquaclub farmers and hatchery operators are highly appreciative of this transparent and mutually beneficial system.

- quality issues can include size at sale, cheating on species and number as well as the usual survival and growth parameters; and
- perception and assessment of quality can vary within the same network depending on experience, market orientation and role within the network.

Quality assessment is subjective and a variety of measures can be made. Many farmers base much of their assessment of seed quality on activity. A system of subjective evaluation may be a good management tool for assessing the potential survival and productivity of the seed stocked, but such techniques need to be correctly evaluated if they are to be of substantive use in the field. Corsin *et al.* (2003) examined the relationship between white spot syndrome virus (WSSV) and indicators of quality in *Penaeus monodon* post larvae in Karnataka, India as a part of a larger epidemiological study. Briefly, the study describes the relationship between indicators of quality and WSD in PL of *Penaeus monodon.* Three outcome variables were considered: the WSD status of the PL, as determined by PCR, and two subjective assessments of PL quality, namely the activity of the PL and the quality of the PL as determined by research assistants and farmers, respectively. The quality assessed by farmers and the PL activity assessed by research assistants showed only fair agreement (kappa 0.252) reaffirming the subjective nature of such techniques. The only variables consistently associated with either assessment of quality in univariate analysis were PL length, number per bag and salinity of the water in the delivery bags. The research assistants' assessment of PL activity was also associated with the hatchery and a brown-orange hepatopancreas in univariate analysis. The farmers' assessment of quality was associated with PL length, date of stocking and duration of transportation in both univariate and multivariable analyses. There was no relationship between quality assessment and WSD in PCR-positive PL. The study provides some useful research models for assessment of seed quality using population-based approach.

ROLE OF STAKEHOLDERS TO IMPROVE SEED QUALITY

Farmers

The role of the farmer must not be confined only to leveling allegations on seed producers for all post-stocking failures. Farmers should make an attempt to understand the concept of seed quality, select the right kind of seed and apply BMPs to give the stocked seed the ideal conditions to grow. Farmers and farmer associations should hold regular consultations with seed producers and suppliers. Such meetings could help to avoid misunderstandings and ensure consistent supply of quality seed. Farmers must also consider offering premium price for supply of better quality seed. Such initiatives would motivate hatcheries and seed suppliers to implement BMPs to improve quality.

Seed producers and suppliers

Seed producers and suppliers have major responsibilities to ensure production and delivery of quality seed to farmers. Seed producers should consider formation of hatchery associations for the establishment of professional, technical and ethical standards. Such initiatives would ensure members to adopt BMPs, minimum biosecurity measures in hatchery design, regular training for technical staff and adherence to an ethical code of practice (COP). Hatchery associations in many countries have developed voluntary COPs. Self-regulation and compliance to voluntary or government COPs would bring about major changes in the quality of seed produced. Like farmers, seed producers should also enter into regular consultations with farmers to understand their needs and respond proactively. Improvements in quality should be seen as benefitting both the seed producers and farmers.

National governments (development and research organizations)

Aquaculture in many countries contributes not only to the livelihood of rural poor but also to the national economies. Government institutions therefore have the responsibility to develop and implement mechanisms that will ensure supply of quality seed to farmers. Government agencies and policy makers need to understand the importance of fish seed quality and its impact on fish production, if resources are best to be targeted, and policy decisions on future investment and management options improved. The role of government institutions should not just be regulatory. Where possible, government institutions should act as facilitators of the process. Little *et al.* (2002a) have suggested some areas where national governments can intervene. Maintenance and improvement of high quality germplasm, and its multiplication to support the private sector, have been identified as key roles for public sector institutions. Some governments in Asia have helped to establish domestication programmes for shrimp based on SPF stocks. Such initiative can assist the private sector and also contribute to significant improvements in quality. On the other hand, in some countries, governments have set up state-of-the-art model hatcheries, which have become training centres for the private sector. Government should develop programs to enforce controls on chemical usage including prohibition on the use of unsafe chemicals. Government should also consider providing adequate infrastructure and facilities to seed traders during transportation.

Seed quality monitoring, certification of quality and accreditation of hatcheries producing quality seed are becoming important. Government institutions should consider taking up the monitoring role and developing simple and practical certification schemes which could finally lead to accreditation of good hatcheries. There is evidence of this happening slowly in many countries. For example, government institutions in India (Indian Council of Agricultural Research [ICAR], MPEDA, Aquaculture Authority of India [AAI]) are collectively working to promote codes of practice for hatcheries and develop certification systems. Similarly, DOF Thailand is promoting Code of Conduct (COC) and Good Aquaculture Practices (GAP) for hatcheries.

In addition, government extension institutions have a major role in developing and disseminating BMPs for all the actors involved in the seed production and supply chain. This should happen through a consultative process involving all the stakeholders. Only through raising awareness of all the stakeholders would it be possible to bring about improvements in the quality of seed.

Research institutions should undertake appropriate exercises to identify researchable issues on fish seed quality and initiate appropriate research programs. The likelihood of genetic and non-genetic factors influencing seed quality is a major issue. Population-based studies involving seed producers, suppliers and farmers are essential to identify the major risk factors leading to poor quality seed. Research institutions should develop quality assessment criteria for important cultured species based on sound research and post-stocking assessments.

Regional and international organizations

Regional and international organizations should endeavor to create awareness about global standards, international instruments and market requirements (e.g. food safety, traceability) in national governments. In addition, they should facilitate capacity and awareness building in relevant stakeholders in member countries. Some of the relevant international agreements and standards include:

- FAO Code of Conduct for Responsible Fisheries (CCRF), created in 1995, sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity.
- International Council for Exploration of the Sea (ICES) Code of Practice on the Introductions and Transfers of Marine Organisms, created in 1973 and updated in 1994, gives recommended procedures and practices to reduce the risks of detrimental effects from the intentional introduction and transfer of marine (including brackish water) organisms. The ICES code is endorsed by FAO Regional Fishery Bodies.
- World Trade Organization (WTO), established in 1995 is the only global international organization dealing with the rules of trade between nations. The Sanitary and Phyto-sanitary agreement (SPS Agreement) specifically addresses the management of diseases and pathogens associated with trans-boundary movements.
- World Animal Health Organization (OIE), established in 1924, in association with WTO helps, *inter alia,* guarantee the sanitary safety of world trade by developing sanitary rules for international trade in animals and animal products.
- Within Asia, the Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and their associated implementation plan, the Beijing Consensus and Implementation Strategy (BCIS), (FAO/NACA, 2000) provide expert guidance for national and regional efforts in reducing the risks of disease due to trans-boundary movement of live aquatic animals.

CONCLUSION

Globally aquaculture is active, expanding and diversifying. Increasing aquaculture development will likely lead to more demand for quality seed. Although poorly understand, risks due to poor quality seed will include socio-economic impacts on the livelihoods of small-scale aquaculture farmers, and possibly impacts on wild fish species and fisheries. Aquaculture has suffered enormous losses due to trans-boundary diseases and increasing risks are expected in future as aquaculture expands leading to increased movement of seed and broodstocks across national and international boundaries. Some countries in the Asia-Pacific region still face significant challenges in the practical implementation of health management strategies, specifically in the areas of diagnosis, surveillance, risk analysis, and quarantine and certification programs. These challenges are mainly due to inadequate national capacity. There is, therefore, a need to continue to strengthen regional and international cooperation in aquatic animal health.

Undertaking further research, data gathering, analysing and sharing information on the impact of seed quality will become increasingly important to aid stakeholders in developing sound COPs, BMPs and appropriate regulations. Only through strong resolve and commitment among stakeholders, can production and supply of quality seed be assured. This workshop should provide the basis for discussing seed quality issues in the broader context of sustainable aquaculture development and come up with recommendations and action plans for the future.

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8.2 Genetics and breeding in seed supply for inland aquaculture[1]

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ABSTRACT

It is estimated that no more than 20 percent of global aquaculture production utilizes genetically improved stocks. Furthermore, the vast majority (>95 percent) of freshwater aquaculture production comes from the developed world where resources are limited and breeding technologies less advanced. Thus, the proportion of production derived from genetically improved fish in freshwater aquaculture is likely to be considerably lower than the global average. The past 15 years have seen a rapid increase in the number and scope of breeding programmes for genetic improvement of aquaculture species and a number of important national and regional programmes for improving, commercializing and disseminating important aquaculture species are now underway or planned. There have been a number of important advances in research, most notably in the verification of the potential gains to be had from well-managed selection programmes with genetic gains for growth related traits of 7-10 percent readily achievable in well-managed programs. However, it is also evident that there has been genetic deterioration of existing domesticated and cultured stocks through poor genetic management during and subsequent to the domestication process. These effects need to be reversed and whilst progress has been made there remains a need to support implementation of best practices in basic genetic management when domesticating, translocating and maintaining discrete aquaculture stocks. Whilst the success with selective breeding in recent times has placed this technology at the core of efforts to improve aquaculture stocks, there has been some successes with other technologies such as sex control, hybridisation and polyploidy induction and these do have a role as components of integrated approaches to genetic improvement. Some extreme improvements in culture performance have been demonstrated using transgenesis but societal and regulatory concerns continue to preclude commercial application. Major research advances have been made in recent times with the application of genetic markers and the costs of widely applied and, to some degree standardized, techniques such as the application of microsatellite markers which have come down considerably. Genetic markers are thus now becoming valuable tools and will be increasingly applied to enhance traditional selection programmes and in more specific programmes of marker-assisted selection.

[1] This paper was peer-reviewed by Dr Devin Bartley of the Aquaculture Management and Conservation Service, Fisheries and Aquaculture Department, FAO, Rome, Italy.

Of the major freshwater aquaculture species, there have been very significant genetic gains through the application of genetics in tilapia and carps in particular. Efforts are now expanding to include shellfish species such as *Macrobrachium*.

This paper reviews core issues and progress in genetic management and improvement of species for inland aquaculture and highlights some of the technical, environmental and socio-economic issues still constraining the full implementation of genetic improvement programmes and the equitable dissemination of their outputs and benefits. A number of recommendations are made concerning the appropriate role of applied genetics in seed supply systems for the future development of inland aquaculture.

INTRODUCTION

With a few exceptions, aquaculture is a relatively recent development and contributor to global food security, having expanded at an average rate of 8.9 percent since 1970. During this time, aquaculture has increased from representing just 3.9 percent of global fisheries production volume up to almost 50 percent in 2004 (FAO, 2006). It is inevitable that aquaculture production will overtake capture fisheries production within the next 10-20 years. All future predictions call for further significant increases in aquaculture production to meet expanding demand from a growing population and increases in per capita consumption of seafood. In this context, the supply of quality seed has increased, and must continue to increase dramatically to sustain growth in aquaculture. Gjedrem (2002) estimated then that genetically improved stock accounted for no more than 10 percent of aquaculture production. Whilst this figure is undoubtedly rising, as the benefits of genetic improvement become apparent, it is unlikely to be more than 20 percent at present. It is almost certainly much lower in most developing countries. Relatively high adoption rates of genetically improved stocks exists in some developed countries such as Norway where Gjedrem (2000) estimates 65 percent of aquaculture production takes place using stocks resulting from modern and efficient breeding programs. Likewise, for species such as Atlantic salmon, over 97 percent of global production is from genetically improved lines.

The major factor in the relatively low impact of genetic improvement in aquaculture is the embryonic status of aquaculture production sectors. During the early stage of aquaculture development, rapid advances can be made in production volumes and efficiency with relatively simple and cost effective improvements or innovations in general husbandry, nutrition and health management. In contrast, genetic changes whilst capable of dramatic improvements inevitably require long-term strategic planning and investment in order to secure medium to long-term gains. A further reason for the 'slow start' in implementing genetically based technologies, was an early misconception that, despite positive evidence from livestock and crop sectors, selective breeding might prove ineffective in aquatic organisms. This view was perpetuated by the failure to bring about significant improvements during early attempts to consciously select for commercially important traits in carps and tilapia (e.g. Moav and Wohlfarth, 1976; Moav, 1979; Wohlfarth, 1983).

An era of substantial genetic improvement, contributing to a "blue revolution" in aquaculture, is undoubtedly upon us with some form of genetic improvement evident in the majority of important aquaculture species. This paper focuses on the role that genetics is playing, and will play, in developing the supply of quality seed for inland aquaculture. Given that FAO statistics (FAO, 2006) record that 97 percent of freshwater aquaculture production (27.8 million tonnes in 2005) comes from the developing world (95 percent from Asia) this paper will, by default, focus on seed supply for aquaculture in developing countries. The paper will review the current status of genetic improvement technologies focusing on finfish, molluscs and crustacea and will describe their applications to some important species in inland production systems. One of the key objectives, in the context of current developments and status of genetic improvement, will be to identify and discuss the key issues facing the future application and uptake of genetics based technologies and genetically improved stocks in inland aquaculture. This will include a review of technological and environmental constraints to genetic advancement, identification of research priorities to address these along with issues related to human and physical resource capacity and mechanisms for disseminating improved seed focused on equitable uptake of benefits.

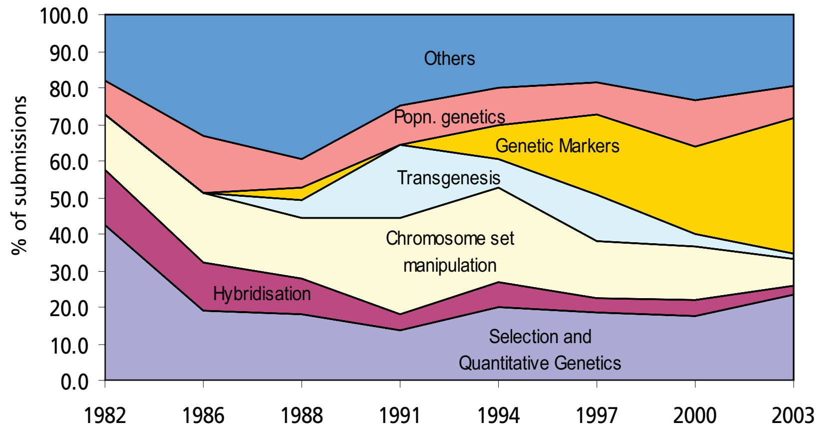
GENETIC TECHNOLOGIES IN AQUACULTURE

This section of the review focuses on the technology options for genetic improvement. Over recent decades there has been a very significant body of research on applying genetic technologies to aquacultured species and distinct trends are visible. An analysis of the main subject areas of papers published in the proceedings of triennial symposia on genetics in aquaculture from the first in 1982, up to 2003, shows the trends in the main focal areas of aquaculture genetics research (Figure 8.2.1). This indicates a decline in selective breeding research up to 1991 followed by a steady increase. This decline was mirrored by an increase in research on alternative or 'competing' technologies such as chromosome set manipulation and transgenesis. The basis of this was the prevailing belief, at this time, that these technologies were likely to bring about more rapid genetic and culture performance gains than selective breeding. Research in both these areas has now declined and some of the reasons behind this will be discussed later in this paper. Another evident trend, since the early 1990s, is the rapid increase in the volume of research focused on the applications of genetic markers.

DOMESTICATION AND MANAGEMENT OF GENETIC VARIATION

Domestication and subsequent broodstock management practices have very important implications for the long-term quality of cultured stocks. A domesticated species is defined broadly by the Convention on Biological Diversity to be one *in which the evolutionary process has been influenced by humans to meet their needs*. In the context of aquaculture, domestication is the process whereby a population becomes adapted to man and the captive environment by some combination of genetic change over several generations and environmentally induced developmental events recurring during each generation. The consequence of domestication for the subsequent development of aquaculture based on these domesticated stocks can be profound. Due to the relative infancy of aquaculture as a major form of primary production, many cultured stocks

FIGURE 8.2.1
Trends in genetics research as reported in the triennial symposia of the International Association for Genetics in Aquaculture (IAGA)



are only relatively recently domesticated, still undergoing domestication or in some cases yet to be domesticated. Several genetic processes operate during domestication and the subsequent genetic management of domesticated stocks impacts both positively and negatively on culture performance and culture potential. These processes include domestication selection, indirect selection, inbreeding and genetic drift. Several studies have illustrated that domestication can lead to the loss of alleles and/or reductions in observed heterozygosity in domesticated stocks. For example, salmonids (Kim *et al.*, 2004); tilapias, *Oreochromis mossambicus* (Agustin, 1999) and *O. shiranus* (Ambali, Doyle and Cook, 1999); a siluriform catfish, *Heterobranchus longifilis* (Agnese, Oteme and Gilles, 1995); penaeid shrimp (Goyard *et al.*, 2003; Ramos-Paredes and Grijalva-Chon, 2003); and oysters, *Crassostrea gigas* and *C. angulata* (Sly and Hedgecock, 1988; Rebordinos, Garcia and Cantoral, 1999; Kittel and Chew, 2000).

The ideal population size is infinitely large, ensuring no loss of genetic variation. In reality hatchery managers must work with relatively small, finite populations. However, the total number of broodfish held at the farm is not the critical factor in broodstock management but rather the number that contribute genes to subsequent generations. Of critical importance thus is the concept of effective population size (N_e), which is a function of the total number of breeding individuals, the mating system employed, the sex ratio and the variance of family size in the grow-out of fish that are used to produce the next generation. Several publications (e.g. Tave, 1999) describe the principle and its application. Greater use of the principle would assist hatchery managers in determining strategies and best management practices to minimize inbreeding in hatcheries which are responsible for long-term genetic management of their stocks.

Whilst loss of genetic variation in cultured stocks is commonplace, the opposite can occur when several wild stocks are deliberately interbred during domestication to create a highly genetically variable base population. This is now being carried out in several species with the objective of maximizing genetic variation as the basis for selective breeding.

The impacts of domestication on culture performance may be more variable and less predictable than on genetic variation. Eknath *et al.* (1993) demonstrated in the Nile tilapia *O. niloticus* that newly introduced, wild caught specimens performed better in aquaculture systems than their "domesticated" counterparts despite the fact that the cultivated stocks should have undergone domestication selection for adaptation to these environments. In reality these cultivated stocks were probably inbred and/or introgressed with other species, due to the lack of any conscious genetic management, leading to their poor performance. Similar experiments with Indian carp, rohu (*Labeo rohita*) produced ambiguous results from consecutive trials of wild caught and domesticated stocks (Gjerde *et al.*, 2002; Reddy *et al.*, 2002). Conversely, Dunham *et al.* (2001) indicate that "domestication effects" can have substantial positive impacts upon growth rate in the channel catfish, *Ictalurus punctatus.* They cite 3-6 percent increases in growth per generation during early domestication, also noting that the oldest domesticated strain (of 89 years) had the fastest growth rate of all channel catfish strains prior to the initiation of selection programs.

It appears likely that the relative impact of positive (domestication selection) and negative factors (loss of genetic variation through founder effects, genetic drift, inbreeding and negative selection) on production performance will vary between species. Likewise, the degree of heritability of the key traits will impact performance as will the amount of genetic variation that might be lost. The results will also depend on the circumstances of domestication with regard to the attention given to both genetic factors and the nature of the production environment.

One further genetic factor linked to domestication is the potential for hybrid introgression, either between stocks and or more particularly between species. This issue is dealt with below (see section on hybridisation).

The major challenge in domestication is to ensure that new aquaculture species and stocks are domesticated and managed with a view to optimal retention of genetic diversity. Genes and genotypes that are favored in the wild may be lost from cultured populations as a result of domestication processes without evident negative consequences. However, genetic variation must not be reduced to a point where inbreeding, loss of adaptive capacity and other problems arise. In the domestication process, the potential impacts of the widespread culture of genetically variable composite or genetically changed strains on natural genetic diversity must be actively considered and this issue is covered further later in this paper. This issue is particularly important in the case of culture-based fisheries where hatchery reared stock are deliberately released into the environment. If domesticated stock, genetically changed by the domestication process, are released the genetic integrity of wild con-specific populations can be seriously compromised.

SELECTIVE BREEDING

Relatively little research or development had been conducted on selective breeding in fish prior to 1970. This changed with the initiation of several selection programmes including a major salmon breeding programme in Norway (reviewed by Gjedrem, 2000) and smaller programmes in various other species (reviewed by Hulata, 2001). The success of the GIFT (Genetically Improved Farmed Tilapia) project (Eknath and Acosta, 1998) based in the Philippines extended this belief in selection approaches to the developing world. It is now widely considered that selective breeding should be at the core of most genetic improvement programmes in fish. A number of conditions must be met prior to initiating a breeding program. Firstly, the lifecycle of the species in captivity must be closed. It is then necessary to identify the commercially valuable traits to target and establish that these traits have both genetic variability and moderate to high levels of heritability.

Given the long-term commitment implicit in initiating a selective breeding, it is imperative that the stock to be improved forms a commercially significant and sustainable industry. There is clearly little point in initiating genetic improvement of a species that might be a component of a “boom and bust” commercial development scenario, as appears to have happened for example with the introduction of the African catfish *Clarias gariepinus*, in several Asian countries. The majority of freshwater species used in aquaculture today has been or can be bred in captivity with major advances being made in induced breeding during the late 1950s. The most important freshwater species in terms of volume of production are the Chinese and Indian major carps which were effectively domesticated in the 1960s. However, the initiation of selective breeding has only recently occurred for some of these species.

Whilst this section deals primarily with the improvement in quantitative traits (i.e. those phenotypes that are quantitative in nature and continuous in distribution) there are examples of simpler breeding approaches to modify qualitative traits such as colour, body shape and sex. Such breeding programmes generally involve research to understand the genetic basis of inheritance of the trait followed by a planned programme to either remove or fix the trait within a breeding population. Breeding programmes based on qualitative traits are usually focused on ornamental species but there are some examples in cultured food fish such as in body and peritoneal lining colour in tilapia (Shirak *et al*., 2000), shell colour in scallops (Winkler *et al*., 2001) and shell colour in freshwater crayfish (Walker, Austin and Meewan, 2000).

In developing country inland aquaculture, the major quantitative trait targeted in selective breeding has been growth rate. The objective of these programmes is commonly the production of faster growth, larger size at harvest, shorter culture period or possibly higher stocking densities whilst maintaining harvest size. Growth rate is generally the key trait of highest economic value in the majority of inland aquaculture systems. This is especially true in extensive and semi-intensive systems where fish are sold whole or gutted and chilled rather than processed. More intensive systems see traits such as food conversion efficiency and fillet yield become relatively more economically important, these particularly traits are however more difficult to select.

Traits such as growth rate in fish and shellfish have relatively high levels of genetic variability and heritability. Tave (1993), Dunham *et al.* (2001) and Lutz (2001) reviewed heritability for growth-related traits (commonly weight or length at a specific age) in fish and shellfish with estimates for freshwater species ranging from -0.2 up to 0.8 with an average heritability value of 0.2 which is considered moderate. Moderate to high heritabilities and/or response to selection have recently been observed for other traits such as carcass quality (Rye and Gjerde, 1996; Neira *et al.*, 2004; Bosworth and Wolters, 2005; Cerda, Neira and Baria, 2005; Quinton, McMillan and Glebe, 2005) and health related traits (Okamoto *et al.* 1993; Kolstad *et al.*, 2005; Gitterle *et al.*, 2006).

High levels of genetic variability in today's cultured fish stocks compared to other livestock breeds are likely to be due, in part, to their relatively recent domestication and thus shorter period under which inbreeding and genetic drift have reduced genetic variation within a breed. In addition, the majority of aquacultured organisms are highly fecund and cultured in larger numbers compared to terrestrial species, permitting much higher selection intensities. Selection intensity must always be balanced with maintenance of adequate N_e to ensure long-term retention of genetic variability. Many species have relatively short generation times permitting selection on multiple generations within relatively short time frames enabling rapid improvement. This is compensated to some degree in aquatic species by characteristics such as lower survival, difficulties in marking/tagging and difficulties associated with sampling and visibility of fish along with a lack of standardization of production systems. In principle, it should be possible to secure genetic gains, through selection, in most aquatic species faster than is possible in terrestrial species. This has been shown to be the case in well planned selection programmes to date. There are, nevertheless, differences in the properties of aquatic species which affect their potential for genetic degradation or improvement through domestication processes and deliberate genetic improvement and these are summarised in Figure 8.2.2.

It is beyond the scope of this review to discuss selection methods and breeding programme design in detail. Decisions on designs invariably involve a series of compromises of breeding objectives given the resources available and the characteristics

FIGURE 8.2.2

Matrix showing the implications for effective population size (N_e) and selection intensity of differing properties of cultured aquatic species on the rate of genetic change (which can be negative in the case of poor genetic management or positive in the case of well managed genetic improvement)

		Generation time	
		Long	**Short**
Fecundity	High	*Few broodfish required so N_e is often low but long generation time slow down rate of genetic change. e.g. major carps, abalone, sturgeon*	*Few broodfish required so N_e is often low and rapid genetic deterioration can occur. Genetic gains from genetic improvement breeding programmes can be rapid. e.g. common carp (especially in the tropics)*
	Low	*Rare. Required to retain large numbers of broodfish so N_e is high with slow rate of genetic change so little genetic deterioration but difficult to improve. e.g. dragon fish (arowana), gouramis*	*Required to retain large numbers of broodfish so N_e is high but poor genetic management can rapidly lead to deteriorating culture performance. However breeding programmes can produce rapid gains. e.g. tilapia*

of the species in question. Ideal designs should maximize the chance of correctly ranking the performance of individuals or their relatives whilst minimizing loss of genetic variation. Ideal designs are rarely possible and are most commonly restricted by the limitations on marking/tagging or physical separation of families and individuals.

The basis of selective breeding is to identify traits which are significantly influenced by genetic factors and to choose individuals possessing a majority of positive (desirable) genes responsible for that trait, to be parents in the next generation so that their progeny, as a group, have the highest possible additive genetic merit for the trait or traits in question. A major rational for applying selective breeding is that it is a continuous and long-term approach to genetic improvement with gains being secured with each generation of selection. Implementation of genetic improvement, thus, represents a long- term and sustained approach to improving the culture performance of stocks. It is not always obvious which phenotypic characters are genetically determined rather than primarily influenced by the environment and what component of the genetic determination results from additive genetic variance, i.e. the type of genetic variance that can be selected. It is thus usually necessary to attempt to quantify this through the estimation of heritability, a measure of the degree to which a trait is transmitted from parents to offspring. Due to high fecundity the selection methods usually applied are individual (mass), family or combined selection. Decisions on the correct approach to adopt also depend on the long term objective of the breeding program, the resources available, the nature of the targeted trait itself and its degree of heritability.

Individual or mass selection is based on the performance of the individual itself and is often the simplest and cheapest method to apply. However, problems may occur if there are significant environmental variations (e.g. age or culture system differences) affecting individual performance; these must be controlled as far as possible. Furthermore, given that pedigreed mating is rarely possible in mass selection, it is very difficult to control inbreeding. This has led to problems in several breeding programmes as exemplified in a mass selection programme for common carp *Cyprinus carpio* in Vietnam in which the realized heritabilities for a growth trait dropped to almost zero in just four generations of mass selection (Dan, Thien and Tuan, 2005; Tran and Nguyen, 1993). There are alternative approaches to mass selection designed to obviate this problem such as the PROSPER approach (Procedure Optimisee de Selection individuelle Par Epreuves Repetees = enhanced individual selection procedure through recurrent challenging) in which two lines are mass selected and production stock is generated by crossing between the two lines (Chevassus *et al.,* 2004).

Mass selection is also limited to traits that can be measured in live breeding individuals and cannot thus be used effectively for important traits such as carcass quality or disease resistance. Mass selection is also inefficient for traits with low heritability.

Family selection involves family groups being ranked and either retained or discarded according to their mean performance. Individuals from each selected family are then used as breeders for the next generation. The selection differential is thus a function of differences among families, not among individuals. Family selection is most efficient where heritability for the target trait is low and when environmental deviations contribute a large part of phenotypic variation. The efficiency of family selection is compromised by significant environmental differences between families and thus culture systems for all families should be standardized, e.g. by marking families and stocking them in common environments. A major advantage of family selection is that breeding values can be estimated for traits that cannot be measured directly on the breeding individuals such as carcass quality traits and disease resistance. The successful Norwegian salmon breeding programme (Gjedrem, 2000) and the GIFT programme in tilapia (Eknath and Acosta, 1998) have combined family and individual selection to maximize efficiency of their breeding designs. Family deviations and the mean individual phenotypic values are taken into account in the estimation of breeding values when selecting breeders for the next generation.

Within family selection involves individuals within a family being selected based on the deviation of each individual from the mean value of its family. This method is inefficient compared to other mating schemes but can be relatively easy to manage and apply and the use of rotational mating schemes between families minimizes inbreeding over the long term. Genetic gains from within-family selection have been demonstrated in rainbow trout (Gall and Huang, 1988) and tilapia (Bolivar and Newkirk, 2002).

With the recent initiation of numerous selective breeding programmes some impressive results are starting to emerge in terms of response to selection. Dunham *et al.* (2001) review the progress made in a number of significant breeding programmes and tabulated selection response in 13 key aquaculture species (predominantly freshwater). This indicated genetic gains in growth related traits from 4.4 percent per generation in shrimp (Fjalestad *et al.*, 1997) to 20 percent in a single generation of selection in channel catfish (Bondari, 1983) with an average response to selection of 11.6 percent. Similarly Gjedrem (2000) tabulated genetic gains from programs, primarily in coldwater fish, averaging 13.5 to 15 percent per generation. These summaries may serve to highlight the more successful breeding programmes from which results have been published and it has been observed that gains estimated under experimental conditions are not always fully realized in commercial systems. Nevertheless, it is very evident that in most stocks of aquatic organisms genetic gains in growth-related traits of 7-10 percent per generation are readily achievable. Clearly the economic value of such significant gains, over several generations, are very significant and Gjedrem's estimate of a 15:1 return on investment in the Norwegian salmon breeding programme is not unrealistic (Gjedrem, 2000).

One of the major selective breeding innovations in recent years has been the integration of genetic markers as tools to enhance traditional selective breeding and as markers of quantitative traits for selection. These advances will be reviewed briefly later in this paper.

Significant challenges in the development of selective breeding in inland aquaculture include the identification of resources (funding, expertise and facilities) for initiation and long term sustainability of appropriate breeding programmes which address the real needs of the industries which they support.

HYBRIDISATION AND CROSSBREEDING

Hybridisation is breeding individuals from two separate species whilst crossbreeding is mating two different varieties/strains within a species. Both these crosses are commonly made with the objective of exploiting non-additive genetic variance through identification of significant positive heterosis, also known as "hybrid vigour", for commercially important traits. Positive heterosis occurs when the hybrid or crossbred performs better than the average of the two parental species or stocks. In practical terms, heterosis only becomes really significant when the hybrid or crossbred performs better than either parental species or stocks.

Both crossbreeding and hybridisation are relatively simple techniques to master and can have an immediate impact on performance within one generation. However, this benefit is finite and only present in the F_1 hybrid, unless the parental lines are then selected over generations for their general or specific combining ability, resulting in highly complex and relatively slow breeding programs. Crossbreeding is thus usually looked upon as a supplement to a programme for additive genetic improvement, as mentioned above, to negate the effects of inbreeding in mass selected lines by producing progeny crossed between two such lines (e.g. Chevassus *et al.* 2004; Camara *et al*., 2006). Substantial evidence for heterosis for growth (Hedgecock, McGoldrick and Bayne, 1995) suggests a role for crossbreeding in commercial improvement of oysters.

Due to its relative simplicity there has been considerable research effort to evaluate hybrid crosses between multiple species with hundreds of hybrid crosses being attempted in the past three decades. Considering this large research effort, particularly with cyprinids in Asian aquaculture, there are relatively few hybrids in commercial production. Bartley, Rana and Immink (2000) presented a comprehensive review of hybridisation in aquaculture concluding that hybrid application is under reported and that there remains a significant potential role for hybrids under specific circumstances. In inland aquaculture, there is significant production of a small number of hybrids including hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) in Thailand and Southeast Asia, hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) in China and Israel and hybrid striped bass (*Morone chrysops* x *M. saxatilis*) in North America. The significance of these hybrids is however more related to a specific combination of desirable traits between the two parental species, including the growth rates, appearance and flesh quality of the hybrid catfish and the high proportions of males in the hybrid tilapia, rather than heterosis for any specific trait. One of the major challenges of applying commercial-scale hybridisation is the risk of introgression of pure species parental stocks through contamination by hybrids. Once this occurs the system tends to break down and performance of the supposed F_1 hybrids will become inconsistent and unpredictable.

Planned hybridisation is based on the exploitation of the desired, defined and predictable traits of the F_1 hybrids between the two parental species. Given the relative ease of hybridisation between closely related fish species, hybridisation can be haphazard, as has been seen, for example, in the production of major carps in some countries. This can occur in captivity, either through deliberate or accidental hybridisation. Hybrids may then be used as broodstock in backcrosses or in the production of F_2 crosses. Over generations there is a general mixing and segregation of genes from the original parental species, known as introgression. With this independent segregation of the genes the phenotypes resulting are highly variable and some of the fish carrying the introgressed genes cannot be easily distinguished from the original pure species. Introgression is common in tilapia and other interbreeding species groups, where hybrids can be easily produced either artificially or naturally. Hybrid introgression is thought to have occurred in some major carp populations, e.g. in Chinese carp in Bangladesh (Mia *et al*., 2005; Simonsen *et al*., 2005) where hybrids were originally produced, either out of scientific interest or through reasons of shortage of broodstock. Hybrid introgression in the Chinese or Indian major carps, which form the basis of successful polyculture systems, is very likely to have negative consequences as a result of loss of the distinct feeding strategies of the pure species.

Long-term consequences of *ad hoc* hybridisation events can be avoided if systems are in place that exclude hybrids from use as future broodstock. However, typically such hybrids are rarely recorded or traceable and the evidence of the occurrence of hybrids among both production stock and broodstock in Bangladesh (Mia *et al*., 2005, Simonsen *et al*., 2005) would indicate that it is not an uncommon occurrence.

The major challenge in planned hybridisation is to ensure that it is used appropriately, that there are real economic benefits to a hybridisation programme and that it is managed such that unwanted or uncontrolled introgression does not occur in hatchery or wild stocks.

SEX CONTROL

There is a strong commercial incentive to culture single sex (monosex) populations in species in which there is significant sexual dimorphism for commercially important traits and where species become sexually mature within the culture environments before attaining harvest size. There may also be applications of monosex stocks for biological containment although this is less effective than using sterile stocks. These factors combined can profoundly affect the profitability of culture in some species, most notably in the tilapias.

Monosex populations can be generated through manual sexing, hybridisation, direct and indirect use of hormonal sex reversal. Manual sexing tends to be labour-intensive and inefficient and hybrid crosses only apply to specific combinations of species, again notably in the tilapias (important hybrid crosses including tilapia are summarized by Bartley, Rana and Immink, 2000). The most generally applicable biotechnological methods for producing monosex stocks are through direct sex reversal using hormones or indirectly through genetic breeding programs. Direct sex reversal can generally be applied regardless of the sex determining system and has been successfully achieved in a range of species (Piferrer, 2001). The indirect approach, however, relies on an understanding of the genetic mechanisms of sex determination in a species, the main factor for success being that it is a monogenic system such as male heterogamety (XX female; XY male) as in salmonids or female heterogamety (WZ female; ZZ male) as in some tilapias and crustacea.

The potential benefits of monosex female stocks in salmonid aquaculture have been long established and relate to the enhanced availability of female broodstock and to avoid precocious maturation of males which results in reduced growth, poorer survival and loss of flesh quality post-maturation (Hunter and Donaldson, 1983). In salmonids, sex differentiation occurs at the time of hatch and first feeding (Piferrer, 2001) and direct feminization can be achieved by exposing the fish to exogenous estrogens at this time, either by oral administration or immersion treatments. Sex reversed "neofemales" have normal female phenotypes.

Indirect feminization in species with heterogametic males is achieved by fertilizing normal ova with sperm derived from masculinized (XX) homogametic 'neomales'. This model has been applied for large scale production of several species, most significantly in salmonids (see review by Donaldson and Devlin, 1996) but also in silver barb *Barbodes gonionotus* (Pongthana *et al.,* 1999). Whilst relatively few all female salmon or silver barb are produced worldwide, a significant proportion of commercial production of trout is all female, particularly in Europe, and all-female Chinook salmon are produced in New Zealand.

Monosex male stocks can also be produced, again by either direct or indirect masculinization. Sex reversal to male has been achieved in a range of finfish through application of exogenous androgens. Breeding programmes for all-male production depend on the sex determining mechanism for the target species. In female heterogametic species, the breeding programme is similar to that described above for salmonids involving feminisation to produce ZZ neofemales, and has been developed in the tilapia *O. aureus* (Melard, 1995) and in the giant freshwater prawn *Macrobrachium rosenbergii* (Sagi and Aflalo, 2005). In male heterogametic species, it is also possible to produce genetically all-male progeny through the generation of novel YY "supermales" and such a breeding programme has been developed commercially with Nile tilapia *O. niloticus* resulting in the commercial scale production of genetically male tilapia (GMT) (Mair *et al*., 1997).

Sex control programmes are likely to be of relevance only to some species for which significant economic benefits would accrue from culture of monosex stocks. Direct induction of sex change is always likely to meet resistance from consumers unless achieved using ecologically and ethically sound approaches (such as manipulation of environmental sex determination rather than by hormone treatment). Indirect approaches such as breeding programmes for monosex production are likely to meet with broader acceptance but face the major challenge that they are based on comprehensive understanding of the genetic mechanisms of sex determination which can require considerable research effort.

CHROMOSOME SET MANIPULATION

In fish it is possible to manipulate whole sets of chromosomes through disruption of the process of cell division in the newly fertilized egg. These techniques are generally not possible in higher organisms. There are four types of manipulation which have been commonly applied in fish and shellfish, i.e. gynogenesis, androgenesis, triploidy and tetraploidy.

Androgenesis and gynogenesis are forms of induced uni-parental inheritance in which respectively the female or male genetic contribution is de-activated and the chromosome complement from the male or female is doubled. In androgenesis, the maternal DNA is denatured prior to fertilization, usually via gamma, X-ray or UV irradiation. In finfish the fertilized eggs are then subjected to some form of physical shocks (cold, heat or pressure) at a fixed intervals postfertilization (depending on the species) to disrupt mitosis and restore diploidy resulting in homozygous androgenetic progeny. In gynogenesis, the paternal DNA in the sperm is denatured, commonly through exposure to ultraviolet light, but the sperm remains motile and can activate egg development. Physical shocks (in finfish) or sometimes chemical shocks (common in molluscs) are administered to restore diploidy. Early shocks can block extrusion of the 2nd polar body in meiosis restoring the diploid chromosome complement but retaining some heterozygosity. Later shocks can disrupt metaphase of first mitosis retaining two identical chromosome complements within a single nucleus. Such 'mitotic' gynogens, like androgenetic progeny, are completely homozygous. These homozygous fish can be used as the basis for producing isogenic clonal lines.

Polyploids are produced in a similar way with application of physical or chemical shocks to normal fertilized eggs with disruption of meiosis resulting in triploids with two maternal and one paternal chromosome set. Disruption of mitosis produces tetraploids with a duplicate diploid chromosome complement.

Gynogenesis and to a lesser extent androgenesis has been applied to a wide range of finfish and shellfish species and have a number of research and practical applications such as for the elucidation of the genetic basis of sex determination (Flynn *et al.*, 2006; Pongthana *et al.*, 1995; Tariq Ezaz *et al.*, 2004) and the rapid induction of inbreeding (Komen *et al.*, 1992; Nagy and Csanyi, 1985). Generally, induction and survival rates for these techniques are very low, typically being less than 5 percent of all eggs treated and for homozygous mitotic gynogens and androgens, less than 1 percent, due to the deleterious impact of the physical shocks and the expression of deleterious recessive genes.

Androgenesis could also be used in principle, to recover genotypes from cryopreserved sperm. Clonal lines have value for research, for example as isogenic controls in a selective breeding programme or in eliminating genetic variation in experimentation on the effects of environmental factors or in immunogenetic research. Clonal lines have been produced in a number of inland aquaculture species including Nile tilapia *O. niloticus* (Hussain, Penman and McAndrew, 1998), crucian carp *Carassius auratus gibelio* (Yang *et al.,* 2001), common carp *Cyprinus carpio* (Ben-Dom *et al.,* 2001), rainbow trout *Oncorhynchus mykiss* (Young, Wheeler and Thorgaard, 1995) and the Japanese ayu *Plecoglossus altivelis* (Han, Taniguchi and Tsujimura, 1991).

The main commercial application of chromosome set manipulation has been associated with the sterility of induced triploids which have been produced in many fish species and several bivalve molluscs. Sterile fish have attractions for aquaculture. Firstly, they may put relatively more energy into somatic growth and secondly they provide potential biological containment benefits facilitating the culture of exotic genotypes and possibly in the future, the culture of growth-enhanced transgenic fish. However, generally triploid finfish do not grow faster than their diploid counterparts (Tiwary, Kirubagaran and Ray, 2004), although this may occur post-maturation when the triploids may also have higher dress-out proportions. All induced triploid female finfish produced to-date have been shown to be fully sterile; triploid males show more gonad development than females, are generally sterile but rare incidences of fertility of triploid male finfish cannot be completely discounted. Conversely, many studies have shown that triploid bivalves, although not fully sterile in several species, show better performance than control diploids.

Triploids can also be produced from diploid x tetraploid matings in species for which tetraploids have been produced and shown to be viable, most notably in oysters (Guo and Allen, 1994) and this is likely to represent a more commercially viable and reliable means of mass producing triploids, as demonstrated in oysters (Eudeline, 2001). However, viable fertile tetraploids have been produced in few commercially important fish species, predominantly salmonids but also in the Korean mud loach *Misgurnus mizolepis* (Nam *et al.,* 2001) and the blunt snout bream *Megalobrama amblycephala* (Zou *et al.*, 2004). Sterile triploids are likely to grow in importance for intellectual property protection of broodstock and for biological containment. For this latter application, it will be necessary to quickly and cost effectively verify rates of triploidy induction and assess the potential for fertility of triploid fish and the associated risk.

Whilst much research on chromosome set manipulation has been carried out on finfish, probably the most significant applications are in bivalve shellfish where triploids are cultured widely, for example approximately 50 percent of cultured oysters produced in the US and France are triploids produced from diploid x tetraploid matings (Boudry, pers. comm.). Crustacea have not proved amenable to chromosome manipulation research due to the challenge of obtaining ovulated eggs for artificial fertilization. However, manipulations have been possible in some species including reports of triploidy having been successfully induced (Norris *et al.,* 2005).

One further form of chromosome set manipulation is nuclear transplantation in which cell nuclei from various donor cells can be transplanted into recipient eggs. This research is outside the scope of this review being mainly carried out for research purposes (Liu *et al*., 2002) with, as yet, no commercial application.

Probably the mass production of sterile triploids is the most important application of chromosome set manipulation in aquaculture. The main challenges for these technologies are to reliably and verifiably produce 100 percent sterile fish in a range of commercially important species, particularly those where the resulting options for biological containment and/or IP projection have significant value.

GENETIC ENGINEERING AND TRANSGENESIS

Main form of genetic engineering of practical interest to aquaculture at present is transgenesis. Transgenesis is a technology wherein a novel isolated gene sequence is used to transform an organism. This transgene, which is a construct of a functional gene and a promoter gene that acts as a switch to activate the functional gene, can be from a different species than that of the recipient or a gene cloned from the same species. Indeed there has been a trend away from early research which used foreign gene constructs including human growth hormone genes (Dunham *et al*., 1987) to use of all-fish and con-specific constructs (Wu, Sun and Zhu, 2003) in response to concerns over ethics, human health and environmental impacts of transgenic fish (Maclean and Laight, 2000). Organisms resulting from successful transgenesis are classed as genetically modified organisms (GMO) and thus subject to societal and regulatory concerns over GMOs. Transgenesis has been a major area of research in fish genetics since the early 1990s and research in this area is more advanced in fish than in other livestock as the reproductive biology of fish makes them more amenable to induction compared to higher organisms such as poultry or mammals. Figure 1 clearly indicates a peak in transgenic fish research in the 1990s with a decline at the turn of the decade, most likely associated with difficulty in securing funding to develop transgenic lines which were unlikely to be approved for use in commercial aquaculture in the near future.

The induction of transgenesis involves a number of steps: identification of the target gene and construct development; introduction of the gene into newly fertilized eggs, usually by micro-injection or electroporation; determination of incorporation of the transgene into the host genome; determination of transgene expression; determination of inheritance of the transgene and quantification of the effect of the transgene on target and non-target traits. The main target trait of transgenic research in fish to-date has been the enhancement of growth rate in aquaculture through the introduction of growth hormone constructs. This research was relatively successful with the above-mentioned steps have being completed and a number of transgenic lines produced with sometimes dramatically improved growth performance. Such transgenic lines have been produced in a number of species important in aquaculture including Atlantic salmon (Du *et al.*, 1992), Coho salmon (Devlin *et al.*, 1994) tilapia (Martinez *et al.*, 1996; Rahman and Maclean 1999), channel catfish (Dunham *et al.*, 1987) and common carp (Wu, Sun and Zhu, 2002). FAO (2000) produced a timely and useful review of the transgenic fish that had been produced and were being evaluated for use in aquaculture (Table 8.2.1). Whilst early research focused on growth related traits more recent research has looked at disease resistance (Zhong, Wang and Zhu, 2002; Weifeng *et al.*, 2004) and product quality (Yoshizaki *et al.*, 2005) issues. Clearly transgenesis has the potential for integration with selective breeding programs, particularly for the improvement of traits which are difficult to improve through quantitative approaches.

TABLE 8.2.1
Summary of transgenic fish being evaluated for aquaculture production indicating the nature of the transgene, the target trait and the location of the research (adapted from FAO, 2000)

Species	Novel gene	Desired effect and comments	Location
Atlantic salmon	AFP AFP salmon GH	Cold tolerance Increased growth and feed efficiency	United States, Canada United States, Canada
Coho salmon	Chinook salmon GH + AFP	After 1 year, 10- to 30-fold growth increase	Canada
Chinook salmon	AFP salmon GH	Increased growth and feed efficiency	New Zealand
Rainbow trout	AFP salmon GH	Increased growth and feed efficiency	United States, Canada
Cutthroat trout	Chinook salmon GH + AFP	Increased growth	Canada
Tilapia	AFP salmon GH	Increased growth and feed efficiency; stable inheritance	Canada, United Kingdom
Tilapia	Tilapia GH	Increased growth and stable inheritance	Cuba
Tilapia	Modified tilapia insulin-producing gene	Production of human insulin for diabetics	Canada
Salmon	Rainbow trout lysosome gene and flounder pleurocidin gene	Disease resistance, still in development	United States, Canada
Striped bass	Insect genes	Disease resistance, still in early stages of research	United States
Mud loach	Mud loach GH + mud loach and mouse promoter genes	Increased growth and feed efficiency; 2- to 30-fold increase in growth; inheritable transgene	China, Korea, Rep.
Channel catfish	GH	33% growth improvement in culture conditions	United States
Common carp	Salmon and human GH	150% growth improvement in culture conditions; improved disease resistance; tolerance of low oxygen level	China, United States
Indian Major carps	Human GH	Increased growth	India
Goldfish	GH AFP	Increased growth	China
Abalone	Coho salmon GH + various promoters	Increased growth	United States
Oysters	Coho salmon GH + various promoters	Increased growth	United States

Note: The development of transgenic organisms requires the insertion of the gene of interest and a promoter, which is the switch that controls expression of the gene.
AFP = anti-freeze protein gene (Arctic flatfish). GH = growth hormone gene.

Transgenic fish can also be useful as models for studies of gene regulation and gene expression and have potential as biofactories to produce valuable pharmaceuticals (Hwang *et al*., 2004).

Although enhanced performance under culture conditions has been clearly demonstrated for a number of species there are no transgenic food fish currently under commercial production. The only example on the market at present is the GloFish®, a fluorescent transgenic zebrafish which has been approved for sale and is only sold in the United States (Blake, 2005).

Whilst there are some technical reasons behind the lack of commercialization of transgenic fish the main reason is the concern over the ethical, fish health, human food safety and environmental risks associated with the culture of transgenic fish, the full analysis of which is outside the scope of this review (see Maclean and Laight, 2000 and FAO, 2000 for discussion of these issues). Some research has been carried out in attempts to allay consumer fears over these issues (Guillen *et al.*, 1999; Wu, Sun and Zhu, 2003). However, there remains an absence, in many circumstances, of clear guidelines for appropriate risk assessment. There is a very important test case with a North American company AquaBounty Technologies having applied to the US Food and Drug Administration (FDA) for permission to distribute their AquAdvantage™ growth enhanced transgenic Atlantic salmon. Whilst this is a lengthy process there seems little doubt that conditional approval by the FDA will rapidly lead to approvals for other transgenic fish in other locations.

With solutions now developed for many of the technical constraints to successful application of transgenesis in fish, the main challenges lie in full assessment of environmental, ethical and consumer health risks which currently limit the commercialisation of this technology.

GENETIC MARKERS AND THEIR APPLICATIONS

A genetic marker is a polymorphic genetic property for which there is an experimental procedure allowing identification of genotypes. Prior to the advances in molecular genetics since the 1980s, isozymes and other proteins were the markers of choice. Nowadays there are a variety of DNA markers, such as mitochondrial DNA (mtDNA) polymorphisms, restriction fragment length polymorphisms (RFLP); random amplified polymorphic DNA (RAPD), repeat sequent markers (mainly microsatellites), amplified fragment length polymorphisms (AFLPs) and single nucleotide polymorphisms (SNPs). The most used markers in aquaculture genetics are microsatellites although AFLPs and SNPs are finding increasing application. The nature of these markers and their potential applications are reviewed in full by Lui and Cordes (2004).

There is a long history of application of genetic markers in fisheries and aquaculture but Figure 8.2.3 clearly illustrates a significant increase in the research application of genetic markers in aquaculture in the past decade, coinciding with the development and standardisation of DNA based marker technologies and the reduction in the cost of their application. DNA markers that can be amplified by polymerase chain reaction (PCR) have the additional advantage over protein based markers that samples (typically of fin tissue) can be readily taken in the field or farm without killing the fish and easily and cheaply preserved for the medium to long term.

Polymorphic DNA markers have now been developed from DNA libraries for the majority of the important aquaculture species including the carps, tilapias, shrimps, salmonids and catfish. These markers have a number of important applications which are being increasingly utilized in aquaculture (mainly in research but there is now some commercial use) and in some fishery management applications; the following paragraphs summarize these applications in regards to aquaculture.

Species and strain identification

Several polymorphic DNA markers can be used for identification of species or stocks which can be applied to differentiate between cultured stocks or cultured from wild stocks. Such techniques can be applied from a biosecurity perspective to identify sources of escapes from aquaculture, to determine the impact of introductions and/or escapes of cultured stocks on wild stocks (see review by Utter, 2003) and to trace the origin of non-native farmed stocks. They can also be used for traceability and intellectual property protection in the case of distinct genetically improved strains. Population genetic markers can also be used for the identification of genetically differentiated wild stocks of cultured species which can then guide the collections from the wild to form base populations for aquaculture and breeding programmes. The same markers can also be used for characterizing genetic diversity in founder broodstock. The markers most commonly used for stock identification today are primarily microsatellites and SNPs.

Detection of hybrid introgression

In species for which diagnostic markers have been developed, these markers can be readily used for detection of hybridization in cultured or wild stocks. As outlined above, this can have significant consequences if it occurs in hatchery stocks. Padhi and Mandal (1997) used RFLP to identify F_1 hybrids between catla, rohu and mrigal in fry from a mixed species spawning pool in a West Bengal hatchery indicating that 'incidental' hybridisation can occur in such systems making it likely that hybrids would eventually enter the broodstock. Allozymes were the tools of choice by Simonsen *et al*. (2005) in their identification of hybridisation in between Chinese carp species in Bangladesh, with mitochondrial markers used to identify how such hybrids might have been produced. These findings were confirmed to some extent by Mia *et al*. (2005) in their investigations into the extent of uncontrolled hybridisation in Bangladeshi carp hatcheries using microsatellite markers.

Parentage assignment

Due to their highly polymorphic nature and the ability to combine (through multiplexing) several markers in a single reaction, microsatellites are generally the markers of choice for parentage assignment. These enable progeny to be identified to parental pairings after they have been reared in communal groups. One application of this technique is to determine the consequences of spawning or mating designs on genetic contributions and effective population sizes. For example in pooled spawnings it is often known which females have contributed eggs but often impossible to know how many and which males have contributed to matings. With parentage assignment this can be determined and even compared between different mating systems. It has been shown that relatively small proportions of males contribute to progeny in pooled matings in Barramundi *Lates calciferer* (Frost, Evans and Jerry, 2006) and tilapia (Fessehaye *et al*., 2006) leading to low effective population sizes.

Parentage assignment can be particularly usefully applied in enhancing selective breeding programmes based a family designs which often requires families to be reared separately for several months until they are big enough to be tagged. This may then increase the probability of confounding environmental effects on the trait in question. Parentage assignment allows progeny to be pooled at a very early stage (preferably at the same age to minimise interaction effects between families) and to be identified to family at harvest. One of the draw backs of this method is that contributions from different families can vary substantially due to differential larval survival and size-based grading, especially when pooled very early, which may result in numbers being highly skewed to just a few families reducing effective population sizes. One way to partially circumvent this problem, even in mass selection, is to use parentage assignment to identify selected progeny and then 'walk-back' from those with the highest breeding value for the trait(s) being selected to those with lower values until enough pairs have been selected from enough families to meet the targeted effective population size (Sonnesen, 2005).

Genetic mapping, QTL and marker assisted selection

Genetic markers can be used to construct genetic maps in which linked markers are assigned, using pedigreed matings, to linkage groups resulting in the assignment of chromosomal location, order, and distance between markers. Genetic markers (not necessarily genes themselves) that are closely linked to genes that contribute to quantitative traits are known as quantitative trait loci (QTLs). Gene mapping programmes are now going on for several important aquaculture species including the Pacific oyster, Atlantic salmon, Arctic char, Japanese flounder, rainbow trout, channel catfish, Nile tilapia, and European sea bass (Garber and Sullivan, 2006). Once linkage maps have been developed they can be screened to identify QTLs of interest.

QTL mapping is based on the premise that the QTL and the marker are closely associated on the same chromosome and that they co-segregate. The QTL effect can then be quantified by correlating the inheritance of marker alleles with individual performance for the targeted trait. QTL analyses rely on high levels of heterozygosity which can be achieved by looking for QTL markers in F_1 crosses between species or strains.

A number of QTL for important traits have been identified in fish such as temperature tolerance, growth and disease resistance (e.g. Cnaani *et al*., 2003 in tilapia broodstock).

Marker assisted selection (MAS) is the use of genetic markers linked to QTL in genetic improvement programs. In effect QTL refers only to major genes, as only these will be large enough to be detected and mapped. However, it is likely that most of the traits of interest to aquaculture will be polygenic traits, controlled by a large number of loci. Thus MAS using single QTL markers will be unlikely to generate major responses to selection and should best be combined with traditional selective breeding. Maximum benefits of MAS will be for traits that cannot be measured directly on breeding individuals and for traits that have low heritability. Whilst there are a number of research efforts developing and evaluating QTL there is as yet, no commercial stocks utilising MAS.

The potential benefits of genetic markers in the majority of applications is not contested although the real potential for incorporation of marker assisted selection into breeding programmes and the production and economic gains that will result remain to be verified and this currently represents a major research challenge.

DISSEMINATION AND UPTAKE OF GENETIC IMPROVEMENTS

One of the major challenges in the supply of genetically improved quality seed is to effectively and equitably disseminate the benefits of research and development. In the case of selective breeding, the majority of work carried out to date in developing countries has been supported by international donors and implemented by state and international agencies. There are exceptions where multi-national companies get involved in proprietary breeding programmes such as in Chile with Atlantic salmon. Clearly, genetic improvement programmes must have long term objectives and thus cannot depend on international donor funding indefinitely so it is of critical importance that strategies are developed for the long term sustainability of genetic improvement programs. The main strategy to achieve this would be through a commercialization process where revenue generated from dissemination of improved fish is used to fund the cost of on-going genetic improvement. This can be achieved through the development of a quasi private body such as a foundation or the transfer of the control of the breeding and dissemination to a private sector breeding company.

Taking a look back at similar progressions with genetic improvement of livestock it is possible to see a pattern of transition of roles and responsibilities of the government and private sectors with regard to seed supply and genetic improvement of seed quality as illustrated in Figure 8.2.3.

It is already possible to see differing phases of this development for different fish species in different locations. For example Indian major carp production in Karnataka, Southern India is in Phase I where virtually all seed is supplied by state run hatcheries although there is some progression to Phase II with the initiation of genetic management of stocks in some state hatcheries. Tilapia seed production in the Philippines and to some extent internationally, is in transition from Phase II to Phase III with commercial or quasi commercial entities adopting the outputs from projects on selective breeding and sex control. Currently these commercial entities work alongside and even compete to some extent, with state controlled supply of improved seed which is perhaps to be expected during this stage of transition. Managing this transition represents a major challenge in ensuring equitable uptake of genetic improvements and should be the subject of coordinated policy among the major stakeholders.

One of the other challenges in dissemination of the benefits of genetic improvement is in the maintenance of quality and of genetic gains through the dissemination process. Effective dissemination in most cases will involve the establishment of a breeding nucleus where the genetic improvement (or effective genetic management of introduced improved stock) takes place. The nucleus would be at the centre of a network of multiplier hatcheries mass producing quality seed and/or further broodstock, depending on the scale of the dissemination strategy. Where there is a regular supply of future broodstock from the breeding nucleus then the responsibility of maintenance of genetic gains lies only with the nucleus and not with the multipliers. However, where one-off introductions or very irregular introductions are made then it is beholden to the multipliers to also manage stocks to maintain genetic gains. In the absence of a coordinated dissemination strategy, incorporating a genetic management plan, developed in consultation with key stakeholders, genetic gains from introduced stocks can be readily lost. There are undocumented cases of both successful and unsuccessful introductions of genetically improved stocks such as in the dissemination of GIFT and GMT producing broodstock tilapia, predominantly in Asia. In successful cases introduced broodstock were successfully managed and distributed to avoid significant genetic deterioration and even in some cases used as founders to initiate local breeding programmes to further improve the stocks. In unsuccessful introductions

FIGURE 8.2.3

Illustration of the potential evolution of seed supply systems and the respective roles of state and private sectors as aquaculture develops. Similar evolution has been seen in other agricultural production sectors

Phase I	**Phase II**	**Phase III**
Government agencies play a major role in providing quantities of seed required for aquaculture whilst private sector hatcheries develop.	Government agencies take responsibility for quality of germplasm used in aquaculture including conduct of genetic improvement programmes anddissemination of improved breeds. Private sector hatcheries are primary seed producers and become multipliers for improved breeds.	Private sector become developers and primary multipliers for improved breeds. Government sector responsible for ensuring rural and small-scale farmers can access benefits of improved breeds.

stocks are either poorly managed resulting in inbreeding or introgression with inferior local stocks or simply not distributed effectively. It is important to learn lessons from introductions that have taken place and to ensure that adequate advanced planning has taken place.

KEY ISSUES IN THE FUTURE APPLICATIONS OF GENETICS

This section of the paper briefly highlights some of the key issues, currently facing the development and application of genetics based technologies in aquaculture in addition to technical challenges identified in earlier sections. These issues will ultimately impact upon the benefit to be derived from these technologies.

CENTRALIZATION OF GENETIC IMPROVEMENT

Given the benefits of concentrating resources for genetic improvement at a single location it is evident that significant and sustainable genetic improvement is more readily achieved through centralization. Some of the most successful breeding programmes to date such as the Norwegian salmon breeding programme and the GIFT tilapia project have been highly centralized with genetic improvement, at least in the first instance, being carried out in a single breeding nucleus facility with dissemination achieved through sale or distribution of improved broodstock to multiplier hatcheries. Such centralization is not always possible where international or commercial cooperation is lacking or where effective seed supply systems are decentralized. Such a system exists in the North East of Bangladesh where a decentralized rice-field based seed supply system has developed to effect a sustainable supply of seed (Haque and Barman, 2004). Maintenance of genetic quality of such a stock is a major challenge in the development and sustainability of such as system. On the other hand, the benefits of centralization as part of a national strategy for genetic management and improvement of aquaculture stocks can be seen in the development of a series of National Broodstock Centres in Viet Nam (Mair and Dan, 2001). These centres are strategically located in the key aquaculture producing regions of the country. Each is responsible for the long term genetic management or genetic improvement of species important to its respective region. The development of these centres is as a result of a coordinated national policy on supply of quality seed and should enable the development and distribution, through networks of multiplier hatcheries, of genetically superior strains nationwide.

HUMAN RESOURCE CAPACITY BUILDING

Often one of the key constraints to implementation of effective genetic management or genetic improvement programmes is the lack of adequate knowledge of the key principles and, particularly in the case of implementation of effective selective breeding, the lack of trained and skilled personnel. Many of the principles for effective genetic management are not complex but require hatchery operators to have a clear understanding of them in order to effectively implement best management protocols. Whilst some well written summaries of the key principles and effective management practices have been produced (Basavaraju, Mair and Penman, 2004; Tave, 1993; Tave, 1999) there remains a need for widely distributed, accessible and highly readable information resources covering these topics.

Implementation of modern and effective breeding programmes requires specialist expertise in quantitative genetics for which extensive specialised training in needed. In general, and especially across the developing world, there is shortage of people adequately training in the application of quantitative genetics to the genetic improvement of aquaculture species and thus a need for key personnel to receive training in this discipline. There is a similar deficit of people adequately trained in the principles and practice of ecological and economic risk assessment of introduced and genetically improved fish stocks

AQUACULTURE GENETICS AND CONSERVATION

Balancing the need for genetic change (i.e. improvement) in aquaculture stocks with the desire to conserve genetic diversity in wild stocks represents a central dilemma in aquaculture genetics. For the sustainable development of aquaculture and the preservation of the potential for long term genetic improvement (through selective breeding) of a domesticated and cultured stock it is highly desirable to maximize the genetic variability of the stock at the outset of the domestication process. However, in so doing, it is likely that representatives of distinct wild populations will be mixed in the creation of composite populations, as was performed for example in the initiation of the GIFT project (Eknath and Acosta, 1998) for improvement of tilapia, based in the Philippines.

However, it becomes inevitable in most cases that this genetically variable stock, further modified by genetic improvement and genetic processes that occur during domestication, when widely adopted in aquaculture, will re-enter the natural environment through deliberate stocking (for example in cultured based fisheries) or escapes. This then creates a risk to the integrity of wild populations and may result in a breakdown in the population of wild stocks and the loss of unique reservoirs of genetic diversity for the species.

There exists therefore a dilemma for authorities wishing to promote aquaculture development. Policies based on long term strategies for genetic management and improvement of cultured stocks to support the sustainable growth of aquaculture risk compromising the genetic diversity of local indigenous population. It thus becomes imperative that good risk assessment is carried out when developing aquaculture and the genetic management and improvement options within the industry.

Another important aspect of conservation is gene banking, the protection of genetic diversity through preservation of diverse genotypes. At the moment the options for gene banking in fish are limited to live gene banks or cryopreserved sperm gene banks. Live gene banks are difficult to maintain and require the application of best practices in domestication and genetic management as outlined in previous sections of this paper. There are relatively few live gene banks being maintained for fish due to the challenges of maintaining adequate effective population size. However, some do exist for example for sturgeons in Russia (Chebanov Galich and Chmir, 2004) and for common carp in Hungary (Bakos and Gorda, 2001)

The technology for sperm cryopreservation has been developed for a range of aquatic species (Chao and Liao, 2001; Tiersch and Mazik, 2000) but has not been successfully extended to eggs or embryos other than for a few bivalve molluscs (Chao *et al.,* 1997). Generally it is not a major technical challenge to cryopreserve sperm provided that milt quality is good prior to freezing, the correct cryoprotectant is used and freezing protocols stay within accepted parameters. Generally the quality of thawed sperm following cryopreservation is lower than that of freshly collected sperm but, given the high fecundity of many fish species, adequate to obtain significant numbers of fertilized eggs. Whilst this lower fertility from cryopreserved sperm might be a constraint to the routine use of cryopreservation of sperm in commercial hatcheries this should not represent a major problem in gene banking where the primary objective is to preserve genotypes rather than to produce large numbers of seed.

Whilst cryopreservation is in widespread use for some livestock, including in developing countries, it is rarely used for gene banking in fish. The main reason for this may be the lower priority of gene banking for conservation relative to the commercial incentive for genetic improvement.

Cryopreservation has a range of applications in addition to conservation including enhancing breeding programmes through maintenance of larger effective population sizes, maintenance of specific genotypes (such as sex manipulated broodstock), preservation and biosecure dissemination of improved breeds, and as controls to quantify genetic gains in selection programs. It seems likely, as breed development becomes more sophisticated and moves more into the realm of the private sector, that cryopreservation will become a more common biotechnology in aquaculture in coming years.

STRAIN NOMENCLATURE AND CERTIFICATION

One of the problems facing farmers today is that there are a lot of so called "strains" available for culture but there is no consistently applied definition of what is a strain. The term "strain" should be reserved for domesticated sub-populations within a species which exhibit one or more distinctive and heritable physiological and/or morphological traits. However, the term is more often used to refer to stock at a particular location or of a particular origin, which very often will not have any distinctive recognizable or quantifiably distinct trait. The situation can be further confused by claims and counter claims for particular qualities or properties of these "strains", many of which are difficult or impossible to verify. This situation is particularly prevalent in species such as tilapia, which have been the subject of genetic improvement efforts and in which translocation of stocks is common place.

This scenario generates a strong need for a certification system which would only certify true strains and would incorporate some form of verification and/or monitoring of the properties of the strain. Such a certification system would assure genetic quality of certified seed but could also integrate assurance of appropriate husbandry, handling and point of sale quality measures. The author is not aware of such a certification system currently being applied to seed for inland aquaculture and it would be appropriate to look to the livestock sector for examples of certification systems that could be adapted to aquaculture seed. Certification systems could be applied nationally but ideally would also be applicable for the relatively small but growing international trade in fish seed.

SUMMARY AND RECOMMENDATIONS

It is estimated that no more than 20 percent of global aquaculture production utilizes seed from directed genetic improvement programmes; many more species will be domesticated, or are now domesticated to some extent, through the process of controlled breeding and cultivation. Furthermore, the vast majority (>95 percent) of freshwater aquaculture production comes from the developing world where resources are limited and breeding technologies often less advanced, indicating that the proportion of improved fish in freshwater aquaculture is likely to be considerably lower than the global average. Given that major rapid advances in production possible from implementation of outcomes from R&D in husbandry and nutrition and, in some cases, health management, are likely to have already been made, the era of genetic improvement is truly upon us. The past 15 years has seen a rapid increase in the number and scope of breeding programmes for genetic improvement of aquaculture species and a number of important national and regional programmes for developing, mass-producing and disseminating important aquaculture species are now underway or in train.

There have been a number of important advances in research, most notably in the verification of the potential gains to be had from well managed selection programmes with genetic gains for growth related traits of 7-10 percent readily achievable. However, with these potential benefits in mind it is also evident that there has been genetic deterioration of existing domesticated and cultured stocks through poor genetic management during and subsequent to the domestication process. These effects need to be reversed and basic genetic management needs to be considered when domesticating and translocating aquaculture stocks.

Whilst the success with selective breeding in recent times has placed this technology at the core of efforts to improve aquaculture stocks there have been successes with other technologies and these do have a role as components of integrated approaches to genetic improvement. These include sex control techniques in species which exhibit precocious sexual maturation and/or sexual dimorphism for commercially important traits; chromosome set manipulation, particularly the induction of sterility through triploidy; crossbreeding or hybridisation where heterosis for commercially important traits are evident or where hybrids have a particularly marketable combination of traits. Some extreme improvements in culture performance have been demonstrated using transgenesis but biosafety and societal and regulatory concerns have restricted them to research use for the time being and until such time as some transgenic fish are licensed for commercial aquaculture it is difficult to see a significant role for this technology in aquaculture. Major research advances have been made in recent time with the application of genetic markers and the costs of widely applied and to some degree standardized techniques such as the application of microsatellite markers have come down considerably. Genetic markers are thus now becoming valuable tools and will be increasingly applied to enhance traditional selection programmes and possibly in the future to more specific programmes incorporating marker assisted selection.

Of the major freshwater aquaculture species there have been very significant genetic gains through selective breeding and to some extent also sex control in tilapia, with improved strains exhibiting performance gains of up to 100 percent compared to unimproved stocks. Past research on selective breeding of carp, which was focused in Eastern Europe, has impacted little on current production but several genetic improvement programmes are underway in Asia for a number of species. There have been relatively fewer advances to date in catfish with the exception of the prevalence of hybrids in the production of Clarias catfish in some countries. Similarly there have been few attempts to genetically improve crustaceans but *Macrobrachium* species are becoming a major focus for genetic improvement in Asia.

There are some major technical, environmental and socio-economic issues facing the full implementation of genetic improvement programmes in freshwater aquaculture. One of the fundamental dilemmas is the need for creation of highly genetically variable base populations to provide adequate additive genetic variation from which to select. This is an important first step in initiating a selective breeding programme but is often achieved by interbreeding two of more genetically distinct stocks. When these composite ‘synthetic’ stocks are adopted widely in indigenous species aquaculture there is significant risk of contamination of natural genetic diversity.

Efforts to disseminate the products of breeding programmes has to date met with variable results. The success of dissemination appears to depend upon well planned and structured strategies including good genetic management or further improvement of stocks, accompanied by awareness programmes and/or appropriate and enforceable seed certification systems. It is also important to consider mechanisms for economic sustainability of the publicly supported breeding programmes and the potential for inequitable distribution of the benefits of improved strains associated with commercialization. There are additional challenges where seed supply systems are decentralized as can occur in rural areas. A number of recommendations are made concerning the appropriate role of genetics in seed supply systems for freshwater aquaculture.

RECOMMENDATIONS

This section outlines a number of general and specific recommendations applicable on a global or regional scale, which if implemented, would further enhance the contribution of genetics based technologies and genetic improvement to seed quality and the sustainable growth of aquaculture.

General

- Good genetic management of stocks should be an essential component of all aquaculture production systems and should be an active consideration when new species are domesticated and when cultured stocks are translocated.
- There is a strong need for the development of national dissemination strategies with a focus on the advancement of plans for the effective, equitable and sustainable dissemination of improved fish stocks. This should include designation of areas where certain fish or even the aquaculture sector should not be allowed.
- There is a need to strengthen awareness of and institutional capacity to deal with ecological risks associated with introductions of alien and/or genetically improved fish.
- There are several genetic technologies available to the sector ranging from traditional animal breeding to advanced genetic engineering; risk assessment should be based on the changes the technology imparts on the organism and not on the technology itself. Where the changes are unknown the precautionary approach should be applied (see Pullin *et al*., 1999).
- It is important to conserve genetic diversity in wild relatives of cultured species
- There is a need to improve information systems related to genetic resources for aquaculture, e.g. FishBase strains registry and FAO aquaculture fact sheets.

Technical and environmental

- Selective breeding should be at the core of the majority of genetic improvement programmes for species for which sustainable aquaculture industries have developed. Selective breeding should focus on traits identified as economically important to the sector. Estimation of genetic parameters including correlations between traits is an important pre-requisite to initiation of breeding programmes and genetic gains should be measured against good genetic controls. In the longer term multiple trait selection not limited to production related traits (e.g. product quality) should be encouraged. Active consideration should be given to integration of other genetic technologies into selection programs.
- Efforts should be made to domesticate cultured organisms for which aquaculture remains dependent on wild caught seed or broodstock.
- Genetic markers, such as microsatellites and SNPs, are becoming increasingly useful and affordable tools for such tasks as characterising founder populations, assessing genetic impacts of aquaculture, parentage assignment and estimation of effective population sizes and their appropriate development and application should be encouraged.
- Hybridisation should be limited to cases where heterosis for commercially important traits has been clearly demonstrated or where the hybrid has a highly marketable combination of traits. The potential risk that hybrid production imposes on the genetic integrity of wild stocks should be actively assessed.
- Chromosome set manipulation is a useful research tool and triploidy is, in some species, an efficient and rapid means to improve production and/or a valuable mode of biological containment to reduce the potential environmental impact of aquaculture. Further research is required to assure reliable induction of sterility through triploidy in a range of species.
- Marker- (or gene) assisted selection has potential for improving traits such as disease resistance and carcass quality that are difficult to select by traditional means and the development of such approaches should be considered where these are economically important traits.
- Functional and comparative genomics and bioinformatics are rapidly developing fields and are likely to have important applications to breeding programmes in the near future and developments should be closely monitored.

- The potential for environmental and perceived human health risks contribute to producer and consumer resistance to commercialization of transgenic fish but the demands of food security may influence risk: benefit assessments in the developing world. Risk assessment and biosafety issues should be foremost in any consideration of development and adoption of transgenic fish for aquaculture.
- It is important to maintain and conserve genetic diversity of farmed species and genetic monitoring programmes are recommended utilizing genetic markers. Where appropriate cryoconservation of gametes should be applied to create international repositories for conservation of germplasm from both geographically diverse unselected lines and improved lines.

Economic and social

- Centralized coordinated dissemination programmes where resources can be shared between National Agricultural Research Systems (NARS) and farmers are more likely to lead to good genetic management and effective application, uptake and dissemination of the benefits of genetic technologies. However there may be some cases where dissemination through decentralized systems may be appropriate.
- Coordination between research institutions and development/extension agencies needs to be improved in many countries for effective implementation of dissemination strategies. International networking can assist in circumventing limited resources.
- Development of dissemination programmes should involve full consultation with stakeholders in aquaculture including policy makers, development or extension agencies, research institutions NGOs, seed producers and fish farmers at all levels.
- Dissemination strategies, where possible, should involve private sector hatcheries and NGOs as primary multipliers.
- Evaluation and verification of new or further improved breeds under different production systems is desirable and should involve extension agencies and the private sector as appropriate. An independent process can form the basis for certification of these breeds. Certification systems can incorporate both genetic and non-genetic factors contributing to seed quality.
- Strong awareness building including the development of brand names, through various media, is important to the successful uptake of genetically improved stocks.
- Government and NGO agencies should adopt a long term commitment to ensure the equitable dissemination of improved stocks to ensure that small scale, poor and geographically isolated rural farmers are not marginalized from the benefits of improved stocks. Such commitments should take into account the commercialization strategies of private sector producers/suppliers of quality seed.
- Institutional capacity could be strengthened in many of the developing countries with significant freshwater aquaculture sectors including the construction of appropriate facilities and the development of technical expertise in quantitative and molecular genetics. Expertise in environmental and socio-economic risk assessment associated with improved fish stocks is much needed.

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8.3 Seed networks and entrepreneurship

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ABSTRACT

Fish seed networks, the web of physical and human connections producing and marketing fry and fingerlings, have been a major factor in the rise of inland aquaculture in Asia. Dominated by private sector entrepreneurs, these networks comprise hatcheries, nursery operators, traders and service providers. In recent decades, these networks have greatly increased in terms of the number and range of actors involved and their geographical spread. As a result, fish seed has been made accessible in areas distant from traditional sources and stimulated aquaculture development in marginal areas. Although the public sector has had important roles in the emergence of seed networks, linkages are currently weak. If technology and knowledge are to be accessible to a large but heterogeneous private sector then new approaches to private-public sector linkages are required.

Traditionally, most fish seed were caught from the wild. As technology to control breeding of fish became available and demand for seed increased, hatcheries tended to develop either near these natural sources of hatchlings or centres that disseminated hatchery technology. Normally, private sector enterprises developed in clusters at these sites necessitating delivery of typically small-sized seed to widely dispersed customers.

Fish seed networks in different parts of Asia have grown organically and in doing so encouraged and then supported this growth in aquaculture in rural areas. Bringing seed to potential adopters of fish culture, often with information of how to grow them, has been a critical factor in the now widespread stocking of water bodies. In Asia, seasonality of water availability makes timing of seed distribution to the farmgate important. Private sector traders have local knowledge and are usually adept at supplying seed when they are required.

Lessons learned from West Bengal, northwest Bangladesh, Viet Nam, northeast Thailand, southern Lao PDR and Cambodia suggest that seed networks extend to international linkages. Networks often emerge based on kinship, at least in the early stages of their development. Close cultural and social relationships enable networks to function properly and help in establishing business relationships between providers and consumers.

Seed networks enable entrepreneurship among the poor, allowing them to be involved as small seed producers, nursery operators, traders or sellers of materials and supplies related to seed production and delivery. As networks expand, roles become more specialized, such as water suppliers based in seed markets, *hapa* makers, hormone sellers, suppliers of plastic bags and other equipment, including transport providers. The diversity of livelihood niches tends to benefit even the more disadvantaged people and groups.

Fry traders are key actors within networks often moving fish seed over long distances to foodfish producers in remote locations. Public sector attitudes to this type of informal entrepreneurial business are often negative. Supportive policies that engender positive attitudes can go a long way to empower such entrepreneurs to perform a vital role in supporting rural aquaculture.

Locally available seed, especially large-sized advanced fingerlings, can bring benefits to both traders and foodfish farmers. While risks and costs can be reduced for seed traders the consistency and size of harvests of their customers are increased.

Some recommendations are given to strengthen seed networks and to encourage entrepreneurship within the private sector.

INTRODUCTION

Fish seed networks, the web of physical and human connections producing and marketing fry and fingerlings, have been a major factor in the rise of inland aquaculture in Asia. Dominated by private sector entrepreneurs, these networks comprise hatcheries, nursery operators, traders and service providers. Traditionally, most fish seed were caught from natural sources and were either sold to grow-out farmers directly or after nursing by local specialists. Gradually a network of local nurseries and traders developed to distribute seed more widely. The importance of wild seed persisted after ready availability of hatchery hatchlings (Figure 8.3.1), partly because the seasonal fishery for hatchlings remained profitable and many perceived the quality of wild hatchlings to be higher than from hatcheries. A huge scaling up of seed production and distribution occurred as hatchery technology spread into the private sector. In the Mao Dien commune in the Red River Delta, the number of nurseries has increased by a factor of more than 10 in the last five decades (Prax *et al*., 2000).

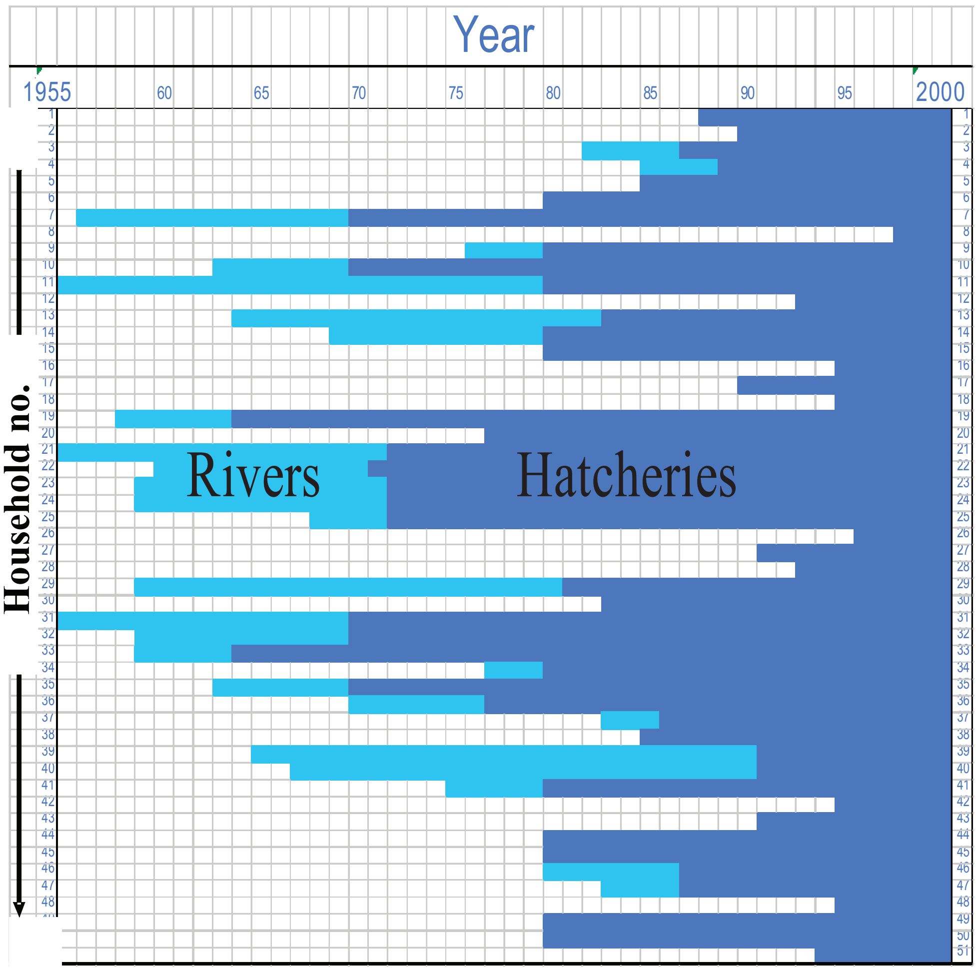
As technology to control breeding of fish became available and demand for seed increased, hatcheries tended to develop either near these natural sources of hatchlings or centres that disseminated hatchery technology. Normally, private sector enterprises developed in clusters at these sites necessitating delivery of typically small-sized seed to widely dispersed customers.

In recent decades, the number and range of actors in seed networks have greatly increased in terms of the number and range and their geographical spread. This made fish seed accessible to farmers in areas distant from traditional sources, and stimulated aquaculture development in marginal areas. Although the public sector has had important roles in the emergence of private hatcheries, linkages or relationships are currently weak. If technology and knowledge are to be accessible to a large but heterogeneous private sector, then new approaches to private-public sector linkages are required.

Fish seed networks in different parts of Asia have grown to both encourage and then support this growth in aquaculture, including generating employment to the rural areas. Bringing seed to potential adopters of fish culture, often with information of how to grow them, has been a critical factor in the now widespread stocking of water bodies. Traders bring seed to the farm gate at the time of year when they are required.

These networks have developed through the involvement of large numbers of stakeholders. The poor are largely involved in the seed marketing network as traders and

FIGURE 8.3.1
Schema showing the development of individual carp nurseries and source of hatchlings in Mao Dien commune northern Viet Nam



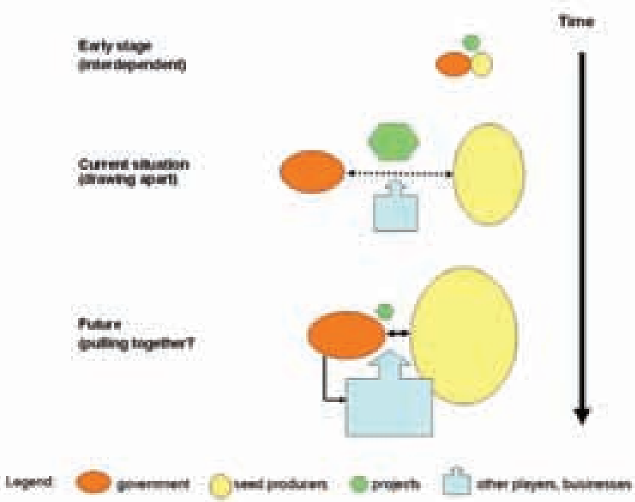
Source: Prax *et al.*, 2000

service providers, thus any improvement of these networks are likely to impact on them.

DEVELOPMENT OF THE PRIVATE SEED PRODUCTION SECTOR AND THE GOVERNMENT

A common pattern to the early emergence of fish seed production can be identified in many countries in Asia. Government efforts to promote aquaculture focused on establishing public sector hatcheries but typically the knowledge of controlled breeding techniques quickly spread to enterprising farmers in the area. In these early stages of hatchery seed production, the relationship between the government and private hatchery operators was close (Figure 8.3.2) unsurprisingly as employees at government facilities often benefited

FIGURE 8.3.2
Relationship between government and private seed producers



Source: Little *et al.*, 2006b

financially. Development was often rapid with hatcheries located in close physical proximity to these government institutions. As time passed, private sector hatcheries developed and expanded, in terms of numbers of hatchery operators and quantities of seed. Other promoters such as externally-assisted projects and non-governmental organizations (NGOs) also supported this development (Little *et al*., 1989). In recent years, the relationship between the government and private sectors has often weakened. A lack of clear strategy and poorly targeted resources on the part of the government sector have stalled impact and destabilized relationships with the private sector. Often subsidized government sector hatcheries produce and market seed that competes with the private sector. As development projects using hatchery development as an entry point to stimulate aquaculture have declined in importance, the role of other, especially commercial, interests has increased.

Re-orientating government agencies to service the needs of private sector seed networks is urgent. Many agencies now have enhanced scientific and other manpower capacity and funding but investment in research and development is frequently poorly targeted and misunderstanding of fish seed demand and quality issues widespread (Little *et al.,* 2006b). Improving communication between the public and private sector is an essential first step to improving this situation. This task is relatively straight forward in terms of government and private sector hatcheries that are owned and managed by better off, more educated people. A greater challenge is improving links with the far more numerous nursery operators and service providers that tend to be more spatially dispersed and less formally educated.

The physical co-location of hatcheries and many nurseries, as described above should reduce the costs of public-private sector communication and certainly has enhanced innovation by producers themselves. Such 'clusters' of enterprises, like any other, enhances the spread of knowledge. Production clusters also, by attracting traders and distributors, reduce transaction costs. Typically, the availability of specialist goods and services increases and prices decline. Moreover, local competition stimulates niche opportunities and specialist knowledge to develop. Often, poorer people with less land and other physical assets benefit from such employment opportunities.

Such 'centralized', physically clustered seed production systems, despite the advantages mentioned above, have limited capacity to meet the demand for seed directly, especially from farmers located far away from such hatchery and nursery clusters. Furthermore intense competition between seed producers typically results in declines in profits and seed quality. Smaller, more vulnerable seed, that are cheaper to produce and easier to transport over long distances, are increasingly produced in such seed centres. These constraints have proved an opportunity for fish seed traders and led to complex seed networks developing to distribute these highly perishable products over long distances.

SEED NETWORK

Fish seed networks are composed of groups of people producing and distributing fish seed and those marketing related supplies and services (Gregory *et al.,* 1997). Their activities are most often informal and yet coordinated, as they are operating in a business environment dealing with supply and demand. Networks are characterized by the co-location of many small seed producers, nursery operators and entrepreneurs, with family/kinship and social relationships among each other, sharing common cultural norms, values and language (Little and Gregory, 1996). These relationships increase trust and makes it easier for people to start-up their business activities, expanding later on once they obtain more experience and knowledge of the seed business. Most hatchery and nursery operators obtained knowledge and credit from neighbours and family rather than formal institutions in a multi-site study of seed producers (AIT/DOF, 2001; AIT/RIA1, 2000; AIT/CAF, 2000; AIT/DOF, 2000). Institutions, mainly non-government, may have important roles in facilitating learning and innovation among network members.

Fish seed networks are important as they play a major role in aquaculture development, enhancing and promoting seed availability especially in more remote rural areas (Haitook, 1997). Seed networks also promote information exchange through face-to-face encounters between seed sellers/traders and farmers, and sellers/traders and seed producers. Through informal and social interactions, information can be exchanged regarding changing demand. This is particularly important for the large areas in which stocking fish seed is rainfall dependent. Good communication and feedback between consumers and traders as well as traders and producers, make networks efficient; technologies especially mobile phones have, especially, become critical in this respect.

Private sector traders are an important part of this network, as they provide a critical function of distributing seed from producer to consumer, often traveling long distances to remote rural areas where fish farmers are located and untouched by conventional government extension services and seed distribution channels. Attitudes from public sector towards such traders are often negative, typically expressed as middlemen ‘exploiting’ vulnerable farmers. Any analysis of risk, however, quickly, confirms that it is the trader that is usually most vulnerable in transactions involving long distance transportation of such a highly perishable product. Supportive policies that engender positive attitudes could empower such entrepreneurs to perform a vital role in supporting rural aquaculture as demonstrated in the training of fry traders as part of the Northwest Fisheries extension programme in Bangladesh Lewis, Gregory and Wood, 1993. This project developed the training programme based on the premise that direct face-to-face contact between traders and growers can facilitate information exchange on fish production and other development issues.

In reality, increased numbers of traders visiting rural communities improves the choice for farmers purchasing seed. Moreover, with experience farmers become more knowledgeable and discriminating about the quality of the seed they buy. Locally available seed, especially large-sized advanced fingerlings, can bring benefits to both traders and foodfish farmers. While risks and costs are reduced for seed traders, the consistency and value of harvests of their customers are increased.

Other actors involved in the seed networks include sellers of hatchery and pond inputs, e.g. acetone dried pituitary glands and other hormones for induced spawning, pig farmers selling manure for tilapia broodstock ponds, night soil traders on fertilization contracts with nursery pond operators, *hapa* makers and sellers and transport providers.

CHANGING CHARACTERISTICS OF SUPPLY AND DEMAND

Long distance transportation of fish seed still often relies on unsophisticated technologies and local knowledge but is changing rapidly as infrastructure improves and technology becomes more affordable. In Bangladesh, fry traders increasingly use bicycles instead of moving fish by foot and motorized rickshaws are used for larger quantities. Improving road networks can have major impacts on the nature of fish seed marketing networks.

Until recently, fish seed sold in northwest Bangladesh was predominantly produced from outside the region, especially in Jessore (355 km away) and transported via the rail network to wholesalers at the Parbatipur Railway Station where a large, seasonal fish seed market developed Lewis, Wood and Gregory, 1993. Nursed seed was then sold on to locally based traders who traveled long distances, typically by foot, to sell them to farmers with ponds. This trade between poor traders and often better–off pond owners was based on a pre-arranged or opportunistic basis. Other transactions included transportation of hatchlings from Jessore to nursery operators located in the northwest for nursing before local traders moved them on to final customers without passing through the wholesale seed markets. Recently, the importance of the fish seed market at the railway station has declined as small seed networks have become established within the region, reducing the distance fish seed has to travel from producer to consumers. The changes have partly occurred in response to more hatcheries and nurseries in nearby Bogra (<100 km south), the establishment of a large government hatchery in Parbatipur and the development of small hatcheries and nurseries in the northwest. Better road infrastructure and communications have encouraged these trends but a large demand for fish seed from Bogra persists as local conditions there allow fish breeding and nursing to start earlier in the season. Stimulating the rapid increase in supply resulted to a steady increase in demand from farmers all over the region. Intensification of agriculture and water use, especially for irrigated rice production has led to declines in wild fish and increased interest in stocked aquaculture.

Recent research and development (see Barman *et al*., 2007 this volume) has identified decentralized seed production based on breeding and nursing of common carp and Nile tilapia in irrigated rice fields to be a rapidly growing approach to meeting seed needs between farmers and communities in the region (Barman and Little, 2006; Barman *et al.*, 2004; Haque *et al.*, 2006); thus, local fish seed traders have become key actors.

The Thai Government has promoted aquaculture in northeast Thailand through a provincial-wide network of public sector hatcheries over the last decades. The Department of Fisheries (DOF) Centres, that also carry out research, training and outreach projects gave critical support to the emergence of a dynamic private sector. Private sector hatcheries are typically located as geographical clusters close to the DOF centres attracting mobile traders to buy fish seed and sell them in areas where there were no hatcheries. Some of these mobile traders sell other merchandise at other times of the year. As aquaculture developed and more people cultured fish for consumption and sale, the demand for fish seed increased, encouraging entrepreneurs to establish hatcheries in other locations although many of these subsequently failed for a variety of reasons (Ingthamjtr *et al*., 1998). Fry traders continue to be important for seed distribution in areas not within reach of a hatchery and as hatcheries seek to specialize. In addition, hatcheries have developed in areas along the Mekong River with good physical and social links with agents in neighbouring Lao PDR (Haitook *et al*., 1999).

Mao Dien, in Thuanh Thanh district, Bac Ninh province is a traditional centre of fish seed production and marketing for the whole of northern Viet Nam and beyond (Prax *et al.,* 2000). Seed nursing and itinerant trading of seed are common aquaculture activities (food fish culture is very limited) in this specific commune where an estimated 95 percent of households are involved in producing in excess of 1 500 000 000 fry and fingerlings annually. Villagers learned techniques for catching hatchlings from the river, nursing and fish trading in mid-19th century from traders who learned of these techniques from another district close to Hanoi. Interestingly, Prax *et al*. (2000) found that there had been little spread of the practice to surrounding communes suggesting that the specialised knowledge has been retained within the community. This reflects typical behaviour of competitive clan-based communes within the Red River Delta (Di Gregorio, 1994).

The proximity of Mao Dien to the Red River Delta where wild spawn could be easily accessed has probably contributed to making nursing a traditional activity. Nursing of fish seed helps in minimizing the impact of stress and shocks from agricultural activities, which remain dominant parts of their livelihoods. Hatchlings now come from hatcheries within the commune and from outside brought in by traders into Mao Dien. These traders also nurse hatchlings and sell them to neighbours to supplement their income. Nursery operators in Mao Dien sell fish seed to traders who then travel long distances to sell them to fish farmers in remote areas. Traders are often younger members of households who also nurse seed. Often costs are reduced by hiring trucks or vans and traveling together to reach areas where their customers are located. Markets in the upland and mountainous areas are popular as they can sell fish seed at higher prices. Local markets within the Red River Delta are now mainly served by other concentrations of nursery operators and traders, especially those that have developed to provide very large seed for producers targeting bigger urban markets (Little, 2005).

INTERNATIONAL LINKAGES

The dependence of production and marketing networks on relationships shaped by culture and kinship has encouraged their development across national boundaries. Variable rates of adoption of seed production have also made some countries and areas dependent on imports of seed. Imports from southern Viet Nam into Cambodia and from northeastern Thailand into Lao PDR remain important; in southern Lao PDR, more than 90 percent of fish seed were estimated to originate from neighbouring Thailand (Haitook *et al*., 1999). Readily available imported fish seed can reduce incentives for local production, especially in areas with poor access to information and/or supporting environment. This can result in low quality seed and loss of local opportunity Litdamlong, Meusch and Innes-Taylor, 2002. Linking supplies of fry from northeast Thailand through established trading networks to local advanced nursing in southern Lao PDR appeared to improve overall availability and quality of seed over a reliance on seed produced in the local provincial hatchery or those supplied directly from Thailand (Little and Edwards, 2004).

The legality of such cross-border trade is often unclear and subject to local interpretation and control that hampers its development and the adoption of appropriate quarantine procedures. Current trade linkages should be acknowledged and steps taken to strengthen and legitimize trade whilst ensuring the quality and proper handling of fish seed, quality of other materials sold, protection of legal rights of traders as they cross borders or transact business and price regulation. Trade is not limited to live fish alone. Materials and supplies such as *hapa* nets and equipment are important exports from Thailand into Indochina and a long established trade exists between India and Bangladesh in carp pituitary glands obtained from retail and wholesale markets in and around Calcutta. Pituitary glands are extracted and preserved before selling on to the hatcheries in Jessore, Bangladesh for induced breeding of carps and catfish. Some of the fish seed produced subsequently find markets back to India. *Clarias* sp. catfish seed, for example, are transported by train through a network of expatriate Bangladeshis. These people, who fled their country as refugees decades previously, move fish from the Bangladesh-India border to as distant locations as Tamil Nadu in the south.

ENTREPRENEURSHIP

Seed networks enable entrepreneurship among the poor, allowing them to be involved as small seed producers, nursery operators, traders, or sellers of materials and supplies related to seed production and delivery. As networks expand, roles become more specialized, e.g. water selling based in seed markets, *hapa* making, hormone suppliers, traders of plastic bags and other equipment and different types of transportation providers. These roles involve men, women and children and typically include disadvantaged groups such as landless families and whole communities. Entrepreneurship has been considered an important driving force in motivating people to innovate and create employment, resulting in economic growth (Georgellis and Wall, 2006). Although government policies such as taxation and bankruptcy laws may discourage entrepreneurship on one level, it is unlikely that these factors encourage or discourage people to become entrepreneurs in seed networks which are initiated at a local level and grow through household and neighbourhood affiliations and relationships. The effect of macro-policies and a legal framework on seed network entrepreneurs have yet to be studied but have been most important in the context of broader economic change such as *Doi moi* in Viet Nam that resulted in large-scale divestment of seed production capacity at state, province and commune levels (Little and Pham, 1996). People are driven to be entrepreneurs more as a response to the opportunities for supplying seed, either its production or delivery has become apparent or as the networks develop a broader range of niche services or products that meet the needs of other network actors become evident.

Entrepreneurs have entered the fish seed business in many ways. Typical routes into the business include being formerly employed in other hatcheries before deciding to set up their own hatchery. A common route is for employees (or their relatives) of government hatcheries, concurrently start up small hatcheries whilst retaining their position (Little *et al*., 1986; Little, 2001). Many hatchery operators in southern Viet Nam and northeast Thailand learned the required techniques from their relatives and friends and through training provided by the government and development projects in their area (AIT/CAF, 2000; AIT/DOF, 2000). Fish seed trading was the entry point for some farmers who advanced from trading into seed nursing, before accumulating capital to set up a hatchery Lewis, Wood and Gregory, 1993. Seed networks have grown in centres such as Jessore in Bangladesh, not just because of its originally favourable geography in terms of availability of wild riverine hatchlings, but because of other factors. The productive 'mini-hatcheries' set up by nursery operators in Jessore were based on very little land and this was possible because mature broodfish could be rented or purchased from other 'actors' within the network locally.

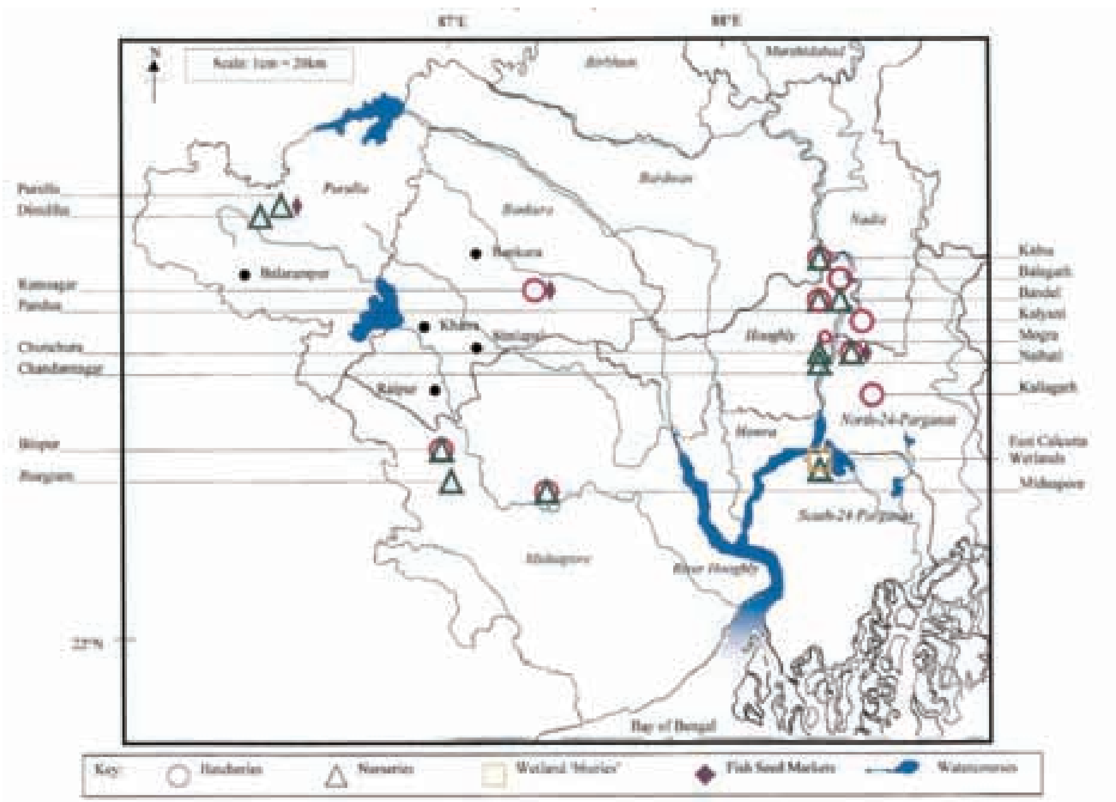
Visscher and Keppy (1995) observed that cultural dimensions and networks are predominant among Southeast Asian entrepreneurs. This supports one of the lessons learned which points to kinship as one of the major basis for the formation of networks in the areas studied, where cultural and social relationships enable these networks to function properly and help in establishing business relationships between providers and consumers. Little and Gregory (1996) identified this phenomenon during efforts to stimulate local fish seed networks in Cambodia. The dominance of expatriates involved in the fish seed business on either side of the Indian/Bangladesh border has been linked to the migration of people occurring decades earlier at the time of Partition (Little, 2001). Hindus moving from Bangladesh to India and Muslims in the other direction typically left secure and relatively wealthy livelihoods but brought knowledge and other transferable assets with them. Access to leased ponds locally allowed them to nurse wild hatchlings, from which some of them later developed pioneer hatchery enterprises in both countries. In addition to technical know-how, the building of trust and linkages has been found to be a key element in developing successful, small-scale seed businesses in other sectors (Lyon and Afikorah-Danquah, 1998). In the context of West Bengal and Bangladesh, a shared language and close cultural affinity of the refugees with local people may have been important. Immigrant entrepreneurship is a common phenomenon (Kloosterman and Rath, 2003).

Many areas of Asia where aquaculture has expanded rapidly remain characterized by enduring poverty and growing markets Lewis, Wood and Gregory, 1993. The fish seed sector is dynamic. However, poorer network members such as fingerling traders can become nursery operators whilst trading seed may become a more dominant part of the their livelihoods. This flexibility and duality that often occurs between production and marketing are important parts of the entrepreneurship process that often appears to develop, depending on the particular context and perhaps a response to availability of 'market space'.

The changing face of fish seed supply networks increasingly reflects the impacts of modern technologies such as mobile phones. Network members in many areas rely on mobile phones to communicate with each other, especially for making/receiving and confirming orders, price negotiations and appointments, facilitating communication and interaction among network actors (Carayanis *et al*., 2006). Motorized transportation of fish seed is having large impacts on the nature of seed networks. Very large seed are being moved in the panniers of motorcycles from specialized producers in some communes of Hai Duong Province in Viet Nam to neighbouring areas where the fish are raised to final market size. Motorcycles allow movement of fish to areas removed from paved roads over short distances. Better water quality, allowing longer distance transportation, is facilitated by use of bottled oxygen and local fabrication of aeration devices all of which improve consistency and quality of the product and service.

Clusters, or the conglomeration of businesses in the same geographical area, are also a feature of fish seed production. Enterpise clusters generally develop and are important because they result in benefits (Van Dijk and Sverrisson, 2003) largely through creating innovative and competitive businesses (Porter, 1998). When nurseries and fish seed markets are clustered around hatcheries such as in the area to the east of Kolkata, West Bengal (Figure 8.3.3), delivery of goods is faster and communication is more efficient. Transaction costs are reduced and related entrepreneurs and service providers are typically motivated to co-locate their businesses in the same area, further increasing overall efficiency. These include fry traders, hormone/feed/net/hatchery equipment sellers, restaurants, transportation and communication companies and middlemen of all kinds. Any enterprise located within a cluster can have a competitive advantage (Carayanis *et al*., 2006) over seed production activities in isolated locations as the latter would typically spend more money and time to obtain materials and to market their products as was observed by Ingthamjitr, Phromtong and Little, 1998 in northeast Thailand. Clusters of small businesses have also been associated with higher levels of innovation; knowledge is more likely to 'spillover', close interaction with customers to occur and competition to drive cost reduction. Moreover, close proximity

FIGURE 8.3.3
In West Bengal, seed production areas are located near fish seed markets, which facilitate the distribution and marketing of fish seed to wholesale and retail traders



Source: Milwain *et al*., 2002

can reduce the overall costs of trialing novel techniques and products. The importation and breeding of the African *Clarias gariepinus* in carp hatcheries in northeast Thailand in the early 1980s quickly led to locally appropriate production techniques and ready availability of broodstock. Furthermore, once ready for marketing, this new species were in a perfect location for attracting the attention of customers. Clusters are also advantageous because they favour both the emergence of new start-ups and reduce the cost of failure (Ketels, 2003). Support (logistic and financial) and partners are more available in clusters and entrepreneurs can fall back on other local employment opportunities accordingly.

Clusters may have particular benefits in the production and marketing of a range of highly perishable and diverse products such as fish seed; a variety of species is usually demanded by farmers (and thus traders) as polyculture is the most popular form of foodfish production. However, as competition and experience develops among producers located within clusters, one trend is towards a level of specialism. Early adopters in West Bengal for example, tend to specialize in certain species that are more difficult to produce and/or produce seed at times of the year which require more knowledge and resources to condition and spawn the fish. Thus, co-location allows such specialization to flourish as choice remains available to customers.

Concentrations of the same or closely related enterprises occur as an outcome of various factors including personal relationships, shared culture and institutional elements. Important original stimuli for fish seed production include proximity to wild seed, research/extension institutions and market channels.

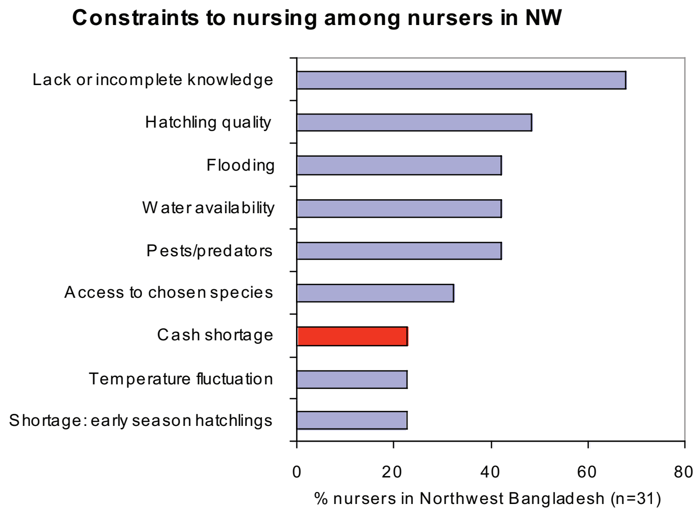
Disadvantages of geographical clusters include a relative isolation from and communication with other important actors, competitiveness within the cluster leading to detrimental impacts on individual enterprises and a tendency towards exclusion of other potential and competitive members. Intensive competition among hatchery/nursery operators in clusters in northeast Thailand gave rise to serious seed quality problems as nurseries sought to reduce costs and by restricting quality and quantity of supplementary feed for example. In contrast to the benefits of the stimulation of competition, a tendency towards isolation may also lead to neglect of further opportunities or the development and refinement of technology and infrastructure in some cluster contexts (Porter, 2001).

The inclusion of extension and training service providers as actors in the fish seed networks adds another dimension to the role of entrepreneurship. In many contexts, salaried staff of government and non-governmental organizations (NGOs) have supplemented their erratic or meagre salaries through working on a consultancy or sharecropping basis with private hatcheries (Little, 2001).

CONSTRAINTS

The rapid growth of aquaculture, the evidence for greatly extended seed supply networks and the involvement of poorer people suggests that opportunities have outweighed constraints in the sector. The highly seasonal nature of associated activities imply that involvement in seed networks may be part of broader ‘pluriactivity’, especially for poorer people. The seasonal trading of fish seed by the poor probably allows them to off-set some of the risks inherent in this activity, for e.g. traders in the Red River Delta achieved attractive incomes during the seed trading season compared to alternative activities (Little and Pham, 1996). Traders reduce risk in other ways particularly through sharing information and labour. In Bogra, Bangladesh, groups of traders from the same community located at a distance from the cluster of nursery operators were found to reduce risk and improve their relative bargaining power by purchasing fish as a group. Also by working as a team they could assess the quality of seed, prior to purchase, more effectively than as individuals by observing the fish behaviour during harvest and conditioning.

FIGURE 8.3.4
Percentage of nursery operators identifying a specific constraint in northwest Bangladesh, late 1990s survey, Fish Seed Quality in Asia



Production and trading of such a quintessentially perishable commodity, inevitably imply a level of risk that actors within networks face and some of the social and technological resources used to mitigate these risks have been described. The social capital that underpins seed networks typically transcend traditional kin or caste-based associations (Immink *et al.*, 2001) or simple exchange of information and credit arrangements.

The availability of informal credit is often critical to timely transactions within fish seed networks, especially as production and marketing seasons are often seasonal. Expenditure on seed by foodfish farmers may dominate investment costs, as was observed by Karim (2006) in Mymensingh District, Bangladesh; purchase of seed is required when households are particularly vulnerable. The ability of private sector hatcheries to provide seed on credit to nursery operators was a major incentive over purchasing seed from government hatcheries in Bangladesh Lewis, Wood and Gregory, 1993.

Financial constraints very widely within seed supply availability networks. Generally, whereas investment costs for hatcheries are significant, entry costs for nursery operators are much lower, especially if pond leasing is possible. Although cash shortages were listed by nursery operators in northwest Bangladesh as a constraint in a survey conducted in the late 1990s, it was not a major issue. Activities in seed networks such as small-scale seed production and nursing require low investment and a modest set of skills, which makes it easier for the poor to be involved. However, support from relevant organizations in terms of seed money and training are still considered useful for such enterprises to improve and expand. The need for short-term credit is more evident among traders who have to invest in seed, materials, transportation and living expenses as they travel from the seed source to farmers in remote areas.

NETWORKS SUPPORT THE POOR

The networks that characterize fish seed supply in Asia are now dominated by the private sector and the influence of public sector institutions has weakened despite considerable investment. A major challenge is how the public sector can develop new and positive relationships within private sector seed networks and, thus, positively impact on the availability and quality of seed available to rural farmers. A major step is recognition of the roles of the poor in seed networks and establishment of channels of communication with them.

The seasonal and informal nature of seed nursing and trading together with its association with low caste or socio-economic class have served to limit contact with the relevant government and other external agencies who are more likely to have other agenda. Improving linkages between external agencies and seed network actors has been shown to deliver a range of benefits.

There are examples of productive initiatives by the public sector. Empowering fingerling traders through conventional training resulted in effective informal extension in northwest Bangladesh Lewis, Gregory and Wood, 1993 with improved performance of their customers' culture systems and their own livelihoods. An *ad hoc* practice at a government fishery station (in Ubon Ratchathani, Thailand) of providing space, clean water and bottled oxygen for fingerling traders appeared to improve both opportunities for buying and selling and the quality of the seed marketed (AIT/DOF, 2000).

A key aspect of any Government support for private sector seed networks, particularly in regions with poor road infrastructure, is a commitment to decentralized approaches. In southern Lao PDR, nursing networks were established by the AIT Aquaculture Outreach together with the Lao PDR Department of Livestock and Fisheries (AIT-AOP, 2000). *Hapa* nursing was promoted as a low-cost, low-risk and simple technology that did not require nursery operators to own a pond or rice field (Little *et al.*, 1991). The training of poorer farmers to nurse and sell small quantities of fish locally grew quickly to dominate seed supplies. In 2003, 13 600 000 fingerlings were produced by household-level seed producers in six provinces compared to 1 700 000 seed produced by the government hatchery. The demand in Savannakhet province alone was estimated at > 30 000 000 fry/year (AIT-AOP, 2004b) much of which was imported by private sector from neighboring Thailand as small fry. In Cambodia, similar infrastructure constraints limit rural farmers access to hatchery seed (Gamucci, 2004) and a decentralized approach has also been promoted by AIT and the Cambodian Department of Fisheries (AIT-AOP, 2004a).

A case study of a decentralized approach is described for northwest Bangladesh (Barman *et al*., 2007, this volume) but an issue is the level to, and mechanisms with which, government agencies can continue to develop active links with the various players in decentralized seed networks

PUBLIC-PRIVATE PARTNERSHIPS

It is generally accepted that upgrading the performance of the aquaculture sector to benefit both producers and consumers requires access to improved germplasm and culture techniques. These may take the form of communication of information and/or access to physical products. Seed supply networks and their downstream linkages with foodfish producers and markets are obvious channels for both communication and introduction of new products. In an era of a rapidly expanding private sector and consolidating or retracting public sector, the concept of local seed clubs being a major forum for communication between network players and external agents is attractive (Little, 2005). Producer clubs have been used successfully in other sectors to reduce the communication and transaction costs between centralized service providers and market intermediaries with producers. They can also become the basis for continuous action learning by their members (STREAM, 2006). One-stop-shops have been used in Bangladesh and India to bring services and information to areas of aquaculture development in a cost effective way through (STREAM, 2006).

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8.4 Role of freshwater fish seed supply in rural aquaculture

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ABSTRACT

As a critical basic input for successful aquaculture, fish seed supply plays an important role in providing a food and an income source to contribute to the Millennium Development Goals. It is expected that this important role will continue to meet the projected aquaculture production to 2020. Therefore, this review focusses on the role of fish seed supply in providing food and livelihoods in the rural sector, demand of fish seed supply and constraints in meeting the demand and some of the interventions in fish seed supply for rural aquaculture.

Reliable statistics do not exist concerning rural households involved in fish seed supply. Nevertheless, its role as a livelihood is reflected in the number of rural households involved in small-scale freshwater aquaculture. Decentralization of fish seed production has offered small farmer-operated hatcheries and fry nursing in rural areas significant income levels for rural households. Break-up of production cycle into breeding and nursing is partly triggered by limited availability of land and the involved cost of accommodating nursery facilities in the hatchery premises. Fish seed production and supply also play a critical role in stock enhancement and culture-based fisheries of natural water bodies. Among the species, carps maintain leading rank in terms of quantity in fish seed supply. Examples exist of small indigenous species with high nutritive value which makes an important dietary component in rural households and that seed production of such fish species for rural aquaculture can make an important nutritional contribution.

In recent years, there has been a general trend in rural aquaculture shifting from extensive traditional fish seed supply practices to more intensely managed systems using new technologies. If the pond-based fish seed production continues, the increase in land area requirement is considerable to meet the projected aquaculture production to 2020. To ease the pressure on land in the expansion of fish seed and aquaculture production, optimal use of paddy fields for rice-fish culture has been suggested as an alternate to pond culture practices. This includes stocking brood fish and encouraging the spawning and incubation of eggs in rice fields and direct stocking of fertilized eggs or fry. Decentralized fish seed production mechanisms such as local and small-scale household hatcheries, hapa nursing and trading networks and on-farm breeding have proven to be good catalysts for fish seed supply for rural aquaculture. Therefore, it is essential to provide continued institutional support, particularly in areas that lack good infrastructure, to enable rural poor to enter into 'spawning' and 'nursing' networks. Fish seed supply is an essential

component of a value chain and its growth as an agribusiness will largely depend on private farmers. Governments have an important role in setting the right framework conditions, building the required infrastructure and capacity and promoting fair local market.

INTRODUCTION

Food security, rural development and poverty alleviation are closely linked. Aquatic products represent an important component of the food of the Asian rural sector and the various types of aquaculture form an important component within farming systems development that can contribute to the alleviation of food insecurity, malnutrition and poverty through the provision of food of high nutritional value, income and employment generation. Specific examples of aquaculture activities that have positive impacts on the rural poor include breeding of fish, fry nursing and the development of nursing and trading networks, integration of fish farming with rice crops in floodplains, raising fry and fingerlings in enclosed or semi-enclosed water bodies for both sale and home consumption and sustaining and restoring aquatic biodiversity through appropriate management methods.

Availability of technology, demand for fish seed and low cost breeding and seed production systems offer opportunities for rural poor people to enter into the fish seed supply chain. With increasing concern on decentralizing fish seed supply, small farmers in rural areas have the opportunities to participate in fish seed supply and even to produce their own fish seed without conventional hatcheries (Edwards, 2000). Farmers in the highland valleys of Viet Nam and Lao PDR have traditionally spawned fish (e.g. common carp in paddy fields); such systems are also common in more developed areas in Indonesia and China. Small carps and tilapias can be bred locally in ponds or simple net hapas, which not only reduces costs and improve quality by avoiding long distance transportation, but also provides employment and income. Such systems have been developed in Bangladesh, Cambodia and Lao PDR where they have had a powerful multiplier effect (Edwards, 2000).

In 2003, total fish production reached 83.73 million tonnes of which freshwater fish culture production was 22.14 million tonnes (FAO, 2005), representing about 26.44 percent of the total fisheries production in Asia. Aquaculture is the fastest growing sub-sector of agriculture; Asia is the largest aquaculture producer in the world. In a short period of 43 years, freshwater aquaculture production increased from 0.721 million tonnes in 1960 to 22.14 million tonnes in 2003, a growth of 2 971 percent. This is a very significant contribution to Asian food fish supply. This impressive growth of freshwater aquaculture production implicates the important role played by fish seed production and supply. It is expected that this contribution will continue to meet the projected aquaculture production target to 2020. Therefore, this review focusses on the following: (i) role of fish seed supply in providing food and livelihoods in the rural sector, (ii) the projected demand of fish seed supply and constraints in meeting the demand and (iii) some interventions in fish seed supply for rural aquaculture.

ROLE OF FRESHWATER FISH SEED SUPPLY IN RURAL AQUACULTURE

Contribution of rural aquaculture to Millennium Development Goals (MGDs)

As a critical basic input for successful aquaculture production, fish seed supply plays an important role in providing a food and an income source. As a food producing sector, the most immediately apparent contribution that aquaculture can make to the achievement of the Millenium Development Goals (MDG) is as a contributor to the eradication of poverty and hunger, outlined in Goal One of the Eight MDGsof the United Nations Millenium Declaration adopted by 189 nations in 2000. In this context, fish seed supply for rural aquaculture may relieve hunger directly through the provision of food, or indirectly by providing a source of employment and income generation for food purchase. The alleviation of poverty and hunger go hand in hand and alleviating poverty may, to a certain degree, reduce hunger, as in many cases, hunger arises not as a result of lack of food availability, but rather as a result of lack of access or ability to purchase it.

At the beginning of the new millennium, the number of hungry people in the world stands at 826 million, of which 514 million (62.2 percent) are in Asia (FAO, 2000a). Rural areas in South Asia, housing more than 70 percent of populations, have high concentrations of hungry people. This means that nearly half the South Asian population suffers from malnutrition (Gill *et al.,* 2003). Diets in many rural areas in the region rely on rice as the predominant form of carbohydrate and for a significant amount of protein. This rice diet is deficient in the essential amino acid, lysine and although animal meat protein has higher lysine content than rice it is only about three quarter of the concentration in fish (Garrow and James, 1993). Aquaculture's contribution to improved nutrition lies in the production of a high quality, affordable source of animal protein, particularly for the rural poor. Food fish represent the most important source of animal protein for many developing countries and low income food deficit countries (LIFDCs) including China. In this regard, fish seed supply and the ability of aquaculture to meet the demand are most critical in countries where the population is dependent upon fish.

Clearly aquaculture has the potential to contribute to achieve one of the goals of MDG as a source of high quality food source, rich in essential micronutrients, (b) rural development and poverty alleviation. Aquaculture can also reduce vulnerability of rural households to shocks and seasonal/annual variability through diversification/ income smoothing.

Fish seed supply as a livelihood

Most of the freshwater aquaculture production in the region comes from small-scale operations in the rural areas. Projects in Lao PDR and Cambodia over the past few years demonstrate that a focus on the participation of poor groups in aquaculture can make significant contributions to improve rural livelihoods. Frequently, rural poor will readily enter into aquaculture if the basic constraints of reliable fingerling supply can be overcome (Philips, 2002).

Reliable statistics on rural households involved in fish seed supply is scarce as small-scale and dispersed production data do not appear in official statistics. Nevertheless, its role in aquaculture is reflected in the amount of households involved in small-scale freshwater aquaculture. At the household level, freshwater aquaculture is becoming more important and throughout much of the Mekong basin, particularly in poor and fish deficit areas away from major wild fisheries, a fact not usually captured in official statistics (Phillips, 2002). In Northeast Thailand, for example, 170 000-200 000, or 6.5–7.6 percent of the 2.6 million rural households are involved in small-scale aquaculture. In Lao PDR, although the annual production of 5 000 tonnes seems quite low, 55 200 rural households, representing 8.3 percent of rural households engaged in some form of aquaculture (Phillips, 2002). In China, in 1997, 3.29 million people against 1.53 million, in the rural sector were involved full-time in aquaculture recording a 115 percent increase (Zhiwen, 1999). Mazid (1999) reported that around 73 percent of rural households are involved in polyculture of major Indian and Chinese major carps and exotic species in ponds, the most dominant aquaculture practice in Bangladesh.

In Viet Nam, culture of fish and shrimp in ponds contribute about 30-70 percent to total household income, although the proportion of pond area is smaller than the land area for agriculture (Luu, 1999; FAO, 2000). The majority of farmers in China are engaged in fish farming as their primary source of income. In Indonesia, FAO reported that about 78 percent of farming households cultivate fish in small ponds of less than

500 m^2 and aquaculture is the main source of income for 66 percent of the households that cultivate fish in paddy fields and ponds (FAO, 2000b).

The income structure shows that the average annual gross household income of the Chinese farmers (about US$17 000) is the highest, followed by the Thai farmers (about US$11 000). In China, the average gross incomes of state-owned, collective and co-operative farmers are US$149 135, US$184 963 and US$53 179, respectively, in China. In general, the gross household income of fish farmers is above the national average income in China. The contribution of fish culture to total household income is as high as 80 percent in India and as low as 15 percent in Bangladesh. The contribution of carp farming to total income in India varies considerably between the states. It is only 15 percent in Orissa and 95 percent in Andhra Pradesh.

Decentralized fish seed production which brought fish breeding and fry nursing and trading networks to rural areas provided opportunities for rural households to enter into aquaculture. Small farmer operated hatcheries and fry nursing operators procured seed from government or private hatcheries. Even though some assets are needed to invest in aquaculture production, poor landless people can become involved and benefit from well-targeted aquaculture interventions. For example, in Lao PDR, landless poor people who did not have access to ponds were involved in a successful and sustainable fish nursing network (Lithdamlong, Meusch and Taylor, 2002). Promotion of decentralized fish seed production and networking offers other advantages – income generation in rural areas, better distribution of income, higher rate of survival of fish to fingerling stage, spread of aquaculture-related activities into a wider area of the country and easier access to fingerlings for aquaculture and stock enhancement purposes (De Silva and FungeSmith, 2005). Fry nursing for fingerling production in rural areas is popular (e.g. Lao PDR) because it requires little investment or risk and profits are made quickly (Phillips, 2002). Once fingerlings are produced, they are transferred to adjoining ponds for on-growing. If farmers are close to a market income can be easily generated from raising fish. In Bangladesh, Hossain and Humayon (2001) reported that carp spawning to fry rearing generated higher net returns (TK124 895 = US$1 874.4) than that of fry to fingerling rearing (TK96 660 = US$1 450), respectively. In contrary, fry fingerling rearing showed a higher cost benefit ratio (4.71) than that of spawn to fry rearing and spawn production in India (Katiha, 2001). Nevertheless, both fry nursing and fingerling rearing bring significant income for rural households.

In most Asian countries, backyard hatcheries are common, particularly for the production of Chinese and Indian major carp fry. Backyard hatcheries are generally effective, not capital intensive and are managed by at most, two persons (De Silva and FungeSmith, 2005). In Orissa, India, for example, community-based carp hatcheries are successfully run by village women (Radheyshyam, 2001). These community-based hatcheries enable poor women who do not have pond resources to be engaged in fish-related activities, providing them with additional household income (De Silva and FungeSmith, 2005). Women in rural Southern India engage in carp breeding, fry nursing, carp polyculture, breeding of catfish and freshwater prawns in backyard hatcheries, ornamental fish breeding and culture, culture of *Spirulina* and *Azolla*, net making and mending and feed preparation for carps and prawns (Shaleesha and Stanley, 2000). Women earn a supplementary income from these activities and increase the family income considerably. For example raising carp seed in a pond of 0.1 ha over a period of 15-20 days will provide a net income of US$119 (Shaleesa and Stanley, 2000). Such hatcheries tend to contribute significantly to rural aquaculture development and indirectly, to poverty alleviation in rural communities.

Role of fish seed in stock enhancement culture based-capture fisheries

Fish seed supply plays a critical role in stock enhancement and culture-based fisheries of natural water bodies such as floodplains, lakes and reservoirs and small water bodies. Culture-based fisheries differs from stock enhancement that stocking of small water bodies undertaken on a regular basis; a person or a group of persons and/or an organization will have property rights to the stock (De Silva and FungeSmith, 2005). The objectives of stock enhancement or culture-based fisheries programmes are to increase fish production, provide employment opportunities and enhance the food fish supplies to the population living around natural water bodies. The source of stocks for enhancement may be derived from capture, but more typically are obtained from hatchery operations. In certain countries, e.g. China, the practice of culture-based capture fisheries includes under aquaculture. In Asia, significant stock enhancements of floodplains are restricted to Bangladesh and Myanmar, while stock enhancement of man-made lakes or reservoirs are practiced in many countries (e.g. Bangladesh, India, Indonesia, Myanmar, China, Sri Lanka). Floodplain fisheries in both countries are important not only from a fisheries production viewpoint, but also socio-economically, sustaining the livelihoods of large numbers of rural people (De Silva and FungeSmith, 2005).

However, the floodplain stock enhancement programmes have resulted in an increased number of private hatcheries operated by local entrepreneurs, rather than increased employment of the poor (De Silva and FungeSmith, 2005). Comparing costs and returns in stock enhancement of floodplains and small water bodies under Third and Fourth Fisheries and Oxbow Lake Projects in Bangladesh, Hambrey (2003) reported that overall, costs are likely to be lower and returns higher for smaller closed or near closed water bodies than for the larger floodplain systems. Protection of stocked fish will be easier. Production will be more consistent from year to year. Fishing/harvesting will be undertaken over a smaller area and catch per unit effort is likely to be higher. Management committees will tend to be simple with more convergent interests and correspondingly lower transaction and management costs.

SPECIES DIVERSITY AND FISH SEED DEMAND

Species diversity and trends in freshwater fish seed production

Freshwater omnivorous and herbivorous fish have been important food fish for developing countries in Asia. Of the recorded 75 species in aquaculture production reported to FAO, low value species, i.e. carps and barbs, continue to be the most popular species group in Asia (Table 8.4.1), In terms of quantity nine of the top 10 species, are carps (Table 8.4.2). This indicates the most popular fish species diversity in demand for seed production. The low value species, carps and tilapias together contributes more than 80 percent to the total freshwater fish production (excluding aquatic plants) in most of the leading aquaculture producing countries in Asia (Table 8.4.1). One of the attributing factors to this major share in aquaculture production is fish to be cultured should be lower in the food chain as this will allow rural farmers to use more readily available feeds, and because it is more ecologically efficient.

Silver carp, grass carp, common carp, bighead carp and crucian carp maintains the leading ranks both in terms of quantity and value (Tables 8.4.2 and 8.4.3). Catla, mrigal and black carp lost ranks within first 10 in terms of value of production. Among carps, crucian carp recorded the highest growth both in terms of quantity and value for the eight-year period from 1995 to 2003. Despite the concerns on environmental impacts, Black carp recorded the second highest growth in terms of quantity, mainly due to its economic value.

Common carp is the dominant freshwater species in Indonesia accounting for almost 46.2 percent of total freshwater aquaculture production in 2003 (FAO, 2005). Indonesia is the world's third largest producer of common carp after China and the USSR. Other freshwater species in Indonesia are tilapia, Nile carp, and Java barb. In the Philippines, of total freshwater aquaculture production in 2003, tilapia and other cichlids were the major species accounted for 78 percent, (FAO, 2005). Although

TABLE 8.4.1

Contribution of low value species to total freshwater aquaculture production in leading aquaculture countries in Asia

Country	Species contribution (million tonnes)							
	Carps and other cyprinids		Tilapia and other cichlids		Total* freshwater fish production		Percentage contribution of carps and tilapia to total freshwater production	
Year	1995	2003	1995	2003	1995	2003	1995	2003
China	8.3	13.64	0.355	0.879	9.35	17.04	92.1	85.15
India	1.211	1.882	NR	NR	1.58	2.066	76.6	91.1
Indonesia	0.192	0.255	0.045	0.091	0.28	0.478	84.6	72.4
Philippines	0.003	0.009	0.077	0.12	0.098	0.154	82.0	84.00
Bangladesh	0.198	0.617	NR	NR	0.271	0.756	73.1	82.0
Thailand	0.034	0.06	0.076	0.097	0.193	0.283	57.0	55.5
Viet Nam	NR	NR	NR	NR	0.296	0.548	-	-
Cambodia	0.0078	0.016	0.00023	0.0005	0.0087	0.0178	92.0	92.8
Total					12.07	20.80		
Asia total	10.133	16.798	0.579	1.259	12.545	22.14	85.4	81.6

Source: FAO (2005); *Excluding aquatic plants; NR – Not reported

TABLE 8.4.2

Trends in species contribution to freshwater aquaculture production in quantity (tonnes)

Common name	Species name	Year 1995	Year 2003	Percentage growth	Percentage growth/yr
Silver carp	*Hypophthalmichthys molitrix*	2 539 405	3 768 240	48.4	6.05
Grass carp	*Ctenopharyngodon idella*	2 103 875	3 591 492	70.7	8.84
Common carp	*Cyprinus carpio*	1 643 008	3 009 868	83.2	10.4
Bighead carp	*Hypophthalmichthys nobilis*	1 249 910	1 923 740	54	6.75
Crucian carp	*Carassius carassius*	537 555	1 792 501	233.5	29.2
Nile tilapia	*Oreochromis niloticus*	485513 (3.87 %)	1116805 (5.0 %)	130	16.25
Roho	*Labeo rohita*	542 364	713 267	31.5	3.9
Catla	*Catla catla*	447 834	566 051	26.4	3.3
Mrigal carp	*Cirrhinus mrigala*	420 958	514 662	22.26	2.78
Black carp	*Mylopharyngodon piceus*	104 152	270 279	159.5	19.93
Total		**10 074 574 (80 %)**	**17 266 875 (78 %)**		
Freshwater fish nei		1 277 298 (11.25 % of the total production)	3 220 696 (15.72 %)	152.12	19.0
Total		**11 351 872 (90.5 %)**	**20 487 571 (92.5 %)**		
Other species of importance					
Snakehead	*Channa spp.*	558	32 279	5 685	710
Thai silver barb	*Puntius gonionotus*	32 230	56 979	77.0	9.6
Tilapia nei		64 331	120 162	87.0	10.9
White amur bream	*Parabramis pekinensis*	335 034	524 927	56.7	7.1

statistics show that milkfish (*Chanos chanos*) and carps are available, milkfish is not widely cultured in freshwater environments (WorldFish Centre, 2002). Production of milkfish in freshwater environments is decreasing at an average annual rate of 2 percent. Carps, on the other hand, are considered newcomers in the Philippines (WorldFish Centre, 2002). Although the production of carp is not even 1 percent that of tilapia, it expanded at an average annual growth rate of 55 percent during 1993-1997

TABLE 8.4.3
Trends in species contribution to aquaculture production in value (US$ million)

Common name	Species name	Year		Percentage growth	Percentage growth/yr
		1995	**2003**		
Silver carp	*Hypophthalmichthys molitrix*	2 198.93	3 099.32	41	5.12
Grass carp	*Ctenopharyngodon idella*	1810.1	2 893.28	59.8	7.5
Common carp	*Cyprinus carpio*	1 795.45	2 464.62	37.3	4.66
Bighead carp	*Hypophthalmichthys nobilis*	1 072.63	1 649.13	53.75	6.72
Crucian carp	*Carassius carassius*	491.63	1 256.17	155.5	19.43
Mandarin fish	*Siniperca chuatsi*	371.82	1 229.06	230.55	28.82
Nile tilapia	*Oreochromis niloticus*	549.86	1 104..27	100.8	12.6
Roho	*Labeo rohita*	1 149.92	953.35	-17.1	-2.14
Japanese eel	*Anguilla japonica*	1 285.38	871.66	-32.2	-4.0
White amur bream	*Parabramis pekinensis*	403.12	603.67	49.75	6.2
Total		**11 128.84 (74.7 %)**	**16 124.53 (74 %)**		
Freshwater fish nei		1 459.64 (11.6 %)	3 042.2 (15.87 %)	108.42	13.55
Total		**12 588.5 (84.5 %)**	**19 166.73 (88.0 %)**		
Species lost ranks within first ten					
Catla	*Catla catla*	413.86	544.36	31.5	3.9
Mrigal carp	*Cirrhinus mrigala*	370.17	469.67	26.9	3.36
Black carp	*Mylopharyngodon piceus*	172.0	445.82	159.2	19.9

(Dey, Paraguas and Alam, 2001). It is thought that carp has a tremendous potential for culture in the Philippines.

Nile tilapia, catfish and Thai silver barb are the most popular freshwater species in Thailand contributing around 34.3 percent, 32.0 percent and 17.23 percent, respectively, of total freshwater aquaculture production in 2003 (FAO, 2005). These species have also expanded at average annual rates of 3.5 percent, 13.0 percent and 9.75 percent, respectively, over the period of 1995-2003. During the same period, production of common carp has increased at an average annual rate of 11.62 percent (FAO, 2005). A variety of freshwater organisms has been cultured in Viet Nam. However, the information on species-specific production is scanty (WorldFish Centre, 2002). In most cases only a qualitative indication is provided on the level of culture for each species (Lovatelli, 1997). ICLARM (1998, 2001) reported that carps (common carp, silver carp, grass carp and bighead, rohu and catla), contributed 29 percent of fish production in 1996 in the country. Other important freshwater species are tilapia, catfish and Thai silver barb.

Although high-value freshwater species such as mandarin fish in China and river eel in Indonesia are emerging as freshwater aquaculture species, their occurrence is localized (Table 8.4.4). Common carp, Chinese major carps and tilapia are the most frequently used species in aquaculture providing benefits widely in rural Asia. This trend is more likely to continue in future in the expansion of aquaculture in Asia, although markets dictate demands. Prices of high value fish and crustacean species will increase with expansion of their aquaculture as a result of increase in fish meal prices. Therefore, increase in rural aquaculture production is more likely to be favoured towards low-value species from increased number of countries joining the production process, and an expansion of the culture area, particularly in countries the aquaculture expansion is not constraint with land and water (Delgado *et al.*, 2003). Investment in the efficiency of related rural aquaculture production systems of low value species would put these commodities within the reach of more poor people.

It is worth noting that production and frequency of occurrence of "freshwater fish nei" (freshwater fish not elsewhere included in FAO production statistics), which constitutes a species assemblage, contributes a significant share to the freshwater aquaculture production both in terms of quantity and value (Tables 8.4.2 and 8.4.3). Nevertheless, leading candidate species within the assemblage is not reported. It is high time to revisit this species assemblage for any emerging species for rural aquaculture. The contribution of indigenous species within this assemblage in terms of socio-economics is of particular importance in order to influence policy directions to promote their culture.

Even though the common argument to culturing indigenous species is to minimize potential risks to the biodiversity caused by introduced alien species, some indigenous species are more profitable than exotics and may be readily adopted by rural farmers. For example, *Barbodes* (*Puntius*) in Lao PDR was readily adopted by hatchery operators and farmers when simplified hatchery techniques became available (Phillips, 2002). Examples also exist of small indigenous species with high nutritive value which makes an important dietary component in rural households. Roos, Islam and Thilsted (2003) reported that aquaculture can make an important nutritional contribution through the production of Vitamin A-dense small indigenous species. They found that the small indigenous species dominated the total fish intake in terms of amount as well as frequency of consumption, contributing 84 percent to the total fish intake among the surveyed households. In Bangladesh, by integrating Vitamin A-dense small indigenous species, such as *Amblypharyngodon mola,* (Mola carplet) with existing carp production in carp polyculture ponds, the nutritional quality of the production can be improved without any negative impact on the total fish production. This production system offers great potential for providing a valuable source of dietary Vitamin A in rural Bangladesh, if seed of *Amblypharyngodon mola* can be made available. It is estimated that, if 10 kg/yr of *Amblypharyngodon mola* are produced in each of the estimated 1.3 million ponds in Bangladesh, the annual recommended Vitamin A intake of > 2 million children would be met (Roos, Islam and Thilsted, 2003).

TABLE 8.4.4
Frequency of use of aquaculture species

Extent of use/species	Countries in Asia	Countries with significant contribution
Ubiquitous:		
Common carp	30/40	China, India, Indonesia, Myanmar, Lao PDR, Iran, Bangladesh
Silver carp	22/40	China, Bangladesh, India, Iran
Freshwater fishes nei	21/40	China, Vietnam, Bangladesh, India, Myanmar, Indonesia
Grass carp	20/40	China, India, Bangladesh
Widespread:		
Bighead carp	12/40	China, Lao PDR, Iran, Taiwan Province of China, Nepal
Nile tilapia	10/40	China, Philippines, Thailand, Indonesia, Lao PDR
Tilapia nei	10/40	Taiwan Province of China, Malaysia, Philippines
Moderate:		
Crucian carp	8/40	China, Taiwan Province of China
Limited/localized:		
Roho	5/40	India, Bangladesh, Myanmar
Mrigal	5/40	India, Bangladesh
Catla	4/40	India, Bangladesh
Black carp	2/40	China
River eel	2/40	Indonesia, Japan
White amur bream	1/40	China
Mandarin fish	1/40	China

Current and projected fish seed demand

The trend in percentage contribution of carps and tilapia to total freshwater aquaculture production in each of the leading aquaculture producing countries in Asia is more or less similar over the period of 1995 to 2003 (Table 8.4.5). Therefore, to project the fingerling requirement of carps and tilapia to achieve the projected aquaculture production to 2020, an assumption is made that there is no change in the percentage contribution of carps and tilapia to total aquaculture production after 2003 (business as usual scenario). The computed percentage contributions of carps and tilapia to total freshwater aquaculture production for selected Asian countries in Table 8.4.5 are amongst the top aquaculture producers in Asia representing more than 80 percent of the total aquaculture production in 2003, thus not compromising the representation of the sample selected.

To compute the contribution of fingerlings and brood fish of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020 (Tables 8.4.6 and 8.4.7), the assumptions made are given in Annex 8.4.1.

There are resource constraints to meet this fingerling demand. To produce the fingerling requirement to meet the projected aquaculture production to 2020, the increase in land area requirement is considerable, particularly in China, India and Indonesia. The projected land requirement for fingerling production cannot be considered in isolation. It has to be considered in conjunction with projected grow-out area to meet 2020 target as fish seed supply is directly linked to the potential of grow-out production. When considering the cumulative effect of land requirement, the need may increase in many folds.

Although the dependency of tilapia and carp broodstock on fish meal is not as great as that of carnivorous species, fish meal is still generally the preferred protein source for use within compound aquafeeds for tilapia and carp broodstocks, because of its high nutritional quality and biological value to tilapia and carps. When fishmeal requirement for the maintenance of required broodstock to meet aquaculture production to 2020 is considered in conjunction with fishmeal requirement for grow-out, the fishmeal requirement may constrain fish seed production.

INTERVENTIONS IN FISH SEED SUPPLY IN RURAL AQUACULTURE

Traditional fish seed supply systems

In recent years, there has been a general trend in the rural aquaculture shifting from extensive traditional fish seed supply practices to more intensely managed systems using new technologies. There are a number of reasons why these changes have been taken place, but most reported changes include:

- decrease in availability/capture of wild fish seed
- increased availability of fish seed of various non-traditional culture species
- better access to information
- production for sale rather than home consumption

Traditional fish seed supply can be described as very extensive. Fish seed are obtained either collecting them from the wild or through natural spawning of fish (e.g. common carp and crucian carp) being held in ponds or paddy fields. Fish are stocked in paddy fields or ponds to collect eggs or are harvested for consumption at a later date. There is very little management other than maintaining the water level. With the intensification of culture practice, management interventions such as use of lime in nursery pond preparation and for disease control and intensifying rice-fish culture by using more species such as improved common carp, tilapia, Indian and Chinese major carps, with modifications of rice-fields with trenches or refuges have become common.

Stocking was the key element that defined most rural traditional fish seed supply systems. Other than stocking of fish, there is very little intervention on the part of the

TABLE 8.4.5

Projected aquaculture production by leading aquaculture countries in Asia

Country	Estimates						Forecast for 2020[3]		
	Production[1] 1995 (mmt)	Percentage contribution of carps and cyprinids	Percentage contribution of tilapia and other cichlids	Production[1] 2003 mmt	Percentage contribution of carps and cyprinids	Percentage contribution of tilapia and other cichlids	Production[2] (million mt)	Production of carps and cyprinids (mmt)	Production of tilapia & other cichlids (mmt)
China	9.35 (59 %)	88.7	3.4	17.04 (62 %)	80	5.15	52.255[a] (32.4) 40.747[b] (25.25)	25.96	1.67
India	1.58 (95.2 %)	76.6	NA	2.066 (93.3 %)	91.1	NA	10.744 (9.99)	9.10	-
Indonesia	0.28 (43.7 %)	68.5	16.1	0.478 (48 %)	53.4	19.0	7.355 (3.53)	1.88	0.671
Philippines	0.098 (27 %)	3.4	78.6	0.154 (33.4 %)	6.0	78.0	6.30 (2.10)	0.126	1.64
Bangladesh	0.271 (85.5 %)	73.1	NA	0.756 (88.2 %)	82.0	NA	1.340 (1.18)	0.968	-
Thailand	0.193 (34.5)	17.6	39.4	0.283 (36.6 %)	21.2	34.3	0.838 (0.306)	0.065	0.105
Viet Nam	0.296 (77.6)	NA	NA	0.548 (58.5)	NA	NA	5.175 (3.03)	-	-
Cambodia	0.0087	89.6	2.7	0.0178	90.0	2.8	NA	-	-
Total	12.07			21.34					
Asia total	12.545			22.14					

1 Freshwater fish production. (Source: FAO, 2005). Contribution to total aquaculture production is given in parenthesis.
2 Projected aquaculture production to 2020. Freshwater production is in parenthesis assuming no change in contribution of freshwater production to total production after 2003.
3 Source FAO, 2004 (a and b based on 3.5 percent and 2 percent annual aquaculture growth rate)
NA – not available

TABLE 8.4.6

Contribution of fingerlings of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020

	Estimated fingerling production 2003 (million)		Projected fingerling requirement to 2020 (million)		Estimated pond area for fry to fingerling rearing (ha) 2003		Projected pond area for fry to fingerling rearing to 2020 (ha)	
	Carps	Tilapia	Carps	Tilapia	Carps[1]	Tilapia[2]	Carp[1]	Tilapia[2]
China	17 050	1758	32 450 (90 %)	3 340 (90 %)	76 725	3 446	146 025 (90 %)	6 546.4 (90 %)
India	2 352.5	-	11 375 (383.5 %)	-	10 586.25	-	51 187.5 (383.53 %)	-
Indonesia	318.75	182.0	2 350 (637 %)	1 342 (637.4 %)	1 434.4	357	10 575 (637.24 %)	2 630 (637 %)
Philippines	11.25	80.0	157.5 (1 300 %)	3 280 (4 000 %)	50.62	157	709 (1 300.5 %)	6 429 (3 995 %)
Bangladesh	771.25	-	1210 (57%)	-	3470	-	5445 (57%)	-
Thailand	75.0	194.0	81.25 (8.4 %)	210 (8.24 %)	337.5	380.2	366 (8.4 %)	412 (8.4 %)
Viet Nam	NA	NA	NA	NA	NA	NA	NA	NA
Cambodia	20.0	1.0	NA	NA	90.0	NA	NA	NA
Total								
Asia total	20 997.5	2518			94 489			

1. Based on 90 percent carp fingerling production is in earthen ponds at a production rate of 0.2 million fingerlings /ha;
2. Based on 50 percent tilapia fingerling production is in earthen ponds at a production rate of 0.1275 million fingerlings /ha and two culture cycles per year;

Percent increase in land requirement to achieve 2020 fingerling requirement is given in parenthesis

TABLE 8.4.7

Computed contribution of broodstock to meet the computed fingerling production to meet aquaculture production in 2003 and projected production to 2020

	2003 Estimated broodstock (kg)		Projected to 2020 broodstock (kg)		Estimated fishmeal requirement in broodstock feed per year in 2003 (kg)[1]		Projected fishmeal requirement in broodstock feed to 2020 (kg)[1]	
	Carps	Tilapia	Carps	Tilapia	Carps	Tilapia	Carp	Tilapia
China	4 570 000	461 475	869 6600	876 750	4 170 000	421 000	10 839 000	800 000
India	630 500	-	304 8500	-	575 300	-	2 782 000	-
Indonesia	85 420	47 775	629 800	352 275	78 000	43 600	575 000	321 451
Philippines	3 020	21 000	42 210	861 000	2 750	19 163	38 500	785 663
Bangladesh	206 700	-	324 280	-	189 000	-	296 000	-
Thailand	20 100	51 992	21 775	55 125	8 340	47 443	20 000	5 0302
Cambodia	5 400	262.5			5 000	239		
Asia total	5 627 300	660 975						

1. Estimated from 10 percent fish meal use in broodstock feed and at 2.5 percent body weight/daily feeding regime for one year

farmer other than maintaining the water levels. There are a number of different stocking scenarios described in the traditional fish seed supply systems including:

- stocking wild caught fish seed
- stocking eggs of fish (e.g. common carp and crucian carp eggs) that are being collected from the wild
- stocking eggs collected by placing artificial or natural (water hyacinth or straws) substrate in streams
- stocking eggs collected by placing artificial substrate in household culture ponds
- stocking fingerlings nursed in rice fields or nursery ponds that are being produced by collecting of eggs
- stocking gravid adults to spawn in rice fields or household ponds

Various issues related to traditional methods for fish seed acquisition pose possible constraints. The most immediate is the reliance in many cases on wild stocks as the source of seed. Wild stocks are generally perceived as declining, a situation that could threaten the local availability of seed. This being the case, it is important to assist farmers to develop improved practices for maintaining and managing broodstocks within their culture systems.

Fish fingerling production in rice fields

Strategies for the production of fingerlings in irrigated rice fields include stocking brood fish and encouraging the spawning and incubation of eggs in rice fields. Direct stocking of fertilized eggs or fry is also practiced. The fry are directly reared in early rice fields and after they have grown to 4 to 5 cm, they can be transferred to the rice fields in mid-term production cycle to grow them to market size by the time the rice is harvested. This is the easiest and most effective way which brings maximum benefits to fishermen. Another activity that is practiced is the fish fingerling production in rice fields in rotation with rice. The ricef ield is flooded during winter months when the rice fields are idle and with little competition for irrigation water.

Barman *et al.*, (2004) observed that the majority of households supported by the CARE Greater Opportunities for Integrated Rice-Fish Production Systems (Go-INTERFISH) project in Bangladesh used either eggs or fry of common carps for stocking in their rice plots during the first winter season and a very small proportion stocked tilapia brood fish or fry. In the second winter season, the use of common carp eggs remained high but stocking of fry declined, while the use of tilapia brood fish and the direct stocking of other species as fry increased. In the third winter season, the proportion of households using eggs rather than fry of common carp increased further and the use of tilapia brood fish and fry of other species also increased. Households targeted under the latter phase of the CARE Project produced fingerlings mainly by stocking the eggs of common carp and fry of other fish species. In areas under the early phase of the CARE Project, most households used tilapia brood fish and the number of farmers using common carp eggs increased. These data suggests that with previous experience and improved availability of brood fish, farmers choose to stock common carp eggs rather than fry and over time they began to maintain both common carp and tilapia brood fish (Barman *et al*., 2004). This tended to improve the efficiency and consistency of production and reduce investment costs.

Farmers who depended on outside sources such as local nurseries or fry traders for their fry requirement of species other than common carp and tilapia to stock in rice fields gradually increased their dependence on their own fry sources, mainly from their own grow-out ponds (Barman *et al.*, 2004). This strategy of moving fish from small ponds, which often dry up, into the irrigated rice field environment allows the farmers to improve the performance of the resources available. Once stocked in the rice field at low densities and usually low numbers, fish grew rapidly to foodfish size and were used mainly for household consumption. The practice changed the use of rice fields from nurseries to fattening of fish. Silver barb was the most commonly stocked ‘other’ species, showing high survival and growth performance in rice fields.

The main purpose of stocking fry into winter season rice fields was to supply adequate number of fish fingerlings for stocking in autumn season rice fields for grow-out. An important aspect of increasing the trend of stocking other species (that could not be spawned locally) in rice fields, was the increasing linkage between traders and rice field fish seed producers (Barman, Little and Johannes, 2004). By supplying seed of other species, fry traders acted as conduits of knowledge, source of markets for large fingerlings of tilapia and common carp produced in the rice fields, thus assisting in fish seed supply decentralization.

Decentralized fish seed supply

Rural aquaculture is constrained by access to fingerlings, but experience suggests that local small-scale hatcheries can have a big impact (Phillips, 2002). The Asian Institute of Technology (1997) considers that the centralized, large, government hatchery model has not been successful. It is widely accepted that decentralized fish seed production mechanisms such as local and household small-scale hatcheries, hapa nursing and trading networks and on-farm breeding have proven to be a better catalyst for rural small-scale aquaculture.

Break-up of production cycle into breeding and nursing is partly triggered by limited availability of land and the involved cost of accommodating nursery facilities in the hatchery premises and in turn facilitated the decentralization process of fish seed supply. Break-up of production cycle into breeding and nursing offer opportunities for poor farmers to enter into fish seed production. Hapa nursing of fry to fingerling enable landless rural poor to enter into fish seed production provided support for access rights to water bodies. Further development of hapa nursing and nursing networks will also be essential to support rural aquaculture particularly in areas that lack good infrastructure. Without local networks, seed will be transported over large distances between catchments, with an attendant risk of genetic mixing of fish stocks and spread of diseases (Phillips, 2002).

THE WAY FORWARD

Access to fry and fingerlings has been documented as a constraint to rural aquaculture. This may be one of the reasons most of the aquatic production in rural areas is dependent on wild capture fisheries. Experience in many countries in the region proved centralized fish seed production has failed to reach the rural poor. Examples of decentralization of fish seed distribution exist in countries such as Bangladesh, Lao PDR, Viet Nam and Thailand on the development of “spawning” and “nursing” networks where farmers carry out spawning fish to produce hatchlings and the nursing fry to fingerlings, respectively, to distribute among neighbouring farmers. Government and small-scale private hatcheries act as centres for such spawning and nursing networks to supply fry. Such interventions have given positive results and therefore it is essential to provide continued institutional support particularly in areas that lack good infrastructure. For such networks to be sustainable large- to medium-scale government hatcheries should focus more on broodstock management and development to cater to the needs of small-scale private hatcheries which lack facilities for proper broodstock development. It is equally important to offer opportunities for rural poor to enter into ‘spawning’ and ‘nursing’ networks. Apart from continuing need for adaptive, small-scale technological development in order for poor to go into such networks, improve access of landless poor to water resources needs to be addressed.

It was also evident that the problem is not so much on inadequacy in fish seed production, but more on the issue of actual contribution to production being much less since a great proportion goes to ‘waste’. This significant proportion of waste has often been linked to the quality of fish seed. The potential negative impacts of genetics related to broodstock management issues such as inbreeding, genetic drift, introgressive hybridization and unconscious selection have been attributed to the poor quality of seed stocks. This over focus on genetic-related issues has neglected the good practices of fry traders during fry transportation and good husbandry practices of farmers during stocking and post-stocking. Development of strong farmer-decision making management tools to assess the quality of seed before and after stocking may lead to reduce the “waste”.

In the face of increasing resistance to the introduction of exotic species to increase aquaculture diversity, the use of indigenous species may be encouraged to safeguard biodiversity as well as enhance nutritional quality of the aquaculture production. However, the use of indigenous species for aquaculture has to be accompanied by broodstock management programmes that contribute to maintaining genetic diversity. In Thailand, for example, there is some evidence of loss in genetic diversity through hatchery breeding of *Barbodes* (Phillips, 2002). Thus, while promoting fish seed production of indigenous fish is a positive move, the approach needs to be supported by effective broodstock management strategies incorporating genetic concerns and species policies that reduce the movement and mixing of genetically-different stocks and strains (Phillips, 2002).

There is a need to ease pressure on land in meeting the demand for fish seed. To ease the pressure on land in the expansion of fish seed and aquaculture production, optimal use of paddy fields for ricefish culture has been suggested as an alternate to pond culture practices. Rice is cultivated in approximately 147 million ha world wide, of which almost 90 percent lies in the Asian region (Jenkins, 2003). Compared to other forms of aquaculture, additional land and water requirements for rice-fish culture are relatively small. Fish cultured in rice fields satisfy a large portion of their feed requirement from the natural environment. China produced 650 000 tonnes of fish from rice using paddy fields (Xiezhen, 2003). This is equivalent to a fish production from 144 450 ha of pond area. It has been estimated that about 6.7 million ha of paddy fields in China have the potential to practice ricefish culture (Xiezhen, 2003). If half of this potential is developed into rice-fish culture, it is equivalent to fish production from 744 450 ha of fish ponds. Das (2002) reported that 27 250 ha of potential area available in northeast India for rice-fish culture. This resource should be considered as a means of fingerling production to ease the pressure on land and water. However, ricefish culture is not perceived particularly as a good method for growing very young fish fry to fingerling production, mainly due to low survival rates (Kangmin, 2001). Further interventions such as introducing appropriate modifications in rice field systems or conditions conducive to fry to fingerling rearing will help address the issue of land and water limitations. Additional attention should be given to the successful rice-fish system in lowland rain-fed rice as practiced in Thailand. This system is appealing due to its water saving aspects.

Clearly fish seed supply has the potential to contribute to the livelihoods of rural poor. Unfortunately, fry to fingerling rearing has received only marginal attention from researchers and governments in Asia. In many countries, the processes have evolved and adapted as a result of rural entrepreneurship, rather than through governmental encouragement and backing (De Silva and FungeSmith, 2005). Potential of increasing the diversification of fish seed supply systems present a significant agribusiness opportunity to increase livelihoods and wealth generation for all stakeholders. Fish seed supply is an essential component of a value chain and its growth as an agribusiness will largely depend on private entrepreneurs. The government has an important role in setting the right framework conditions, building the required infrastructure and capacity and promoting fair local market.

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ANNEX 8.4.1
Assumptions made for the computation of the contribution of fingerlings and brood fish of carps and tilapia and land requirement for fingerling rearing to meet the aquaculture production in 2003 and projected production to 2020

Assumptions made for carp species:

Average weight of females	1kg
Number of eggs/1 kg female	100 000
Fertility rate of eggs (80 percent)	80 000
Hatching rate of fertile eggs (80 percent)	64 000
Survival up to seven days (75 percent)	48 000
Survival of fry up to one month (35 percent)	16 800
Survival up to fingerlings (80 percent)	13 440

Female brood fish required to produce one million fingerlings — 74.4 kg of females

Female and male brood fish (1:2) required to Produce one million fingerlings — 74.4 kg females + 148.8 males

Actual broodstock required (with 20 percent resources)(74.4 + 14.88) + (148.8 + 29.76)
= 268 kg

Fry density 250 000/ha (80 percent survival)	200 000 fingerlings/ha
Average stocking rate for poly culture	5 000 fingerlings/ha
Average production	4 tonnes/ha

Assumptions made for tilapias:

To produce 1 million fry/yr — 150-200 kg broodstock

With 20 percent resources, required broodstock	210kg
Tilapia fry survival	75 percent (70-80 percent)
To produce 1 million fingerlings/yr required fry	1.25 million/yr
To produce 1.25 million fry required broodstock	262.5 kg
Fry stocking densities (140 000-200 000/ha pond)	170 000/ha
Fingerling production at 75 percent fry survival	127 500/ha
To raise 1 million fingerlings required land area	7.84 ha

Stocking densities of fingerlings	10 000-20 000/ha(average 15 000/ha)
Output production	5-15 t/ha (average 7.5 t/ha)
Two culture cycles/yr	15 t/ha/yr

8.5 Asian experience on farmer's innovation in freshwater fish seed production and nursing and the role of women

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ABSTRACT

Innovations of farmers laid good foundation for aquaculture development in many Asian countries. In China and India where aquaculture has a long history and tradition, the role of farmers in innovating culture practices and seed production techniques are highly visible. The invention of hypophysation technique in the middle of the last century in both countries opened a new era for the expansion of aquaculture on a large scale by ensuring availability of quality seed.

By understanding the working principles of the Chinese hatchery system, many farmers have innovated smaller, cheaper and economically viable and environmentally friendly models of Chinese hatchery technologies. More recent innovations such as hapa nursing technology to produce big size seed or stunting fish seed in ponds to obtain bigger size and aged seed are additional examples to indicate how farmers continue innovations to improve economic viability of the system.

This paper presents information on different types of innovations by Asian farmers and the role of Asian women in the freshwater fish seed sector.

BACKGROUND

Farmers innovate as part of their quest to cope with necessities of life for survival as well as to improve their economy. Evolution of carp culture technology by farmers of West Bengal is an example of how farmers have been able to utilize their inventive potentials to evolve a technology that has stood the test of time for centuries. Traditional technology evolved by farmers gave a yield of 3-4 tonnes/ha and the scientific community attempted to enhance this yield to 10 tonnes, by incorporating additional species into the system. However, this technology evolved by the scientific community, without due consideration to economics and marketing has been completely changed by farmers to develop a new carp culture system with only 2-3 native species of carps that is now giving a yield of even up to 15 tonnes/ha/year (Veerina, Nandeesha and Gopal Rao, 1993; Nandeesha and Ramakrishna, 2005). This has stunned the scientific community in India and has inspired farmers from all over the country to learn from these innovative farmers. While all the innovations of Andhra Pradesh farmers is not possible to be imitated in other parts of the country because of the social, economical, agro-climatic condition variation, farmers in others parts have continued adaptations to evolve systems that would suit their local conditions.

Farmers undertake innovations as a necessity driven by economy to earn the livelihood necessities. Hence, whatever knowledge farmers gain either from researchers or development agents are always tested and verified before integration into their farming operation. Even after integration, farmers continue innovation year after year in order to make sure that operation efficiency of the activity is improved and economic loss does not occur (Reij and Bayers, 2001). This basic principle adopted by farmers has sustained aquaculture activity in many parts of Asia .

This paper presents information on different types of innovations by Asian farmers as well as the role of Asian women in the freshwater fish seed sector.

INNOVATIONS IN SEED PRODUCTION

Although farmers were able to advance the technology for the Indian carp culture, they were dependent on the natural collection of seed from rivers for stocking purpose. As the practice involved not only the collection of desired species of fish but also several other undesired species, farmers of Bankura and Midnapur districts of West Bengal developed a method of fish breeding called the "bundh breeding" to overcome the problem. This technique involved artificial simulation of the natural breeding environment observed in rivers. The technique was successfully applied for breeding of all the Indian major carps as early as in 1882. These techniques of wet bundh and dry bundh breeding provided pure quality seed essential for carp culture; the technique is completely natural and did not involve any hormone treatment.. These techniques are well described by Jhingran (1990) and more recently by Mondal, Mukhopadhyay and Rath (2005). The technique, however, received less importance due to large-scale establishment of carp hatcheries in many parts of West Bengal and other parts of the country. As the quantity of seed obtained through such naturally-induced spawning is reported to be better than other hatchery produced seed, with the growing importance of organic farming, this technique is likely to regain its importance in fish seed production. It should be noted that farmers evolved also the technique for the hatching of eggs in specially prepared small mud ponds plastered with clay soil. This was later improved to evolve the 'hapa-based' hatching system.

Innovations in seed production in Bangladesh, Cambodia and India are described below.

Innovations in seed production and nursing in Bangladesh

Most hatcheries in the private sector of Bangladesh are built and operated using the glass jar hatching principle. Instead of allowing the fish to spawn naturally, farmers identify fish that have come to spawning condition by observing tail movement of fish kept in rectangular cement tanks, which although with shallow water, still provides clear visibility to observe fish movement. Fish exhibiting straight tail movement are considered not yet ready for stripping. However, fishes that show a bend in its tail are considered ready for spawning. Fish in such condition are selected, stripped and fertilized with milt and placed in jars for hatching. Cement jars help carry out hatching operation for small volume of eggs of different species simultaneously and can save water. In some difficult-to-breed fishes like catla, the Chinese hatchery system is used. Seed production is no longer considered as a major constraint in a number of hatcheries established in the country. The "hundi" method of seed transportation still remains as the popular method among farmers.

Common carp breeding by farmers. Small-scale farmers have been successful in producing seed of common carp in their ponds. Mature brood fish of male and female common carp are collected from ponds and are kept for breeding in hapa using water hyacinth as the adhesive agent. Eggs attached to water hyacinth are hatched in cement tanks or small ditches. The ditches are protected from predation by encircling them with plastic or net material. The larvae are fed with egg yolk, wheat flour, cooked rice, etc. until they reach fry stage. At this stage, fry are stocked in paddy fields for further culture. The widespread adoption of this common carp breeding technology by farmers has helped to increase seed availability. Common carp bred during winter season are nursed in paddy fields during the boro season. Those farmers with a facility to continue culture operation during the subsequent season continue to grow fry to market size.

Control of aquatic insects in nurseries. In carp nurseries, aquatic insects (e.g. *Notonecta*) are the major problems that damage the carp spawn. The ditches or paddy fields are heavily loaded with back swimmers. Though various chemical methods are available for the control of insects, farmers are unable to adopt the technologies either because of the cost factor or often such technologies do not resolve the problems. Aquatic insects depend on atmospheric oxygen through their tracheal tube. Preventing insects to come to the surface for drawing air is one of the mechanical ways for the control of insects. Farmers devised a trap box for controlling back-swimmers. The trap box covered with fine mesh net with a size of 10 x 10 ft showed that insects trapped in such a box would die within 30-40 min. The dead insects in turn became a source of good nutrition as they contain high amount of protein.

Gher innovation and nursing of prawn seed. Farmers in the southwestern part of Bangladesh have invented a new method of using rice fields for cultivating both prawns and fish. Farmers invented this method since rice cultivation in such low lying areas was not economically beneficial and was not providing adequate income to meet the family necessities. Hence, some farmers started experimentation of growing prawn in the *gher* which has an elevated embankment with the soil obtained from the trenches dug in the field. The trench covers an area of 30 to 40 percent and rest of the total area and the central portion is left for growing paddy. Stocking prawn seed obtained from the natural collection in the coastal area has not given good results due to poor survival. To overcome this problem, farmers invented a simple method of blocking a portion of the trench creating a pocket *gher* for nursing of prawn seed. After nursing the seed, bundhs are cut to allow larvae to escape into the *gher*. This simple method of improving the larval growth of prawn has resulted in enhancing survival of the prawn seed and increased profitability. Farmers have also evolved a number of artificial food combination for prawn larvae. Nearly 12 different types of feed-making machines have been designed indigenously by farmers and these equipment are widely used by the farming community. These feed makers range from a simple piston-based operation using hollow bamboo to a mechanical pellet making machine. Simple rice noodle-making machine used in houses is modified into fish pellet preparation equipment (Nandeesha, 2003).

Development of breeding technology for *Pangasius*. Farmers have successfully evolved breeding technology for *Pangasius hypophthalmus*. Seed production operation for this species is done efficiently using pituitary gland. The seed produced are nursed in specially prepared nursery ponds. With the present technology, farmers are able to get 30 to 40 percent survival from nursery operation. Successful breeding operation for this species has resulted in the inclusion of this fish into the prevailing culture systems of the country. Egg stickiness is removed successfully by washing with milk.

Acclimation of shrimp to fish water condition. The most successful attempt of farmers is seen in the acclimatization of tiger shrimp seed to freshwater condition and its successful culture under freshwater environment. Although there are controversies with regards to the culture of tiger shrimp in freshwater environment, this activity is likely to be further improved by farmers to make the operation environmental friendly. In Andhra Pradesh in India, several thousands of hectares of water bodies are successfully used for the cultivation of shrimp in the freshwater environment. A similar scenario is likely to occur in Bangladesh, particularly in coastal areas where there is opportunity to have minimal salinity essential to trigger survival and growth.

Innovations of farmers in Cambodia

Small-scale aquaculture is expanding gradually in Camboida to meet the growing need for fish. Seed availability has been one of the major constraints encountered throughout the country for the sustenance and expansion of the small-scale aquaculture activity. Establishment of the Chinese hatchery systems in the capital city Phnom Penh and in some provinces, helped to create large centrally-operated seed production facilities and stimulate aquaculture development. However, as the activity begun to gain acceptance with farmers, seed availability became a major issue. Hence, some of the progressive farmers were encouraged to undertake seed nursing operation in different areas and they were provided with the fry for nursing operation and further distribution to other farmers. With the experience and profitability gained from the nursing activity, some of these farmers initiated seed production of some of the easy-to-breed species like common carp, silver barb and tilapia. Innovations made by farmers in nursing and later in seed production activities have demonstrated the inventive potential of farmers (Nandeesha, 2002).

Breeding common carp. A farmer had developed cement water jars which are placed at an elevated height for water storage and to create gravity flow that will induce common carp to spawn. Bamboos are used as protective material; polythene sheets are laid to store water and for use as spawning place for fish. Recognizing the interest of this farmer, he was given small support to build a circular breeding pool. He was able to build such a simple facility and even provided PVC pipes to provide a sprinkler effect. This circular tank (3 m diameter and 1/3 m of height) served both as breeding and hatching chamber for common carp, silver barb and even silver carp. This facility served as an example to show other farmers how simple breeding facilities can be built on the farm. Many other farmers were inspired because of the simplicity of the structure and the potential profitability that could be obtained.

An officer of the Mennonite Central Committee (MCC) with an agriculture background came in contact with the Central Seed Production Centre which promoted the new concepts in pond design supported by the family food programme. With the successful effort made by the MCC to alter the design of the ponds to suit fish culture activity, large number of farmers initiated seed production. Hence the organization went one step further to help a farmer who had served as a local resource person to promote fish culture to initiate fish seed production. The farmer was able to build the smaller versions of the Chinese hatchery model and was able to produce seed of silver barb, silver carp, common carp using the revised technology. Tilapia seed production was undertaken using the pond breeding method. Another farmer, in area of PADEK project, built a small-scale hatchery using the principle of shallow water tube well pumps. Since the pump required a lot of energy to generate water, an overhead tank with cement rings was built which successfully generated water using a diesel pump. This farmer was highly successful in producing seed of various species including silver carp and supplied seed to other farmers for nursing activity. With further increase demand for seed, there are already other farmers who have established further improved version of the hatchery, to exploit the market opportunity. The European Union (EU)-funded project in some of the provinces of Cambodia, promoted fish culture as an important activity. Some of the EU-sponsored trainees in centralized seed production facility have successfully improved hatchery technology suitable for the production of commonly cultivated fish species. Modification design of hatchery units established have been successfully used for the breeding of common carp, silver carp, silver barb, etc.

Bamboo-based Chinese hatchery and Chinese hatchery through earth excavation. The use of bamboo for the construction of breeding *cum* hatching pool is another successful innovation attempted by the farmer in the AIT-supported project area. A second interesting farmer innovation is the building of Chinese hatcheries through excavating earth and covering the excavated area with polyethythene sheet. The inner chamber was built by bamboo frame and was covered with net material. This farmer used his knowledge to preserve the prepared hormone solution by simply lowering the bottle filled with hormone to the bottom of the pond. All these farmer innovations have helped in providing the required seed. In addition to this, techniques have been adapted by farmers for production of tilapia seed and nursing of seed in ponds. Women are active participants in tilapia seed production and nursing of various species of carps.

Innovations in fish seed nursing operation. In nursing of fish, a number of innovative approaches have been successfully used by the farmers using locally available feed resources. Larvae stocked in the nursery pond are fed with local ingredients such as rice bran, soybean, dry fish that are mixed/cooked. For brood fish, various types of naturally available feed resources such as lemna, Azolla, termites are used. Household waste combined with rice wine waste are also commonly used as feed to pond-grown brood fish.

Innovations by Farmers of Andhra Pradesh, India

Pond construction. The area around Kolluru Lake in East Godavari District is known as the rice bowl of India producing good quality rice. The increasing cost of cultivation of paddy, coupled with recurrent floods and droughts have made the paddy cultivation uneconomical. In search of alternatives to paddy crop, agriculture farmers initiated carp culture activity by transforming paddy fields into fish ponds by employing the trench method of pond construction. In this method of pond construction, trenches around the paddy field are dug to a depth of 0.5 m with a breadth ranging from 5 to 20 m all around the paddy field. The soil excavated from the trench is used for the construction of bundh. Ponds varying in sizes from 0.5 ha to as big as 100 ha are built with the application of this simple technology which has reduced the cost of construction and provided the possibility of returning to agriculture activity in case fish culture proves to be uneconomical. Farmers achieved enormous success in the culture of Indian carps, particularly rohu, as the dominant species in the culture system. In the early stages, farmers were importing seed from West Bengal. Innovative farmers quickly adopted the Chinese hatchery technology for carp breeding which resulted not only to self-sufficiency in terms of seed requirement within the state, but enabled the state to become an important source of seed for other states.

Broodstock management. Unlike the belief promoted that the broodstock of fish need to be reared with special care to bring them to maturity, farmers in this state use the brood fish obtained from the normal culture operation since they believe that every organism will come to maturity in the life cycle when its basic necessities are met. Most farmers in Andhra Pradesh use stunted seed, aged 6-12 months, for culture. Such aged seed attain maturity during the second year of culture operation onwards. Fish seed producers obtain broodstock required for the farm activity directly from farmers and save huge cost involved in broodstock rearing. This has helped farmers to select from large numbers of fish and this appeared, to a great degree, to have eliminated the problem of inbreeding observed in several other states with the limited number of brood fish maintained in the farm.

Breeding innovation. Farmers in Andhra Pradesh have modified the Chinese hatchery technology to some degree to suit their convenience. There is no separate breeding chamber. Most farmers use the hatching chamber itself for breeding fish and once the breeding is completed, eggs are collected and distributed to different incubation units for hatching purposes. This has reduced the cost of construction involved in building the breeding chamber (six to seven m in diameter) as well as the huge volume of water required for the operation of such large breeding chamber. This is expected to save at least 30 percent on the cost of construction of hatchery.

Identification of maturity status. Some experienced farmers have developed the "touch technology" method to ascertain the suitability of fish for breeding purposes; it involves touching the abdomen of the fish to indicate the condition of the breeder. Farmers use this technology when purchasing breeders from the growers. Since farmers breed several sets of fish daily, this touch technology has been very helpful in deciding the suitability of the breeder. Almost 100 percent of the fish selected by the use of this touch technology has given almost 100 percent breeding response.

Substitute to pituitary. As an alternative to the unstable supply of quality pituitary glands, farmers have searched various other drugs that are used in the field of human medicine. Although ovaprim, a compound manufactured using "Limpe" method with a sound scientific basis, farmers have been finding it difficult to use this drug due to its high cost. The technology used by farmers in southeast Asia of combining LHRH analogues with dopamine antagonist has been successfully employed by some enterprising farmers. It was learned that the cost of production is reduced by almost 40 percent, without any loss in breeding efficiency. Although the "Limpe" method used the sGNRH to have the best effect, carps farmers are happy with the results obtained with mammalian LHRH combined with Domperidone. This clearly indicates that laboratory results need to be verified under practical field conditions and the choice to choose the best should be left to farmers.

Innovations in nursing technology. The scientific community believed that small ponds of less than 500 m^2 are the best size for nursery management and medium-size ponds of less than one ha are good for growing market size fish. Farmers in Andhra Pradesh have found more than 500 m^2 ponds as good for nursery and for grow-out ponds. The larger the size of pond, the better is the growth of fish and as a result grow-out ponds are more than one ha. The nursery pond preparation technology has been developed by farmers to get the best economic returns. Lime application continues to be one of the key factors before the initiation of seed nursing and it is applied at the rate of 300-500 kg/ha. Cattle manure is applied in combination with ground cake, mixed using a ratio of 7:3 at a dose of 4 000 kg/ha. The manure cake is mixed with 300 kg of mono-super-phosphate and it is kept in wet condition on pond embankments. Two to three days prior to stocking, this composted manure is applied to the pond. This organic mixture combined with phosphorous is known to provide a rich plankton bloom for the stocked seed. Farmers remove fibrous materials from the manure by sieving and squeezing the entire fermented manure with a cloth. Spawn are stocked at 4 to 6 million/ha. The seed are fed daily with rice-bran and oil cake mixture using a ratio of 1:1. It is reported that farmers were able to get 40 to 50 percent survival by using this technology. The nursing operation is continued for about one month and the nursed seed are sold to other farmers for stunting purpose.

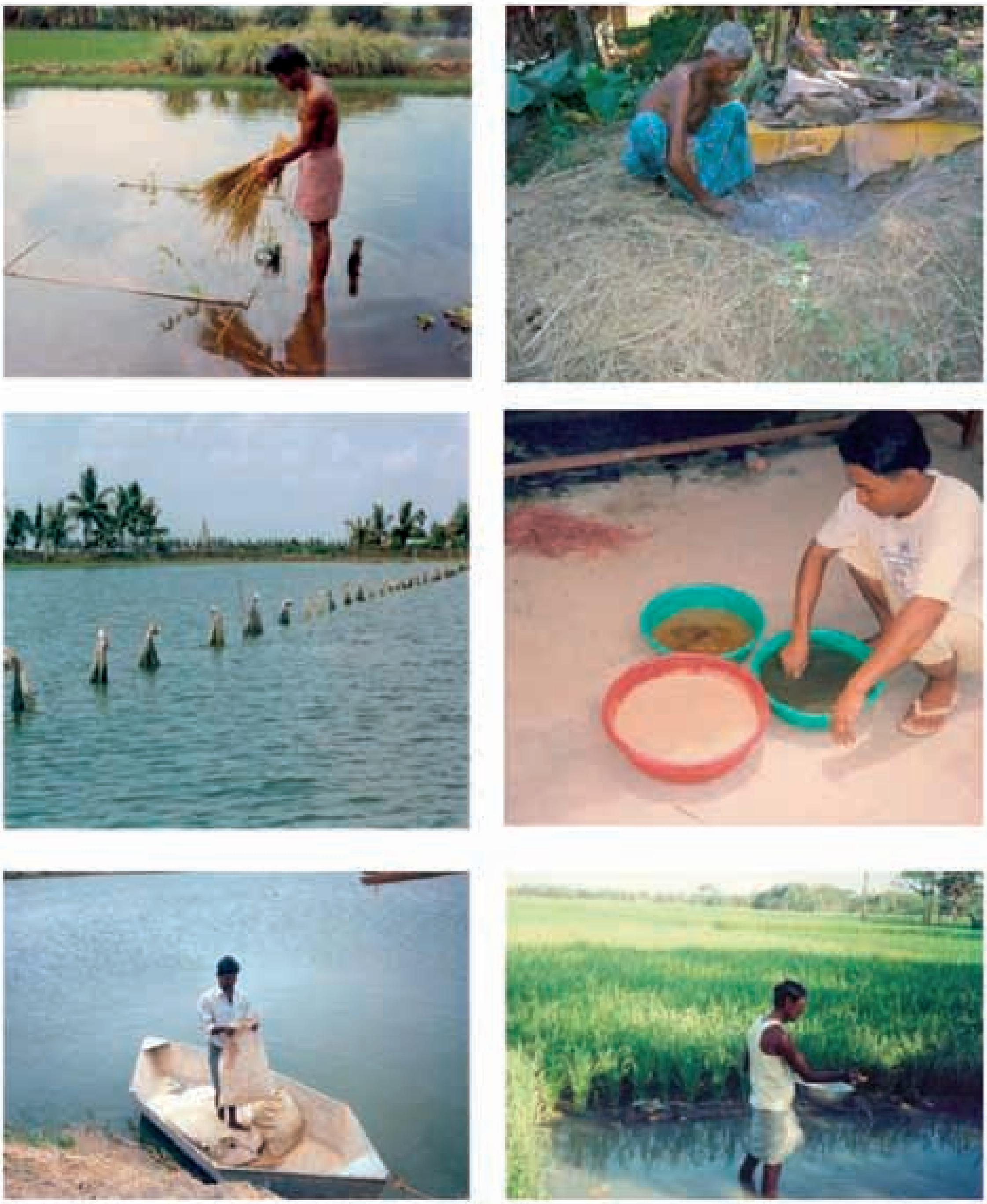
Innovation of stunted fish technology. Carps are known to grow rapidly during the second year of their age. Recognizing this basic growth pattern, farmers have developed a technology to supply stunted fish seed that are aged, but have not yet attained full growth potential. For purposes of stunting, farmers stock the seed at 25 000 to 100 000/ha and feed them with minimal amount of feed, i.e. good enough for their survival. The stocking density used is also based on the final growth desired for stocking in grow-out ponds. For example, at lower stocking density, fish would attain a weight of 100-150 g, but at higher stocking density, fish would reach about 25-50 g. In addition, ponds are fertilized to maintain the green water condition. Seed are stunted for a period ranging from 6 to 12 months. During this period of stunting, weak and unhealthy seed are also eliminated from the system. Healthy seed which survive the stunting process are used for culture purpose. Based on the intensity of stocking and level of feeding adopted, the weight of the fish attained would vary. Such stunted seed when stocked in the culture pond would compensate for the growth lost during the stunting period and attain a weight of one kg. Most importantly, the survival of such stunted fish is almost 100 percent, except for mortalities due to other environmental conditions. This technology of stunting fish seed developed by farmers is considered as one of the most important practical solutions found by farmers to address the problems related to fish growth and yield. As stated earlier, farmers are now able to obtain, most commonly an average yield of 8 tonnes/ha and some of the progressive farmers obtain a yield of more than 15 tonnes/ha/year.

Seed transportation. Farmers have begun to use large PVC containers of 2 000 to 3 000 l capacity for transportation of seed. Tanks placed on trucks are filled with water and the conditioned fish seed are stocked in the tank. These tanks are connected with oxygen supply from the cylinder placed on the truck. Using this method, farmers are able to transport the seed over long distances without any mortality problem.

Feeding methodology innovation. The size of ponds used by farmers is generally large in Andhra Pradesh. Because of this, the broadcast method of feeding resulted in huge wastage of feed and poor growth of fish. To overcome this problem, farmers have developed a simple and effective technique of feeding fish through "feed bags".Chemical fertilizer bags made of polyethylene with a capacity of 20-30 kg are commonly used for making feed bags. Small holes at the bottom of feed bags arranged in 2-3 rows are made. Feeding bags are filled with rice-bran and oil cake mixture and tied to bamboo poles and fixed in the ponds. Fish feed through the holes and the feed is generally exhausted in less than two hrs time after suspension. This simple, practical and economic method of feeding developed by farmers had helped in many ways. Firstly, the technique has reduced feed wastage drastically and almost all the feeds kept in the bag are consumed directly by fish. Secondly, feed bags are an excellent indicator to assess the health and growth of the fish. If the feeds provided in the bag is not exhausted within the given period of time, immediately farmers suspect for problems with health and/or water quality. Thirdly, for treating fish in such large culture ponds, the bag method of feeding has given a very effective pathway. Farmers use various drugs to feed fish through feed and for external treatment, containers filled with chemicals and having perforations are tied close to feed bags. Dissolutions of chemicals into the water provide an opportunity for treating fish infected with disease.

Growth promotion. Farmers in Andhra Pradesh incorporate salt along with feeds to improve the growth of fish. It is reported that incorporation of salt is done at levels

PLATE 8.5.1
Farmer innovations in Asian aquaculture



ranging from 0.5 to 2 percent along with the feed. This technology of using salt for growth promotion is widely known in many parts of Asia since salt is known to be an essential component for physiological activity. Research results carried out by the scientific community to ascertain the value of this practice of farmers has shown that it is possible to improve the growth of carps by incorporating the salt at 0.5 to 2 percent for different species (Gangadhara *et al.*, 2004).

Innovation of farmers in eastern India

Ash, as a substitute to lime. Lime is an essential requirement to promote the healthy growth of fish. However, lime is not easily accessible to all farmers. Due to the cost as

PLATE 8.5.2
Farmer innovations in Asian aquaculture

well as non-availability of lime in remote areas, farmers have begun to use ash produced from banana stem as a substitute to lime. Banana stem with an alkaline condition is known to improve water quality similar to lime. This practical technology has become helpful to farmers to solve the problem of lime availability in rural areas. In addition, ash produced in the family through burning of wood materials for cooking purpose is also used for aquaculture.

Removal of stickiness of eggs. The eggs of catfish are sticky in nature. Farmers have found solution to this problem by using milk to remove such stickiness. The eggs are thoroughly washed with milk and resulted to complete removal of egg stickiness.

Mixing of milk with water during transportation. When carp seed are carried in *hundi,* mortality is known to occur due to high temperature. Farmers have found a solution to this problem by using milk with water. It is believed that milk brings down the temperature and also provides nutrition to the fish during the course of transportation, besides preventing fish from the direct exposure to sunrays.

Hatching technology innovations. Farmers have not only used the technique of Chinese hatchery technology to improve seed production; they have also modified the glass jar technology for building large cement jars that help to hatch small amount of eggs. Cement jars constructed almost like glass jars are used for hatching eggs by ensuring adequate supply of water to keep the eggs under constant motion until hatching and post-hatching to keep the yolk-laden spawn under constant movement. This simple adoption of glass jar principles has helped the hatcheries to produce seed of different species simultaneously.

Innovation in broodstock management. Brood fish are fed with feeds containing additives like molasses and eggs known to improve the quality by providing some of the essential nutrients. In addition, farmers also balance the feed given to fish with such ingredients that will have good amount of protein and provide other essential nutrients.

Seed nursing. The spawn are stocked in nursery ponds prepared with the application of organic manures with oil cakes. Inorganic fertilizers are generally avoided. Seed stocked in such ponds and fed regularly with locally available feed ingredients like rice-bran and oil cake have a survival rate between 60 to 70 percent. These seed are sold to traders who transport them to distant places in *hundies*.

Stimulating and recognizing farmer innovations

There are many ways by which innovations of farmers or groups can be recognized. One of the best methods that have been found in Bangladesh is to provide a platform for farmers to share their observations with other farmers. Organization of farmer science congress at the district level wherein innovative farmers could share their innovation with other farmers and scientific community boosted their morale and built confidence. Many of the scientists from agricultural universities and development personnel from various organizations reacted negatively on organizing such farmer science congress. However, after witnessing the event and observing the enormous interest of farmers and the impact it created on the community, several such scientists endorsed that it is a worthy idea to promote such events on a regular basis. Unfortunately, such events are organized sporadically as part of projects and they are discontinued once the project phase is completed. It is necessary that national policies are developed to acknowledge, respect and recognize farmers' innovations equally like those for scientists. In Indonesia, such farmer events to discuss and debate on innovations are held regularly with the participation of the action research centers that are established in different parts of the country.

There are some good examples available from the agriculture sector like the integrated pest management (IPM) and the Honey Bee Network created to recognize farmer innovation. There are also special awards introduced in some countries including India where farmers are recognized for their innovation in farming activities. However, such programmes are not the regular part of the existing activities of many departments, since it is believed that farmers are takers of knowledge and not the creators of knowledge. If the change in perception is brought at various levels starting from policy formulators down to project implementors at the ground level, it is possible to begin recognizing farmers for their innovation. Such policy shifts would help farmers also to be more responsible and scientific in their approach in carrying out farming activities. In India, in recognition of the successful fish breeding accomplishment made on the 10th of July 1957, this date has been declared as the "Fish Farmers Day" and it is celebrated throughout the country. On all these occasions, Fishing Chimes, a magazine dedicated for the development of fisheries in the country has instituted an award for innovative farmers. For the past three years, this award has been given to farmers who have made a difference not only to their lives but also to the lives of other farmers. Several fisheries institutions also celebrate the "Fish Farmers Day" and innovative farmers of the area are honored. However, the idea is yet to be integrated strongly into the system. More recently, the professional fisheries graduate forum of India has taken a lead to create interest among fisheries graduates by organizing essay competition on farmers' innovations. Such competition has evoked reasonably good response and has inspired some of students to carry out study in this emerging area. The organization has also initiated another national level competition to recognize farmer innovation by involving farmers, scientists, students, etc. It is hoped that in the coming days, this activity can become part of the major activity at the Asian level to stimulate similar interest in other countries. It is also interesting to note that organizations like FAO through IPM, World Bank through CGIAR system, and NACA have been promoting the need for documenting farmer innovations and also promote actively innovations by farmers. Such support by established institutions will have good impact and would result in a major gradual shift in the thinking process of research and developmental organizations in Asia. The Asian Fisheries Society which has been created largely as a forum for professional scientists to drive research in Asia has good opportunity to initiate programmes in the area of farmers innovations and help in making this new activity as a common agenda in its activities.

WOMEN IN SEED NURSING

Overall, the participation of women in aquaculture sector is limited globally. Women involvement in seed production is reported only from a few places, but their role in nursery rearing is more visible in many countries due to the common perception of women's maternal instinct. Described below are experiences of women involvement in the freshwater seed production sector in Bangladesh, Cambodia, China, Indonesia, India, Malaysia, Nepal, the Philippines, Sri Lanka, Thailand and Viet Nam.

Bangladesh. In Bangladesh, several NGOs are active in the area of aquaculture and fisheries. Some of the larger NGOs like CARE, PROSHIKHA, BRAC, CARITAS, etc. have initiated a number of women-centered aquaculture activities. Women have played an excellent role in influencing men to give up usage of pesticides and to undertake fish cultivation in rice fields. Farmers have developed a simple technique of placing water hyacinth roots attached with eggs in paddy fields and allow them to hatch and feed on food available in the system. This technique was found to be economically viable even with a survival rate of only 3-5 percent. In case of cage culture, women groups were more involved in nursing fish in cages using various types of waste materials. Women generally tend to place higher priority on family nutrition than selling all fish for cash. Women in Bangladesh actively participated in small-scale fisheries sector. About 30 percent of women in rural areas were engaged directly or indirectly in fisheries activities, while 10-12 percent women were employed in the aquaculture sector (Siason, 2001).

CARE had experienced that in training sessions, men dominate the discussion. Women's views or needs are often overlooked as the staff are also men. So it is important that extension workers design training and follow-up activities with careful consideration of both information needs of the women as well as learning styles. Women's lack of familiarity with formal learning environments and their lower level of literacy can result to their particular learning needs and requirements being overlooked. Based on this experience the organization is tackling issues through a three-tiered approach by:

- having specific goals for the participation of women as stated in project's frameworks;
- using extension approaches and promoting interventions that will facilitate increased benefits to women in agriculture and aquaculture systems; and
- promoting staff development activities that result in a gender-sensitive organization.

In CARE projects, it has been observed that female groups are more difficult to form in conservative areas, though women want to work, in-laws and husbands do not always support the ideas of women. In such areas, raising community awareness and the provision of longer-term support to female groups helped in the active participation of women in aquaculture activities as the project progressed. It was found that movement of women was restricted to cage culture in the homestead territory or fish culture or seed nursing around homestead area. After the seed is produced and stocked in ponds or cages, women take an active role in nursing operation. The seed production of common carp is usually undertaken within the premises of the house and women were found to be more efficient than men in undertaking this activity. Most impressive progress in terms of common carp seed production and nursing was undertaken by women groups. Once the group formation has been completed and the healthy relationship were established within the group, women group take a pro-active role in disseminating knowledge and skills earned through various activities that included seed production, nursing, vegetable cultivation, etc.

It was also observed that after joining the learning session and utilizing their skill in aquaculture, women used most of their income from sale of fish seed or fish to meet the family needs particularly children. The activities helped them to develop confidence and have greater influence with regard to decision-making on children's education as they were able to contribute in cash towards school fees and other educational requirements. A large portion of the cultured fish often was used for family consumption. Women felt that having a rice-fish plot, cage or pond makes it easier to fulfill social obligations of entertaining guests in the family. Many women feel that their social status and status within their family changed dramatically by undertaking additional income generating activity like seed nursing (Debashish *et. al*., 1998)

In Bangladesh, there is a growing recognition of the capability and potentiality of women due to the efforts of a number of organizations. CARITAS has organized a total of 18 269 beneficiaries including 47 percent women. However, their role in seed production has not been identified clearly, though it was reported that women were involved in raising common carp seed in rice fields (Shelly and Costa, 2001). It was further reported by them that 43 percent of the total beneficiaries engaged in pond aquaculture in CARITAS were women and they did almost all the activities that were done by men like earth-cutting, pond preparation, feeding and fertilizing, accounts keeping, decision-making on marketing, etc. Involvement of women in aquaculture activity enhanced women status both in the family as well as in the society. The living standards have improved and the beneficiaries were able to send their children to schools as they were able to cover educational expenses of children. The women groups in particular, have demonstrated a strong bond and unity as well as commitment towards their quest for self-development through aquaculture.

Cambodia. Goddard *et al*. (1994) reported that Cambodian women had an active involvement in all aspects of integrated aquaculture. In an assessment of the farm activity, it was indicated that women contributed to 31 percent of total activity, whereas 55 percent of the work was carried out by men and 14 percent by children. Women were found to actively participate in feeding and marketing of fish.

A study conducted by Hatha, Narath and Gegory (1994) on the roles and the responsibilities of women and children in small-scale aquaculture, indicated that involvement of women increased with the fish production cycle. It was also reported that women-managed ponds yielded better result as compared to man-managed ponds.

Nandeesha (1994) reported the role of women in small-scale aquaculture in Cambodia. It was observed that a low level of production was obtained (20kg/100m²/eight months) in ponds, where involvement of women was poor. Nearly 45 percent of families obtained high production of (20-40kg/100m²/eight months) with the active involvement of women. Women are actively involved in nursing of *Pangasius* seed. This is a major activity that brings a lot of economic benefits.

Following the success of small-scale aquaculture, women are engaged actively in seed production of common carp, Nile tilapia and silver barb. Women are the most active participants in production and nursing. Much of the success in seed production through small-scale hatcheries was due to the active involvement of women. Some women have undertaken tilapia seed production by daily collection of seed using scoop net and nursing them in ponds and selling to other farmers (Nandeesha, 2004).

China. Rural aquaculture in China is reported to have been carried out by all members in the family. Kelkar (2001) reported that women are active particularly in seed production, seed collection, rearing and stocking. Song (1999) indicated that among the 7 878 workers employed in the seed propagation units, 26.8 percent were women. Zhonghua (2001) presented an interesting account of pond fish farming and gender roles in Yunnan Province of China. The women contribution to fish culture and the improvement in decision making power of women was observed with the introduction of fish culture. Although women had to do several hrs of work in terms of cutting grass, women considered fish culture as an activity that brings benefits to them. Also, how illiterate women learn all activities from their husbands who were able to attend the training is an interesting aspect. Certainly there are many more aspects of women involvement in aquaculture seed production and nursing activity that need to be yet documented. It is also reported that in Taiwan, Province of China, women are actively engaged in various aquaculture activities and there are also many innovations done by women. However, published information on such participation is not available.

India. Women are actively involved in subsistence aquaculture in India, taking care of fish after stocking. However, these women are not targeted for training and empowerment because of the lack of focus on women coupled with cultural and social constraints that prevent women participation in such activities. Women are active participants in fish seed collection from the riverine environment; this activity is no longer a major event since farmers are able to get seed from the hatchery production.

Jena *et al.* (1998) reported that small seasonal backyard kitchen ponds (0.05-0.2 ha) used for carp seed raised by tribal women in Orissa could enhance the economic status of women when managed properly. The result of such activity showed that survival of 45.5-55 percent for catla, 53 percent for mixed rearing of catla, rohu and mrigal were obtained. The project demonstrated the potential of fish seed nursing as an income generating activity for the women.

Ghosh, Mahapatra and Datta (2003) have presented an account of women involvement in the ornamental fish industry in West Bengal. Most of the ornamental fish farmers are based in and around Kolkata. Men are generally involved in seed production and marketing, while women and children carry out feeding, daily change of water, etc. Women are also involved in collection of different types of live feeds from sewage canal and other derelict water bodies for selling to farmers. This provides a good part-time job for extra income.

PLATE 8.5.3
Women involvement in the freshwater fish seed sector

The involvement of women in aquaculture is restricted to certain activities such as the collection of wild seed; men often consider aquaculture as an activity that could not be entrusted to women. In poor families, women were allowed to work in the field but such poor families do not own fish ponds. In the northeastern region of the country, women are actively involved in various field activities; in Manipur, women are engaged in fish seed nursing activity (Gurumayum, Aruna and Nandeesha, 2004). 'Self Help Group' (SHG) is one important social developments witnessed in India and it has been found to be a powerful tool to empower women by helping them to undertake agriculture practices including aquaculture using credit facilities. A number of women SHGs are engaged in aquaculture activity with seed nursing as an important component that is benefiting women (Ray and Pathak, 1998).

PLATE 8.5.4
Women in involvement in the freshwater fish seed production sector

Mohanty and Jena (1996) reported on women participation in Orissa, identified their constraints and presented a plan to overcome these constraints. They reported that a social dogma persisted among women as they thought fish seed production is highly complex and a fear of psychosis disabled them to participate in this activity.

Das (1997) identified that matrilineal society of kinship among the Khashi community in Meghalaya presents a different scenario of women in the society as compared to other parts of the country where patriarchal system is prevalent. Women in this community are actively engaged in a variety of activities. Women are involved in all aspects of livelihood activities; fish culture activity is initiated recently in Meghalya State.

Goswami and Ojha (1997) reported on the role of women in Assam in fisheries and a few cases of women involvement in seed rearing and nursery rearing of carps. Women in rural areas, lacking employment and with low literacy rate, have received funding assistance to undertake such income generation activity. It was also reported that small-sized ponds (100-1 000 m^2) were managed by women easily as they could fertilize them with cattle dung and feed fish with kitchen waste. Backyard ponds of 200 m^2 were suitable for women to undertake seed nursing during the short period of time. In Assam, women are allowed to weave gill nets, work in dry fish industry, make baskets used for fresh fish transportation, sell fish door to door. All such activities are done by women in the lower economic strata of the society to meet their livelihood necessities.

Radheshyam (1999) initiated a program of IVLP (Institute Village Link Programme) under CIFA (Central Institute of Freshwater Aquaculture). In this program, women were particularly targeted to undertake common carp breeding. Women in this village carried out the activity very efficiently by being involved in all stages of operation from collection of brood fish, breeder maintenance, egg hatching and seed nursing. Through this programme, women demonstrated that if a supportive environment is provided, seed production activity can be easily undertaken by women.

Indonesia. Indonesian women have higher participation in society because of low cultural and religious restrictions (Brugere, 2001). Indonesian aquaculture which is dominantly small-scale and household-operated (78 percent of household operated farms have less than 0.5 ha) (Purwanto, 1999) highlights the importance of the system. It is also reported that families derive the best economic benefits from aquaculture in this country, though gender-based information on such benefits are not available. Although women participation is high in aquaculture activity, whether the position of women in the family has improved or not because of this activity is not known. It is reported that women are the major participants of fish seed production, nursing and culture in Indonesia. The study carried out by Brugere (2001) had shown that women need training in entrepreneurship and it was recommended to create successful models of women running aquaculture enterprises.

Malaysia. Freshwater aquaculture is relatively a small size industry, contributing about 25 percent of the total national production. The system is dominated by the following species: tilapia, eel, Chinese and Indian carps, ornamentals, catfish and freshwater prawn; aquaculture of many of these species is carried out at an industrial or commercial scale. It was reported that women's participation in aquaculture activity is very limited due to complex cultural, social and traditional factors. However, women are involved in small-scale, family-based aquaculture activities. Although there are many challenges facing women's active involvement in aquaculture, Jahara (1998) reported that women can be encouraged to participate in small-scale aquaculture within their homestead and which can be easily integrated with other household activities, thus increasing their participation in aquaculture.

Within the Chinese community, women are seen to be involved in the ornamental fish industry and in the fish seed producer group. Detailed information on the extent of their involvement in the activity is not known. Engle (1987) has suggested that a specialized gender training to suit women's conditions and needs be undertaken.

Brugere (2001) reported that fattening of Javanese carp and tilapia in cages showed an indirect opportunity for women's participation. About 20 percent of women are wives of farmers with many cages. In Malaysia, women's control over budget and finances were very limited including their decision making powers; thus, women's roles are confined to traditional reproductive and productive role in the houses. Patriarchal societal structures of both Indonesia and Malaysia restricted women to involve in aquaculture (Brugere, 2001). Development interventions should therefore focus on challenging the existing societal structures even as they try to empower women through participation in income generating activities.

Nepal. In Nepal, aquaculture in the plain region of the country is fast expanding with indigenous carps while in the colder regions apart from tolerant carps, coldwater species like mahseers are promoted. Focus on women in seed production and nursing is yet to be undertaken.

Philippines. Out of one million people working in the fishery industry, 26 percent are reported to be involved in aquaculture. The 1980 comprehensive census did not promote gender-disaggregate data of the 221 492 Filipinos employed in aquaculture (Yap, 1999). Government policies on aquaculture are gender-neutral and do not specifically address women's issues. Much of the women's work is officially unrecognized, unvalued, or underpaid. Women are heavily involved in fry collection, feed preparation, feeding of stocks and disposal of catch in communities which earn incomes from fish cages or fish pens. In Taal Lake, more women are involved in fish feeding than men. Extension work in aquaculture targets only men and a cultural perception that "aquaculture is a masculine job" exist in the community. Men have greater and easier access to credit and women are not assertive and confident enough to seek bank-managed credit. Women have less access to training. There are also some social factors that are responsible for less involvement of women in aquaculture. Shrimp or milkfish farms normally require living on site and this on farm activities makes it less attractive to women. The introduction of labour-saving technologies in farming has reduced the demand for women's labour. In rural areas, alcohol abuse by men and domestic violence are common. Religious concerns are also responsible for women's passive participation in aquaculture._Freshwater fish ponds and cages in larger inland water bodies are controlled by families and though many women are shown as owners, activities are still largely controlled by men and few families (Recide, 1999). Siason (2001) reported poor access to credit as one of the reasons for women not being able to derive benefits from aquaculture. Women's participation in income-generating activities and other development tasks are constrained by the multiple burdens of the reproductive role assigned to them. Unless provisions are made to lighten household responsibilities, such as equitable sharing of tasks with the spouse and children, or by providing community child care arrangements, sustained participation of women will not be realized.

Rabanal (1998) reviewed the 100-year history of the Philippine aquaculture and fisheries and indicated that men dominate both the public and private sectors. It is important to note that in families that earn income from cages/pens, women are heavily engaged in fry collection, feed preparation, feeding of stocks and disposal of catch. In rural areas, women are reported to be active in pond aquaculture operation, though quantified data is not available. Felsing and Baticados (2001) suggested that because of the social structure prevailing in the society, women's control over aquaculture production in the Philippines is unlikely to increase considerably in the near future.

Sri Lanka. In the ornamental fish industry, particularly involving freshwater fish species, women are reported to be actively involved in breeding and nursing activities. Income generated has helped in the improvement of women position within the family (S. Siriwardena, pers. comm.). Aquaculture is not yet a major activity, though some of the organizations have made efforts to promote this activity as a sustainable system.

Thailand. In Thailand, women are involved in various aquaculture activities, including purchase of fingerlings. Marketing is solely a women-dominated actively, while men are responsible for harvesting of fish. Feeding and maintenance of ponds are the activities carried out with the participation of both men and women (Kelkar, 2001). In a study carried out by Suntonratana (2001), it was shown that women are important in the aquaculture sector of Thailand with many men migrating to city for better income, leaving behind women to take care of farm activities. According to the study, while trainers are not gender sensitive to take care of the women necessities, other information media like television, radio, newspapers, technical bulletin, etc. also do not provide benefits to women, either because of their busy schedule or because of the highly technical nature of the information provided. These issues need to be considered carefully when addressing gender issues. It was also shown that men have better access to training and credit because of the other family commitment of women. Like in other areas, women are active in caring the pond after stocking. The need for gender-sensitive policies and generation of gender-disaggregated data are essential in obtaining better information not only on participation, but other related issues such as reasons for participation or non-participation, development of women friendly technologies, long-term implication of the aquaculture policy on gender relations, etc. In another interesting study carried out on women's access to information on aquaculture technology in Thailand, it was shown that it is necessary to increase the interaction of women with others to enable them to have better access to information. However, mobility is another major factor that limits access to quality knowledge and information. Mobile phones appear to play an important role in information exchange in a country like Thailand wherein more than 77.1 percent of the respondents possessing mobile phones indicated the usage of mobile phones for aquaculture purposes. It was further observed that involvement of women in various activities declines as the activity becomes more technical. In hatchery operation, only 13.3 percent of the women respondents were found to make plans by themselves, while 70 percent of the activity was planned by men. Kusakabe (2001) has further shown that as intensification of the activity increased, women's role in aquaculture declined. This is an important issue to be considered to ensure exclusion of women with the anticipated intensification that is likely to occur to all species in various ways. Planners have to take note of this issue and the activities should be designed in such a manner that will meet the necessities of women so as not to exclude them as a result of the intensification process by addressing the issues of access to information as well as mobility.

Viet Nam. In Viet Nam, seed nursing is the activity wherein active involvement of women could be seen as women feel that it is a simple task that they can managed. Minh, Huong and Tuan (1997) reported that the large amount of the family income was earned by women by undertaking seed nursing activity. Women were involved in all activities that included pond preparation, buying fingerlings, feeding, managing fish health and marketing. As ponds are within the homestead area of the house, it has become an attractive income generating activity for women. Although seed nursing added additional work hrs to women, the income earned enabled them to feel that the work is worthwhile.

Voetan and Ottens (1997) presented an account of the gender roles in the VAC system of integrated farming including aquaculture. Though women are responsible for carrying most of the activities of aquaculture, men play the role in buying seed and stocking the pond since men are assumed to have better knowledge on seed quality. After stocking, it is the women who play the critical role in pond management. However, with the harvest of fish, it is the men who get the income from sale of fish to be utilized for various activities.

Increasing women participation in fish seed production and nursing

In ornamental fish seed production, women involvement is higher in many countries. It is believed that as the technique of production of most aquarium fish does not involve hormone application, it appears to have become popular with women. While women are actively involved in common carp breeding and nursing, tilapia seed collection and nursing, whenever any hormonal injection treatment is involved, women appears to be excluded. Necessary training on induced spawning should be provided to women to encourage their participation in this activity.

In seed nursing, women are active participants in many parts of Asia though their visibility is not high. However, in view of their motherly nature, women are always considered as best suited for the job of nursing. It is the change in attitude that has to be brought to involve more women in seed production and nursing activities and enable them to derive the maximum economic benefits from the activity. Once the women are able to see the economic benefits of such activities, the sustainability for the programme will be high. All scientific conferences that have been held so far beginning with the first workshop on Women in Aquaculture in 1987 by FAO until the last Global Symposium on Gender in Fisheries in November 2004 have identified two prominent areas to enhance women participation in aquaculture. These are: (1) training by ensuring clearly defined target number and (2) provision of credit facility to enable women to initiate the activity.

Many scientific events held thus far have emphasized mainstreaming of gender and brought gender awareness. While this is a good start, much needs to be accomplished. Gender sensitization programme should be considered a priority as this will greatly help in gradually mainstreaming gender in various activities of the organization.

With regards to provision of credit, the success of self-help groups (SHG) in different parts of Asia had encouraged many Asian governments to initiate such activity with a focus on women. Since money is involved and some of the basic principles of SHG are sometimes compromised, there have been more failures than successes in government-operated programs. It is therefore necessary that early steps are taken to prevent the loss of opportunities on the enormous potential of this concept in transforming the lives of women.

CONCLUSIONS

The study demonstrates that farmers have been actively engaged in innovations in the field of aquaculture. In fact, farmers do not adopt any technology without innovations to best suit their farming conditions. This may be called as an adaptive research by farmers. There are also farmers who are willing to undertake risk to innovate using new ideas that have completely transformed the aquaculture scenario in many parts of the Asian region. The lessons learnt indicate the need for building a database on farmer innovation. Regional organizations like NACA should undertake such an activity and promote sharing of information through the magazine and via the internet. Reporting of farmer innovations may also be mandatory. In the Asian region, there is a need to recognize farmers' innovation and bring them as partners in policy formulation and identification of research strategies. In the area of human resource development, it is essential that training programs consider gender issues, identify the needs of women and encourage their participation in seed production activities. As a long-term strategy, women strength should be increased significantly in all countries by attracting more women to fisheries courses and making provisions for their employment in various organizations. South Asia needs special attention on this particular aspect. The fisheries curriculum has to be modified suitably to ensure that gender issues, farmer participatory research and other social issues are included in the graduate programme.

THE WAY FORWARD

As an immediate step, it would be worthwhile to stimulate more research into documenting farmer innovations in various countries. Such documentation of farmer innovation should become available to all to stimulate further research and development in the discipline. Conscious efforts to train women in seed production and nursing and provision of required credit would bring major benefits to the sector.

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8.6 Self-recruiting species (SRS) from farmer-managed aquatic systems (FMAS) – the contribution of non-stocked species to household livelihoods

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ABSTRACT

Availability of fish seed is considered to be one of the most important elements in the development of conventional aquaculture. Fish seed are derived mostly from commercial and private hatcheries. Many aquaculture systems in Asia, however, are linked to larger water resources and non-stocked species are often found and valued, at harvest. Self-recruiting species (SRS) are commonly defined as aquatic animals that can be harvested regularly from farmer-managed aquatic systems (FMAS) without the need of regular stocking. FMAS include conventional culture ponds but also embrace a large variety of perennial and seasonal water resources such as rice fields and ditches. SRS have often been considered as "weeds" by scientists and extensionists and steps are often taken to eliminate them from aquaculture systems. However, this study suggests that they are both valued and encouraged by farmers in many contexts, particularly when hatchery seed is less available.

The research was based at subsites in three countries in Asia (Cambodia, Thailand and Viet Nam) selected by agro-ecological characteristics. The three countries reflected a continuum of hatchery seed availability, i.e. southeast Cambodia (SEC) had minimal hatchery seed available, northeast Thailand (NET) had intermediate availability and the Red River Delta (RRD) of northern Viet Nam had high availability. A mixture of qualitative and quantitative field research tools were used in the three-year research project in nine communities from each study site to examine the role of aquatic animals in the general context of livelihoods of resource poor communities.

The most common household-managed aquatic system in rural areas were rice fields that even resource-poor households can access but other, particularly deeper FMAS that included household ponds, trap ponds and ditches, were more likely to be stocked with hatchery-derived seed. The varied criteria used by households to score the importance of different aquatic animals explained the variable but enduring importance of SRS. Whereas qualities relating to food consumption like good taste, versatility in cooking and preservation qualities are more important to both men and women of SEC and NET, financial factors and ease of sale were more important in the RRD. Fast growth was only considered important in the RRD. This was expected because of the status of aquaculture in the area and due to the large proportion of villagers practicing conventional aquaculture. The majority of the households that stocked in RRD (> 90 percent) purchased their seed from hatcheries whereas of the much smaller proportion of households that stock FMAS in SEC (<15 percent), more than half acquired their seed from non-hatchery sources, mostly caught from other FMAS (such as rice field) and perennial water bodies. More than 70 percent of the households that stocked seed in NET used hatchery-reared seed. These findings suggest that SRS can remain a valued component of aquaculture systems even when hatchery seed are widely available. Their importance relative to hatchery-derived species reflect the intensity and orientation of aquaculture and the wider farming system.

INTRODUCTION

Fish and other aquatic animals are very important parts of the diets in south and southeast Asia (Bush, 2004; Roos, Islam and Thilsted, 2003; Mogensen, 2001; Roos, 2001; Saengrut, 1998) and traditionally, they have been obtained from wild, unmanaged stocks. Increasing exploitation of both the stocks themselves and the surface water sources they inhabit probably underlie declines in the availability of aquatic animals from unmanaged systems (Gamucci, Mair and Demaine, 2002; Phelps and Bart, 2001). The development of aquaculture was perceived to play a major role in the continuous supply of aquatic products and to lessen the pressure on depleting population of wild stocks (Phelps and Bart, 2001). The availability of seed for stocking has been a major factor in the rapid spread of conventional aquaculture in Asia, (Little, Satapornvanit and Edwards, 2002).

The majority of these seed are herbivorous/omnivorous carps that are then cultured in semi-intensive culture systems (Coche, 1982; Edwards, 2000) although the range of cultured species continues to grow and include the higher valued carnivorous species. Both the cost and availability of conventional hatchery seed may constrain their use by households in rural areas. Seed costs dominated pond investment cost in one study in Bangladesh (Karim, 2006) and purchase often occurs at a time when cash is in short supply. Most seed are supplied by itinerant traders in rural areas (see Little *et al.,* this volume) resulting in both the individual size of seed and range of species often being limited. These can result in poor performance of the seed. The conventional approach to improving performance of rural aquaculture (Edwards and Demaine, 1997) is to upgrade production and delivery systems of hatchery seed but the importance of unstocked aquatic animals that are typically produced and harvested alongside stocked species has been ignored. Such species, (‘self-recruiting species’ or SRS) that are harvested from farmer-managed aquatic systems (FMAS) appear to be a common feature in Asia (Morales *et al.*, 2006) and meet rural peoples’ needs. Conventionally, such species have been considered as ‘weeds’ in the system that needs to be controlled or eradicated.

Recently, few studies have identified the role and importance of small indigenous species (SIS) to the food security of rural people, many of these are managed and harvested within household systems such as small ponds and rice fields (Mogensen, 2001; Roos, 2001; Roos, Islam and Thilsted, 2003; Saengrut, 1998). Aside from the specific qualitative contribution to diets, SRS also have broader impacts on overall livelihoods of rural households as observed in south and southeast Asia (Little *et al.*, 2004; Immink, 2003; Islam, 2003; Morales, 2003; Beaton, 2002).

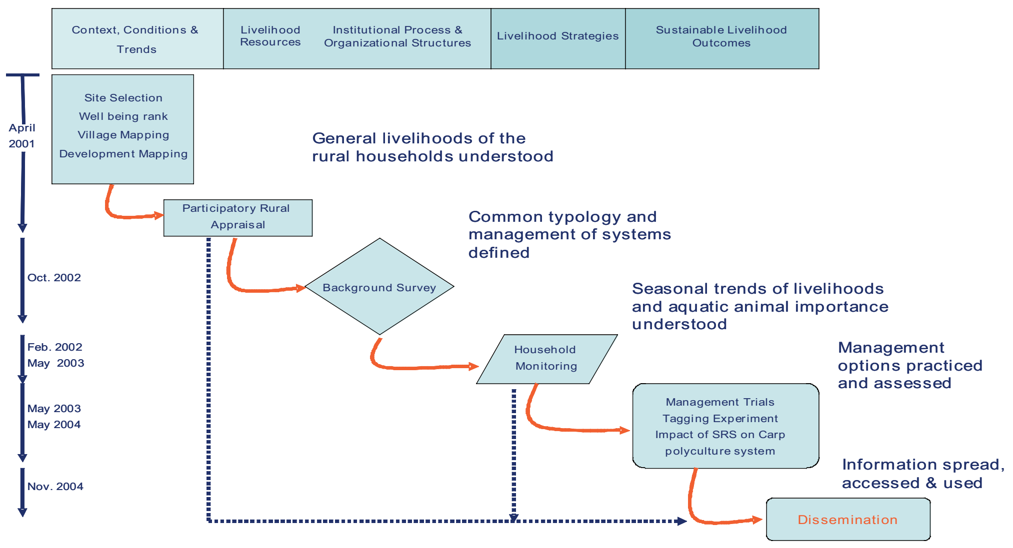
This paper presents information derived from a broader study into SRS and their role in rural livelihoods. The relative importance of SRS and stocked species are compared and interpreted in terms of hatchery seed availability from three sites in Southeast Asia. The perceptions of rural people to the management and utilisation of stocked and unstocked species are also considered.

MATERIALS AND METHODS

The research was based at sites in three countries in Asia (Cambodia, Thailand and Viet Nam) reflecting different levels of conventional aquaculture development and hatchery seed availability. Sites in southeast Cambodia (SEC) were chosen to represent areas where conventional aquaculture is relatively undeveloped and hatchery seed is less available (Gamucci, 2002; Gamucci, Mair and Demaine, 2002; Gregory and Guttman, 2002); the Red River Delta (RRD) in northern Viet Nam represented an area where aquaculture is traditional and well established where hatchery seed is highly available (Luu *et al.*, 2002). Northeast Thailand (NET) was selected as an intermediate between the first two sites based on both levels of aquaculture development and availability of hatchery seed (Pant, 2002; Demaine *et al.*, 1999; Little, 1996; AIT Aquaculture Outreach, 1992). Subsites were selected on the basis of proximity to perennial water bodies which were identified as LOW and DRY. The DRY area tended to be at higher elevations and experiencing short flood duration and distant from perennial water bodies, while the LOW tended to be sites with longer flood duration and closer proximity to perennial water resources.

The study had three main phases in which both qualitative and quantitative research approaches were used. Participatory rural appraisal (PRA) was used during the exploratory stage of the study to understand the role of aquatic animals in the general context of livelihoods of resource poor communities. The second stage (background survey) applied a more quantitative approach to assess the nature and role of aquatic resources accessed by households of different socio-economic groups (180 respondents/site). The impacts of SRS on household livelihoods were further investigated through a longitudinal study of 54 households at each study site. A seven-

FIGURE 8.6.1
Chronology of activities (adopted from Little *et al.*, 2004)



day recall method was used to estimate the sources and quantity of aquatic animals collected and consumed.

Figure 8.6.1 is a summary of the methodological approach of the broader project from which the data was drawn (Little *et al.*, 2004; Morales, 2007).

RESULTS

Farmer-managed aquatic systems

FMAS are distinguished principally by size, depth and type of management, especially in terms of exclusion, attraction or passivity to the presence of SRS. Various types of FMAS were identified in this study to increase production of aquatic animals. Table 8.6.1 provides a simplified description of each type of FMAS.

Farmer-managed aquatic systems can be differentiated based on their purpose (specific or multi-purpose) and physical characteristics, i.e. water depth and size or area (Table 8.6.1). Elsewhere, rice fields (RF) have been identified as an important source of aquatic animals (Middendorp, 1992; Gregory and Guttman, 1996; Halwart, 1994; Little *et al.*, 1996; Berg, 2002). Rice fields dominate farming systems in all of the three sites but predominantly rainfed in SEC and NET, and irrigated in RRD (Little *et al.*, 2004).

In SEC and RRD, household ponds (HHP) are particularly important. In NET, both culture ponds (CP) and trap ponds (TP) are common. Areas of deeper FMAS (i.e. ponds and ditches) in RRD are significantly larger than in NET and almost six fold larger than those in SEC (Table 8.6.2), indicating the significance or level of aquaculture in the area (Luu *et al.*, 2002) where a large average size of FMAS such as in the RRD suggests that aquaculture is well established. In contrast, the size of aquatic systems in SEC is relatively small corresponding to aquaculture being relatively new in this area (ARMP, 2000).

Stocking of hatchery seed is not common in SEC; in RRD, it is the norm in FMAS. Hatchery seed are available in NET and although many farmers have purchased them, a significant proportion of households do not stock regularly. The practice of stocking seed may affect the households' attitudes toward SRS. Typically, these species were allowed and/or attracted in systems not stocked with hatchery seed (SEC and NET) or their entry was discouraged and/or eliminated in FMAS where hatchery seed were stocked (RRD). Self-recruiting species entering HHPs from RFs were mostly eliminated in RRD; but some farmers managing their ponds less intensively did allow them to enter and then practiced regular harvesting.

Farmer-managed aquatic systems are used for different purposes at the three sites. In SEC and in some parts of NET, deeper ponds are used predominantly to hold aquatic animals collected from wild stocks and other FMAS for later consumption. Such water

TABLE 8.6.1

Uses and description of different types of farmer-managed aquatic systems in southeast Cambodia, northeast Thailand and the Red River Delta [modified from Morales (2007)]

FMAS	Description
Rice fields (RF)	mainly used for rice cultivation, typically shallow; breeding ground of many wild aquatic animals during the onset of rainy season
Culture pond (CP)	conventional aquaculture system; dug-out particularly for stocking/culturing hatchery produced seed; usually deep (1 – 2 m).
Household pond (HHP)	usually located near homestead; multi-purpose use; usually used to hold collected aquatic animals harvested from wild stocks; sizes and depth varies
Trap pond (TP)	dug-out in lower portion of ricefields or areas adjacent to perennial water bodies i.e. lakes, streams and swamp; commonly used to trap aquatic animals when water from the ricefields recede; used as refuge of many aquatic animals during dry season; usually deep (2 – 3 m)
Ditch	narrowly dug-out; usually located around the perimeter of the homestead; connected to HHP and RF; main purpose is to keep boundaries of the homestead

TABLE 8.6.2
Summary description of farmer-managed aquatic systems in rural areas of SEC, NET and RRD (modified from Morales, 2007)

Characteristics	Study sites		
	SEC	NET	RRD
Type	Rice fields HH pond Trap pond Ditches	Rice fields Culture pond Trap pond	Rice fields HH pond
Average Total area (m^2)	18,382	36,055	3,534
Area of deeper FMAS (m^2)	85	440	572
Stocking	Not stocking	Both	Stocking
Attitude to SRS	Allow and Attract	Allow and Attract	Prevent Eliminate Do nothing
Harvest	Seasonal/occasional	Seasonal	Seasonal
Selling	*	**	***

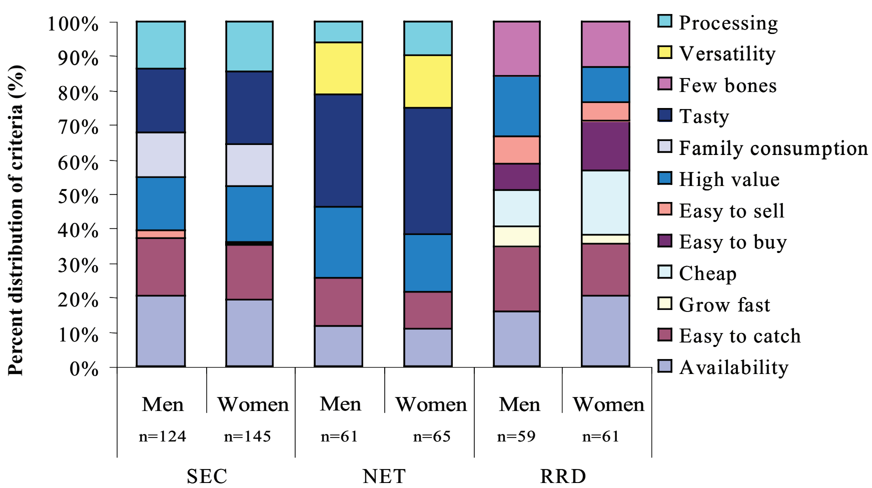
Note: * - represent the amount of households selling some aquatic animals caught or received.
Information presented were based from the background survey and the baseline of the monitoring.
* few households
** many households

bodies are also considered as refuges for aquatic animals during the dry season. In Viet Nam, household ponds are mostly used for raising foodfish for sale from hatchery seed.

Importance of different aquatic animals

The relative importance of aquatic animals, both stocked and SRS, was determined using matrix scoring carried out by male and female focus groups independently. Figure 8.6.2 shows the different criteria used by villagers in determining the importance of aquatic animals. There was no significant difference between gender groups within the study sites in terms of the criteria used for classifying the importance of aquatic animals but there were important differences between sites.

FIGURE 8.6.2
Local criteria used by male and female focus groups in ranking the importance of aquatic animals



In SEC, a high priority was given to the value of aquatic animals for subsistence (family consumption). In NET, good flavour was the most important criteria. Neither of these criteria were mentioned in RRD, where a range of criteria relating to income and collection were highlighted. Suitability for processing was identified as being important in NET and SEC, especially in the latter where household monitoring later established that this was an important strategy to maintain consumption levels when supplies of fresh aquatic animals declined during the dry season. Overall, the different criteria used by different groups in the three study sites can be grouped into: (1) availability, (2) economic value and (3) food and nutritional value.

Stocking practices

In general, the proportion of households with FMAS that had any history of stocking hatchery seed is low in SEC (14 percent) and high in RRD and NET (46 percent), as presented in Table 8.6.3. Only three percent of households had stocked hatchery seed in the DRY area of SEC. Both NET and RRD had similar total numbers of households that stock in FMAS, however the proportion of households (52 percent) that had a history of stocking in DRY areas of NET is higher than the other sites studied.

Source of aquatic seed

Two major sources of seed used by households identified in this study (Figure 8.6.3) were: (1) formal hatcheries/seed producers and (2) non-hatchery sources. Formal hatcheries include private hatcheries/nurseries, research organizations who are involved in aquaculture, government agencies like the Department of Fisheries (DoF) and non-government organizations (NGO) including cooperatives. For the non-hatchery sources, community ponds, rice fields, and other ponds of friends and relatives were identified.

In SEC, more than 50 percent of the households that stock acquire their seed from non-formal hatcheries, mainly other households' FMAS and their own rice fields. The importance of NGOs as a source of hatchery seed is also noteworthy here. In both NET and RRD, stocked seed are mainly from hatcheries, although the relative importance of the type of hatchery is marked. In NET, a significant proportion of households also rely on SRS. In RRD, the majority

TABLE 8.6.3
Households with a history of stocking in FMAS (mostly ponds). Number in parenthesis indicate the value of n.

Study sites	LOW	DRY	Total
SEC	24(120)	2(60)	26(180)
NET	35(90)	47(90)	82(180)
RRD	43(90)	39(90)	82(180)

FIGURE 8.6.3
Percentage contribution of the different sources of seed in rural areas (n= 26, 82, 82, for SEC, NET and RRD, respectively)

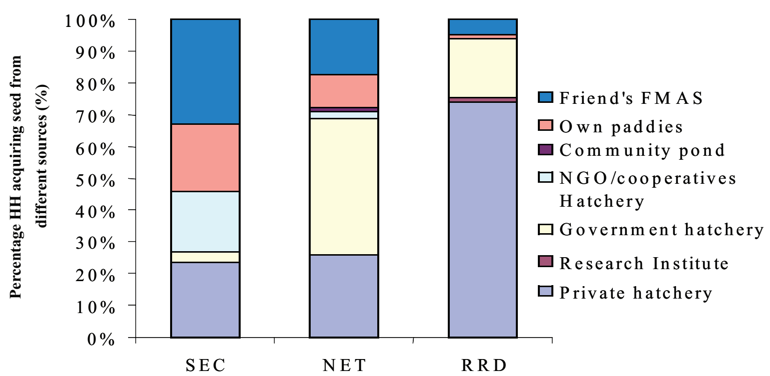
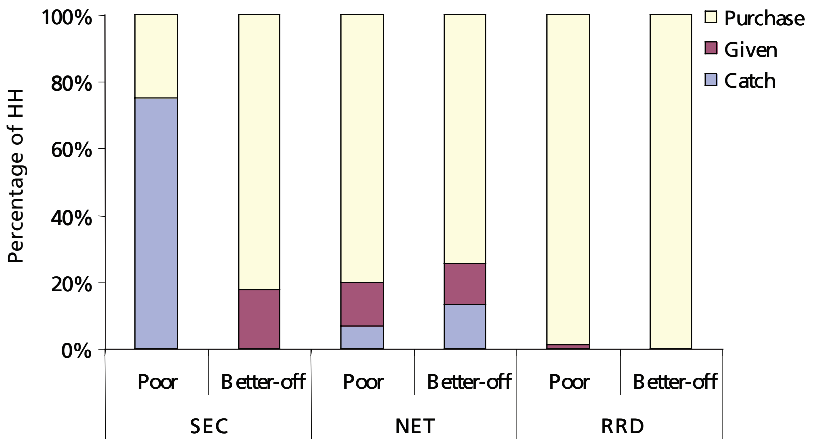


FIGURE 8.6.4
Means of acquiring seed for stocking FMAS by households of different well-being status in SEC, NET and RRD (n=26, 82, 82, for SEC, NET and RRD, respectively)



of the households (> 95 percent) are acquiring seed from specialised seed producers and the importance of SRS is minimal. Government hatcheries were a relatively more important source of seed in NET compared to RRD. Government-run hatcheries were common in NET where most provinces have hatcheries operated by the provincial stations of the DoF.

In addition to purchase, seed may be caught or received as a gift. The majority of households in the RRD, poorer and better-off, stock purchased seed (Figure 8.6.4). In Cambodia, poor households mainly obtained seed from the wild, whereas the better-off purchase seed from hatcheries or receive them as gifts. In NET, most households also purchase seed but acquiring seed for stocking through gifts is also common.

DISCUSSION

The concepts of FMAS and SRS of aquatic animals introduce a different context to any debate regarding rural aquaculture development in Asia. Since Gregory and Guttman (2002a) established that conventional hatchery seed-based aquaculture interventions were only erratically adopted by farmers in southeast Cambodia and linked this to variable availability of 'wild' fish stocks, the importance of understanding rural households' needs for aquatic products has been more widely accepted. A better knowledge of rural peoples' aquatic resources and characteristics of their management have also proved important to understanding their attitudes concerning purchase of hatchery seed. In terms of FMAS area that most rural farming households have access to and management control of, ricefields dominated all three of the research sites. Gregory and Guttman (2002b) and others have identified that rice fields are the major source of the aquatic species that dominate diets in rainfed rural areas of Southeast Asia. The extent of wet season habitat, mainly rainfed ricefields, has been identified as the major factor affecting household fish catches in lowland southern Lao PDR (Nguyen *et al.*, 2005).

The linkages between rice fields and ponds and the strategic management of stocked and SRS seed within a portfolio of different aquatic resources are clear from this study. If the three Southeast Asian sites are considered together - larger, deeper ponds are more likely to be stocked with purchased hatchery seed than shallow systems holding water only seasonally. But whereas this is extreme in the irrigated sites on RRD where water control is more exact, practices were more variable at the other two sites. In particular,

PLATE 8.6.1
Examples of farmer-managed aquatic systems (FMAS)

Ricefield

Fishpond

Trap pond (Cambodia)

Trap pond (Thailand)

Household pond (Viet Nam)

Ditch (Cambodia)

there appears to be more overlap between using stocked and SRS seed between more perennial and seasonal systems in NET where ready availability and low cost of hatchery seed make stocking attractive even in systems where water control is more erratic. But even here, hatchery seed are more likely to be used in ponds situated in DRY areas where loss through flood is less likely and abundance of SRS lower. A trend towards concentration on stocking in deeper ponds have been previously observed in the region (Little *et al.*, 1996) and explained by the availability of non-stocked seed and the high labour cost inherent in managing water levels in extensive, rainfed ricefields. In contrast, the use of deeper water bodies within rice fields to strategically manage SRS for harvesting and maintaining stocks to supply future seed is common in both SEC and NET (AIT Outreach, 1998).

The relative costs and benefits of stocking rice fields have long been the subject of critical review (Halwart and Gupta, 2004; Lightfoot *et al.*, 1992). The present study indicates that both hatchery and SRS seed are often managed within a typically rainfed ricefield-pond environment. The relative openness of the system, abundance of SRS and availability and cost of hatchery seed determine the likely benefits. Thus, in NET, silver barb are cheap enough to be stocked in extensive systems, partly as a lure for more valuable SRS to be used in trap ponds. This contrasts sharply with Cambodia where hatchery seed are relatively less available. The commercial value of seed stocked in rice fields appears to be a major issue. In northwest Bangladesh, Haque *et al.* (2005) found that Nile tilapia seed production in irrigated rice fields was adopted for a variety of reasons but both the value of the tilapia seed produced and increased availability of SRS were important perceived benefits.

This study also indicates that availability of hatchery seed does not necessarily lead to a decline in the importance of SRS in aquatic systems managed by the household. Although the proportion of households stocking seed exceeded 50 percent in the NET sites, similar to that in the RRD, the degree of importance of stocked seed was substantially less. This confirms other studies in this part of Thailand which reported that most households produce fish to meet subsistence needs (Demaine, 1999; AIT/DOF, 2000). In the minority of households that produce only, or mainly, for the market in NET, there was a greater likelihood that a more limited polyculture or monoculture was practiced and thus the number of hatchery species purchased was restricted (AIT/DOF, 2000). The specific sites used for the current study in NET were particularly intact with regard to natural aquatic resources and wild stocks compared with other sites in which detailed studies reveal a greater reliance on stocked seed (Demaine *et al.*, 1999; Pant, Demaine and Edwards, 2005).

The development and promotion of species suitable for pond-based aquaculture in Asia had focused on ease of reproduction and characteristics such as fast growth and herbivorous/omnivorous feeding niches but these were not criteria identified by rural people for scoring species by importance The types of the criteria used to score the importance of aquatic animal species indicated different perspectives of households at the three sites. A lack of gender differences suggested the involvement of both men and women in procurement and preparation in contrast to a related study in Bangladesh that found important differences with respect to criteria used by men and women (Islam *et al.*, 2003). Whereas priorities in the RRD are cash orientated, it is clearly subsistence-focused in SEC. A relative abundance of resources or more options to secure basic supplies of aquatic animals in NET compared to the other two sites is suggested by the focus on criteria relating to taste and other qualities. MacNiven (2001) found that households in NET had different perceptions of the quality of fish seed that were unrelated to performance indicators such as growth. These results also confirm a cultural preference in NET for a variety of species, even if many are relatively small. These findings are supported by the strategies used by households to obtain seed. In Viet Nam, seed is purchased as a cash transaction whereas in SEC and NET, a greater subsistence orientation means that households attempt to reduce cash expenditure, especially poorer households in SEC. The relative importance of non-cash transactions in seed between households also suggests their role in social relationships.

An important difference between government and private hatchery sources in the three sites also indicates a different level of investment by the government in the sector. The relatively high reliance on government in NET reflects a long-term and substantial commitment by the Royal Thai Government in a relatively decentralized (provincial level) physical infrastructure, both hatcheries themselves and the road network through which they can be accessed. One study suggested that farmers stocking hatchery seed mainly for home consumption were more likely to purchase seed, often of indifferent quality, from itinerant traders, whereas more commercially-orientated households would travel to and purchase directly from private or government hatcheries (AIT/DOF, 2001). The dominance of private seed producers in northern Viet Nam reflects government policies to divest provincial and commune level capacities (Little and Pham, 1995) and a traditional nursing sector based on wild riverine fry (Prax *et al.*, 2000). Issues of poor quality seed from this sector common a few years ago (AIT/RIA 1, 2000) appear to be changing in the RRD as consolidation of the hatchery sector and further specialisation of nursery are occurring (Little, 2005).The relative paucity and urban location of hatcheries in Cambodia (Gamucci, 2002) reflect the macro-level development and a continuing dependence on imported seed, especially from southern Viet Nam. The relative importance of NGOs in seed delivery reflects the lack of development in the government and private sectors (Gamucci, 2002).

The range of attitudes to the inclusion of SRS within FMAS can therefore, to some extent, be explained by the nature of the FMAS themselves and the importance of fish produced for sale rather than home consumption and the availability of hatchery seed.

The behaviour to restrict stocking of hatchery seed to deeper more conventional ponds, particularly by households mainly selling fish to produce cash incomes in Viet Nam and Thailand, suggests a need to protect their investment. The relatively high proportion of investment costs for pond-based fish culture used to purchase seed in Bangladesh (Karim, 2006) reflects an underinvestment in other inputs, particularly feeds and fertilizers. But it also explains why households that purchase seed are more likely to reduce risks of stock loss by ‘closing’ their systems. In irrigated systems, where there is greater control of water flows, the risk of stock loss through flood and entry of potentially competitive or carnivorous species may be limited. In contrast, in parts of central Thailand, farmers have used large irrigated rice fields adapted for production of *Trichogaster pectoralis* to include a range of valuable SRS (such as *Clarias macrocephalus)* reflecting their higher value, as food or broodfish, relative to stocked herbivorous species obtained from hatcheries (Yoonpundh, 1997).

The omnivorous rather than carnivorous feeding habits of the most common SRS in Bangladesh suggest that they are more likely to reduce performance of stocked carp systems through competition for feed resources rather than predation. The more carnivorous species of SRS are more likely to reduce other small-sized SRS than the rapidly growing riverine carps. Initial stocking size of purchased seed is a key consideration in their performance in open FMAS in which SRS are present and local advanced nursing has been identified as an appropriate strategy (Little *et al.*, 1991; Hossain *et al.*, 2003; AIT Aqua Outreach, 1997). A recent on-farm trial found that whereas SRS positive management of carp polycultures, including the stocking of juvenile and adult SRS, failed to increase yields of SRS in northwest Bangladesh, performance of the stocked carps was also unaffected. More importantly, even when attempts were made to restrict entry or remove SRS entering FMAS, yields of SRS harvested were not significantly reduced compared to that observed after positive management (Islam, 2007). This indicates the robust nature of important SRS, their adaptation to migration within ricefield-pond environments and/or the subtlety of farmer decision making regarding their management. Evidence elsewhere suggests that farmers are particularly interested in enhancing polyculture through SRS when options for stocking hatchery seed are restricted by availability or cost Barman, Little and Edwards, 2002.

In summary, while the importance of hatchery-derived seed were well established in two of the three sites investigated and a driving force in the design and management of deeper FMAS, there is a range of practice and perceptions that persist which resulted in non-stocked species retaining importance. Self-recruiting species have many values that rural people perceive are complementary to hatchery species. The variable nature of FMAS is such that they are difficult to exclude within rainfed, flood-prone environments. A combination of more intensive aquaculture husbandry practices and a less diverse, aquatic fauna characteristic of irrigated rice land such as in the RRD reduces the relative importance of SRS compared to stocked hatchery species.

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8.7 Decentralized seed – poorer farmers producing large size fingerlings in irrigated rice fields in Bangladesh

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ABSTRACT

Fish seed production and supply are well established in the private sector in Bangladesh and had greatly contributed to the rapid development of aquaculture. Hatcheries and nurseries producing fish seed are largely located as clusters in certain areas of the country and produce mainly riverine carps which are then supplied to farmers through an established trading network. Such clustered locations of hatcheries and nurseries are useful for cost effective institutional support, to share knowledge and to attract customers. But they are facing various constraints. There is high competition to sell their produce which can result in reduced profit margins. Constraints are minimized by increasing the efficiency of production but this is often at the cost of quality and there are few incentives to improve the quality of fish seed. As seed has become more available and aquaculture reached the current level of development, improving production and availability of large size quality fish seed are important to farmers in Bangladesh.

"Decentralized" seed production and supply may result in more benefits to poor people involved in aquaculture in rural areas in Asia. Several methods such as breeding and nursing of fry to fingerlings in hapas in ponds and in rice fields, nursing of fry in cages in ponds and nursing of fry in small seasonal ponds can be considered as "decentralized" approaches. Of these, the use of irrigated rice fields for production of fingerlings of common carp and Nile tilapia had shown great success among poor farming households in Bangladesh.

Common carp and Nile tilapia (GIFT strain) are currently of secondary importance to riverine carps in Bangladesh aquaculture but are showing increasing demand by farmers. Common carp can breed in ponds and farmers can produce fingerlings by stocking fertilized eggs in their irrigated spring rice ("*boro*") field. Similarly, breeding

and production of fingerlings of mature Nile tilapia can be simply managed in irrigated rice fields. Both species reproduce without any special requirements and facilities making production of juveniles possible outside of specialized hatcheries. Considering the simplicity of common carp fingerling production, initiatives have been taken by CARE Bangladesh to promote the technology among poor and marginal farmers. Before on-farm trials to assess GIFT tilapia fingerling production in 1999, only common carp fingerlings were produced in rice fields. Farmers successfully produced common carp fingerlings in their rice fields to meet subsistence needs for stocking ponds and rice fields. There appeared to be little interest in developing more commercial seed production.

A participatory trial was initiated to introduce Nile tilapia (GIFT strain) to farmers already producing common carp in irrigated "*boro*" rice fields. Monitoring of 19 farmers in two communities in northwest Bangladesh showed that the approach stimulated broader behavioural and management changes, was accessible to poor households and led to a range of different benefits. Stocking of very small numbers of broodfish in one rice field plot per household only marginally modified in February-March led to more than 90 percent of farmers producing good numbers of fingerlings. Production during the spring rice "*boro*" rice season (April- July) was more effective than during the rainfed "*amon*" rice season (August- December) for several reasons. Demand for fingerlings is high during spring rice season as majority of farmers stocked their ponds around this time. In addition, the relatively low level of water in the rice fields makes it easier to harvest the fingerlings. The lower risk of flood at this time also means minimal loss of fingerlings during the spring rice season. The cost of fingerling production was low and incomes were four times more than the expenditure. Introducing Nile tilapia resulted to higher yields of juveniles than using common carp alone and a greater diversity of benefits, for e.g. on average 43 percent were sold, 39 percent were re-stocked for grow-out and 17 percent of the large fingerlings were directly used for household consumption. The introduction of GIFT and common carp in rice fields for fingerling production has substantially enhanced resource productivity and profitability (Barman and Little, 2006).

The successes of the initial research programme were quickly extended and replicated directly by other nearby households. Non-producers such as fingerling traders were critical to the approach spreading further afield. The organisation CARE hosted a second strand of research designed to improve adoption and dissemination strategies within a large-scale development project aiming to establish lower external input dependence among rice farmers in the northwest region. The outcomes of this research led to the technology being incorporated into the Farmer Field School (FFS) curricula used by CARE throughout the region.

A further outcome of this research was that extension practitioners have improved selection of appropriate households and production sites and successfully co-developed with farmers new ways to produce fingerlings at different times of the year in varying conditions. The rise in good quality fingerling sales had led to another important outcome. The production of common carp and GIFT as foodfish from rice fish and pond culture increased two fold among households producing juveniles suggesting the value of large-sized seed being available on farm at the right time.

INTRODUCTION

Fish seed production in Bangladesh is concentrated around traditional supply centres and government stations across the country. An informal army of traders distribute the seed to villages even in remote locations which has undoubtedly stimulated uptake of fish culture but not without constraints. Farmers are dependent on unsolicited and often untimely deliveries of small, weak fingerlings which may not be sufficient for their pond or may not have the right mix of species. To counter this, local seed production based on species that reproduce easily were piloted in modified existing production systems owned by poor people. Rice fields were found to be advantageous for production of juveniles of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) by small-scale farming households in Bangladesh.

Since 1990s, the Cooperative for Assistance and Relief Everywhere (CARE) Bangladesh promoted ricefield-based fish seed production in the region initially with common carp and later with both common carp and Nile tilapia, introducing "GIFT' Tilapia in 1999. The Decentralised Seed Project (2003-2006), a collaborative research program funded by the Department for International Development (DFID of the United Kingdom), managed by the WorldFish Center (WFC) and the University of Stirling in the United Kingdom implemented, along with partner NGOs, three key sub-projects to advance this technology for the benefit of poor fish producers, namely: i) promotion and adoption strategies of ricefield-based fingerling production determined in 25 randomly selected communities from five out of 8 Districts in northwest Bangladesh, ii) livelihood impact assessments of fish seed production in rice fields of 30 rice fish households in comparison to 30 non-rice fish farming households selected from the northwest region and iii) fine tuning of the technology and scaling up the adoption process with 33 partner NGOs of WFC who managed on-farm research trials on Nile tilapia seed production in rice fields with 250 households in several regions of the country.

FINGERLING PRODUCTION IN RICE FIELDS

Common carp seed production

Rice fields are normally considered for the production of foodfish but it was in the 1980s when the Northwest Fisheries Extension Project (NFEP) and CARE Bangladesh tried to establish systems on the use of rice fields for fingerling production. It was initially tried with common carp by stocking hatchlings from hatcheries in irrigated spring "*boro*" rice fields in northwest Bangladesh. Later on, the use of fertilized eggs of common carp attached to the roots of water hyacinth, after local spawning in small ponds and ditches, was promoted. These systems showed success in the production of common carp fingerlings with minimum investment. The Food and Agriculture Organization of the United Nations (FAO) supported an initial pilot project in 1992 and from 1993 CARE implemented larger projects to promote ricefield-based common carp seed production. Farmers used the seed produced for subsistence purposes and a field study revealed no development of revenue generation among seed producers (Barman and Little, 2004).


COURTESY OF D.C. LITTLE

Inspecting of water hyacinth roots for common carp eggs prior to stocking in boro ricefields. Common carp broodfish had been stocked in a small ditch close to the rice field with the floating weed to induce natural spawning

Nile tilapia seed production

A research trial in 1999 was implemented in cooperation with the local field offices of CARE IF project participated by two communities (four and 15 households) who had previously adopted common carp production. Each household selected one plot for stocking 18 tilapia broodfish (GIFT strain; 12 female and 6 male) provided to their rice field ditches during the irrigated "*boro*" season from end of February to the beginning of March.

The outcomes of the trial were very successful as most of the partcipating households were able to produce significant

COURTESY OF D.C. LITTLE

Small GIFT strain Nile tilapia broodfish used for stocking ricefields. Fish seed traders have been important in moving broodfish between areas encouraging farmers to produce seed

numbers of large tilapia fingerlings. On average, 43 percent of the fingerlings were sold, 39 percent were stocked for grow-out and 17 percent of the large fingerlings were directly used for household consumption. News of the outcomes of the trial were known to most of the neighbours in the communities, to farmers from outside the trial communities through CARE and to relatives and fish seed traders through informal channels. A significant number of fingerlings were purchased by traders who sold them on to farmers in other communities. Research outcomes were shared, during the trial period, with CARE field staff through workshops and field visits.

PROMOTION AND ADOPTION OF RICEFIELD-BASED FINGERLING PRODUCTION

The number of farming households adopting juvenile fish production and the number of rice fields used increased over three consecutive seasons in communities that were subsequently monitored (Table 8.7.1). The introduction of Nile tilapia in areas where common carp fish seed production in rice fields was already established led to several significant improvements to farming households. There were significant increases in productivity of the system, the numbers of fingerlings used for re-stocking, household fish consumption and the numbers of fingerlings sold for cash income. In addition, farming households further developed their systems to facilitate the production of the other species, such as Indian major carps and Chinese carps, along with common carp and GIFT for restocking and their own foodfish production.

The introduction of the GIFT tilapias stimulated rapid adoption in surrounding communities. Further analysis showed that the practice spread from its introduction to four households in one community to 121 households in 20 communities within three years without further formal/institutional support (Barman and Little, 2004).

The introduction of tilapia in areas where common carps were established also stimulated the advanced nursing of riverine carp species (Indian major carps, Chinese carps and silver barb) obtained from traders as fry (Table 8.7.2). Most households stocked the fertilized eggs of common carp attached to a substrate that can be obtained locally at no cost. Purchase of hatchlings from hatcheries and nurseries is more resource-intensive. The retention and use of brood fish locally, whether common carp or tilapia is an important advantage of these species but necessitates access to perennial water. Evidence suggests that this does not require ownership of perennial water bodies but that a range of strategies are employed. However, most households report that the numbers of tilapia broodfish were insufficient to optimize the contribution of tilapia to their overall production.

A key feature of the pattern of management observed is the harvesting of the majority of fingerlings produced in irrigated "*boro*" rice during times of high demand at the beginning of the monsoon

TABLE 8.7.1

Rice fish farmers and corresponding rice field plots for fish seed production during three years of monitoring

Production season	Number of farmers	Number of ricefield plots
'boro' year 1	134	145
'boro' year 2	163	181
'boro' year 3	174	203

Source: Barman, Little and Janseen, 2004

TABLE 8.7.2
Percentage of households using different species combinations for large size fingerling production in spring (boro) rice fields in northwest Bangladesh

Production season	Common carp (percentage)	Only tilapia (percentage)	Common carp and tilapia (percentage)	Common carp, tilapia and and riverine carps (percentage)
'boro' year 1	54	3	7	36
'boro' year 2	40	4	11	44
'boro' year 3	31	4	9	56

Source: Barman, Little and Janseen, 2004

rains. The productivity of the systems appears to increase if farmers retain fingerlings into the fallow period following the harvest of "*boro*" rice and before the start of the main crop "*amon*" rice transplantation. The fallow rice fields are a favourable environment for the fingerlings to grow and this approach also facilitates harvest of seed from the rice field plots. This strategy, apart from corresponding to the period of maximum demand, also avoids the risk of flood loss which is highest during the season from August to October. The value of using ricefields for fish culture is clearly established in the area and some farmers developed their plots to prevent or mitigate flood loss and allow use of rice fields through both seasons.

The productivity of ricefield-based seed systems was greatly enhanced by using Nile tilapia; the mean productivity of this species (2088 ± 632/household) was almost double the production attained using common carp (1083 ± 135/household) or riverine carps (1281± 438/household). The large-sized fingerlings produced from rice fields (20-30 g) are favoured for their enhanced outcomes during subsequent grow-out production compared to smaller size fry that are typically available in rural areas. They are particularly valued in seasonal water resource based systems (seasonal ponds, seasonal ricefield-based systems) in which production duration is limited. In seasonal pond-based systems, a 36 percent increase in productivity was achieved and obtained by stocking large juvenile Nile tilapia with other species in polyculture compared to ponds without tilapia in northwest Bangladesh (Barman, 2000).

THE IMPACTS OF RICEFIELD-BASED FINGERLING PRODUCTION

The WFC (Bangladesh and South Asia office) reported impacts of the ricefield-based fish seed production in Bangladesh as described below.

Due to its success towards self-sufficiency and opportunity for poor people to earn cash from sales of fingerlings, the approach was incorporated into CARE's national integrated agricultural development program. As a result, studies revealed that of the 194 840 households trained using the FFS approach - over 30 000 households adopted the technology, maintaining both self-sufficiency in seed supply and on average, selling 2 000 fingerlings per seed-producing farmer, valued at $40 to the benefit of 120 000 to 150 000 foodfish farmers per year.

COURTESY OF D.C. LITTLE

Plots used for seed production are often located close to the homestead. This picture shows preparation of the ditch or refuge, used for holding breeding fish and then for concentrating juveniles prior to harvest

In addition to fish seed sales, farmers also benefitted from improved nutrition through improved access to

COURTESY OF D.C. LITTLE

Children catch many of the fish used for home consumption derived from ricefield based fingerling production. The harvest is used for selling juveniles, re-stocking for further culture or eaten or sold for food fish. This flexibility is highly valued by farming households

foodfish. Studies also revealed that annual fish consumption of rice fish households was 23 kg higher than non-ricefish households.

Poverty profile analysis suggests that about two-thirds of the technology adopting households were defined by community key informants as "poor" owning less than 0.4 ha of land, earning less than US$600 per household and home-grown rice supported the family for less than 6 months per year. The pro-poor aspect of this technology may be further highlighted by its modest investment requirement (<15 US$), its simplicity, a relatively simple add-on to existing production technology and applicability to small rice plots (0. 1 ha). In fact, the research has shown that seed production efficiencies were found to be greatest in smaller plots generally owned by poor people as rice plot size is positively correlated with wealth.

The poor rice fish households may be defined as "pluri-active"; 87 percent of farmers reported that the ricefield-based fish seed production is compatible with their other occupations especially for women and children. For 60 percent of adopters, the distribution of some fingerlings as gifts to relatives and neighbours increased their social capital.

Environmental benefits were evident from 97 percent of rice fish farmers reporting no use of pesticides and the majority of households reported that rice fish adoption increased harvest of fish and other aquatic animals from rice field ecosystems thus making better use of irrigated water.

THE IMPLICATIONS OF THE CONCEPT AT NATIONAL, REGIONAL AND GLOBAL LEVELS

The approach has been incorporated by CARE into its aquaculture development programs thus reaching out to many communities across the country. At the regional level, the outcomes of the concept of "decentralized seed" were shared with the project personnel and scientists of north Viet Nam in 2005. Thereafter, the technology has been incorporated into the Aquaculture Program of the Danish International Development Agency (DANIDA) in Viet Nam starting with an on-going pilot project working with 60 farmers. Globally decentralised seed production has the potential to contribute to poverty reduction and economic growth anywhere that rice farming and unmet demand for fish co-exist. It is currently promoted by the WFC and the University of Stirling in international events and scientific publications.

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8.8 Establishment of national broodstock centres in Viet Nam

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ABSTRACT

A rich natural aquatic resource base, extensive water resources and coastline and supportive government policies are the basis for Viet Nam tripling fisheries production between 1990 and 2005.

The planned move by the Government of Viet Nam (GOV) from state run and controlled fish seed production systems to a free market economy with private hatcheries producing the majority of aquatic seed production, have also contributed greatly to the rapid aquaculture development.

The GOV is initiating an aquatic seed development programme to 2010 through a network of national 'level 1' and provincial hatcheries that will service the aquaculture industry on a cost recovery basis. Activities include long-term genetic breeding programmes, the dissemination of improved aquatic seed, farmer training, research and the conservation of germplasm and artificial breeding of endangered aquatic species.

The Support to Freshwater Aquaculture component of the GOV/Danida Fishery Sector Programme Support (FSPS) funded key consultancy input, staff training, equipment and research and development activities at the three national broodstock centres (NBC) in Viet Nam, the details of which are provided in this paper.

BACKGROUND

Viet Nam's dynamic fishery sector has been encouraged by the country's rich natural resources including 3 260 km of coastline and an exclusive economic zone of 1 million km^2. Viet Nam has a registered fishing fleet of just over 90 000 powered vessels (MOFI, 2006).

Viet Nam has an estimated 120 000 ha of ponds, 340 000 ha of lakes and reservoirs and a further 540 000 ha of rice fields which could potentially be used for freshwater aquaculture. Similarly, Viet Nam has approximately 660 000 ha of tidal area and 400 000 ha of lagoons which could potentially be used for brackishwater aquaculture.

The fishery sector is one of the most dynamic and fastest expanding sectors in Viet Nam with growth in excess of 10 percent per annum. Currently, the fishery sector contributes 4 percent to the Vietnamese gross domestic product, provides full time employment to over 4 million people and part-time employment to many millions more.

Vietnamese total aquatic production tripled between 1990 and 2005, reaching 3.4 million tonnes in 2005, with 1.8 million, 1.4 million and 0.18 million tonnes from marine capture, aquaculture and inland capture fisheries, respectively (MOFI, 2006). In 2005, 0.93 and 0.33 million tonnes of fish and shrimp were cultured; the same year when Viet Nam exported US$2.65 billion worth of aquatic products.

With aquatic products providing 40 percent of the animal protein in the Vietnamese diet, the fishery sector is also vitally important for food security and nutritional quality.

HISTORY OF SEED PRODUCTION

Prior to early 1980s, the state provided the resources, subsidized, controlled and managed fish seed production in Viet Nam. In the late 1980s, in its move towards a free market economy, the market reforms of the Government of Viet Nam (GOV) promoted the formation of private seed producers who were mobilized by profits, while state hatcheries were also converted to profit orientated joint stock companies.

In the 1990s, the GOV identified that although government and private sector hatcheries were producing sufficient freshwater fish seed, the quest to maximize profits had resulted in a deterioration of seed quality caused by inbreeding, genetic drift and other factors. In addition, aquaculture development was constrained by the difficulty in enforcing seed quality management guidelines and/or regulations, seed being unavailable when needed for stocking and because of inappropriate management practices.

To counter this, the Prime Minister launched an ambitious aquatic seed development program to the year 2010 (GOV, 2004) with a target production of 16.7 billion fry by 2010. The program included the upgrading of three national broodstock centres (NBC) with a remit to improve seed quality and which were to operate on a cost recovery rather than a profit basis. The three NBCs are located in Hai Duong province in northern Viet

Nam, in Tien Giang province in southern Viet Nam and in Buon Ma Thuat province in central Viet Nam.

COURTESY OF JOE GARRISON FOR MRC

Family rearing of 'tra' (*Pangasius hypophthalmus*) at National Broodstock Centre 2, Tien Giang province

The aquatic seed development program also includes the following: (i) upgrading 11 "level 1[1]" freshwater multiplication seed centres (four in the north, three in the centre and four in the south), (ii) the upgrading of provincial hatcheries, (iii) the strengthening of staff capacity through provision of training, (iv) the creation of concentrated seed production zones, (v) the strengthening of seed quality management and (vi) the implementation of specific research and development programmes on seed production.

[1] Level 1 is a hatchery center servicing several provinces.

The GOV has assigned the three NBCs with the following responsibilities:
- collecting and maintaining the best germplasm of key aquatic species;
- maintaining stocks to minimize inbreeding and genetic drift;
- gene banking and domesticating endangered species;
- developing improved broodstock management and seed production techniques;
- conducting national breeding programmes;
- disseminating improved strains and/or species; and
- training of hatchery operators nationwide.

The Support to Freshwater Aquaculture (SUFA) component of the GOV/Danida Fishery Sector Program Support (FSPS) funded a series of international consultancies to support the upgrading of the NBCs. The SUFA consultancy provided input on the designing and equipping of NBCs, quantitative genetics, seed quality management and evaluation, satellite markers, cryo-preservation and business and production planning.

During a series of workshops facilitated by SUFA staff and international consultants, key fish species at the three NBCs were classified into three categories for differing development strategies. These were as follows:

Class A: priority species for genetic improvement;
Class B: priority species for genetic management to avoid deterioration of stocks; and
Class C: species for which refresher introductions could easily be made either from domesticated and/or improved stocks, or from the wild.

The selection of Classes A, B and C fish species for NBC1 (north) and NBC2 (south) are shown in Tables 1 and 2 below.

At the time of going to print the current situation is that NBC1 (north) has been completely upgraded with GOV funds, equipped and is operating at full capacity. The NBC2 (south) has been fully supplied with SUFA funded equipments, while upgrading funded by GOV funds is underway and will be completed in early 2007.

Construction of NBC3 was delayed and not started when SUFA finished at the end of 2005. However, to meet the increasing demand for freshwater fish seed in the central region, SUFA funded the installation of a fibre-glass tank-based hatchery system at Quang Hiep and provided a full set of equipments for use when NBC3 construction is completed.

The equipments supplied by SUFA were chosen by the respective NBCs themselves and included passive integrated transponder (PIT) tags and readers, water quality and disease testing equipments, closed recirculation systems with bio-filter and ultra-violet sterilization and automatic feeders. SUFA also funded two licences for each of the three Research Institutes of Aquaculture (RIA1, RIA2 and RIA3) for six years for Genstat and ASReml, two quantitative genetics analysis software programs.

SUFA supported field trips, training and workshop attendance for NBC and RIA staff, and in 2005, SUFA funded part of the NBC1 and NBC2 research and training costs against the business and production plans of each institute.

Single pair tilapia spawning hapas at National Broodstock Centre 2, Tien Giang province

COURTESY OF TRINH QUOC TRONG

COURTESY OF TRINH QUOC TRONG

Checking a PIT (passive integrated transponder) tag with a reader before insertion into a 'tra' (*P. hypophthalmus*) broodstock fish

Specific SUFA-supported activities at NBC1 (north) included:

- funding the re-importation of 50 000 P33 and 50 000 Amur common carp fry from Haki, Hungary and 20 000 grass carp and 20 000 silver carp from China;
- funding long-term mrigal and grass carp breeding programs;
- facilitation by NBC1 staff with support from a team of quantitative geneticists of detailed breeding plans for grass carp, common carp and tilapia at NBC1; and
- supply by NBC1 of improved grass carp and mrigal fingerlings to 11 hatcheries in the north of Viet Nam to be grown on as future broodstock.

Specific SUFA-funded activities at NBC2 (south) included:

- long-term selective breeding program for *Pangasianodon hypophthalmus* ('tra') which initially focused on growth and later fillet yield; three year classes of broodstock have been produced with over 100 families of each grown-on;
- selective breeding program for Genetically Improved Freshwater Tilapia (GIFT tilapia) with broodstock with the best estimated breeding values (EBVs) mated in 2005 and seed from over 100 single pair matings being grown-on;
- Facilitation by NBC2 staff with support from a team of quantitative geneticists of detailed breeding plans for tra, tilapia, *Macrobrachium* and silver barb at NBC2.

In addition, the NBCs have also received funding support from the:

- DFID Aquaculture and Fish Genetics Research Programme (AFGRP) 2000- 2004 which focused on carps;
- GOV for a gene banking program 1996- 2000 and Phase 2;
- International Network for Genetics in Aquaculture (INGA); and
- Aquaculture of Indigenous Mekong Fish Species (AIMS) of the Mekong River Commission.

It is anticipated that the Sustainable Development of Aquaculture (SUDA) component of the Fisheries Sector Program Support Phase II funded by the GOV and Danida will work collaboratively with the three NBCs of Viet Nam to continue their further development as genetic centres of excellence for quality fish seed.

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Four of the most important resources to aquaculture, outside human and technological resources, are land, water, seed and feed. Efficient use of these resources is necessary to guarantee optimum production from aquaculture. A project, Study and Analysis of Seed Production in Small-scale Rural Aquaculture, was implemented through a desk study and expert workshop (held in Wuxi, China from 23 to 26 March 2006) to assess the status of freshwater fish seed resources and supply and its contribution to sustainable aquatic production the results of which are contained in this two-part publication. Part 1 contains the proceedings and major recommendations of the expert workshop which tackled three major themes: (a) seed quality, genetics, technology and certification; (b) seed networking, distribution, entrepreneurship and certification; and (c) how rural fish farmers can benefit from the freshwater aquaseed sector. Part 2 contains the detailed outcomes of the desk study consisting of three regional syntheses (Africa, Asia and Latin America) based on 21 country case studies, five thematic reviews (quality, genetics and breeding, seed networks and entrepreneurship, seed supply in rural aquaculture, farmer innovations and women involvement) and three papers (self-recruiting species, decentralized seed networking in Bangladesh and the establishment of national broodstock centres in Viet Nam).

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