FAO Fisheries Report No. 718 **FIRI/R718 (En)**

ISSN 0429-9337

Report of the

FAO/CIFA/NACA Expert Consultation on the Intensification of Food Production in Low Income Food Deficit Countries through Aquaculture

Bhubaneswar, India, 16–19 October 2001

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Report of the

FAO/CIFA/NACA EXPERT CONSULTATION ON THE INTENSIFICATION OF FOOD PRODUCTION IN LOW INCOME FOOD DEFICIT COUNTRIES THROUGH AQUACULTURE

Bhubaneswar, India, 16–19 October 2001

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2003

ISBN 92-5-105021-X

An expert consultation was held from 16 to 19 October 2001, in Bhubaneswar, India, to review the technical issues associated with sustainable intensification of food production through aquaculture in the countries of South Asia. FAO, the Central Institute of Freshwater Aquaculture (CIFA, Bhubaneswar, India) and the Network of Aquaculture Centres in Asia-Pacific (NACA) carried out this activity as a cooperative effort. The overall goal of the expert consultation was to facilitate the preparation of draft technical guidelines on aquaculture nutrition and environmental health management for the sustainable intensification of food production through aquaculture in low income food deficit countries in South Asia. The expert consultation helped in consolidating the information, experiences, ideas and findings related to intensification of freshwater aquaculture systems focusing on nutrition, disease and health management, and environmental management. The consultation brought participation and contributions of major stakeholders, including producers, national aquaculture experts, government planners and policy-makers.

ISBN 92-5-105021-X ISSN 0429-9337

9 789251 050217

TR/M/Y5042E/1/11.03/3200

PREPARATION OF THIS DOCUMENT

FAO/CIFA/NACA Expert Consultation on the Intensification of Food Production in Low Income Food Deficit Countries (LIFDCs) through Aquaculture was held from 16 to 19 October 2001 in Bhubaneswar, India. This document was the result of the discussions, conclusions and recommendations reached during the Expert Consultation based on country reviews (Bangladesh, Bhutan, India, Myanmar, Pakistan, Nepal, and Sri Lanka), a synthesis paper (India), a technical guideline paper (Chinese experience) and resource expert papers (diseases and health management, water use and environment, nutrition and feeding) made available or presented during the Expert Consultation.

Distribution:

List of participants
FAO Regional Offices
NACA General Council Members
CIFA Officials

FAO/NACA/CIFA.
Report of the FAO/CIFA/NACA Expert Consultation on the Intensification of Food Production in Low Income Food Deficit Countries through Aquaculture. Bhubaneswar, India, 16–19 October 2001.
FAO Fisheries Report. No. 718. Rome, FAO. 2003. 58p.

ABSTRACT

The FAO Fisheries Department promotes sustainable intensification of food production through aquaculture, particularly in Low Income Food Deficit Countries (LIFDCs). As part of this initiative, an Expert Consultation was held from 16 to 19 October 2001, in Bhubaneswar, India, to review the technical issues associated with sustainable intensification of food production through aquaculture in the countries of South Asia. The FAO, the Central Institute of Freshwater Aquaculture (CIFA, Bhubaneswar, India) and the Network of Aquaculture Centres in Asia-Pacific (NACA), carried out this activity as a cooperative effort.

The overall goal of the Expert Consultation was to facilitate the preparation of draft Technical Guidelines on Aquaculture Nutrition and Environmental Health Management for the Sustainable Intensification of Food Production through Aquaculture in LIFDCs in South Asia. The Expert Consultation helped in consolidating the information, experiences, ideas and findings related to intensification of freshwater aquaculture systems with focus on nutrition, disease and health management, and environmental management. The Expert Consultation brought participation and contributions of major stakeholders, including producers, national aquaculture experts, government planners and policy-makers.

The Expert Consultation focused on major issues related to intensification, particularly on (i) water use and environment, (ii) nutrition and feeding, (iii) diseases and health management, and (iv) seed resources. The Expert Consultation will benefit planners and policy-makers, technical specialists and primary producers of this Asian region as well other regions.

CONTENTS

Background and Scope

Freshwater fish production through aquaculture continues to dominate farmed finfish production in many Asian countries. With increasing demand for food fish from freshwater aquaculture, and growing competition for resources, such as water, land, feeds and manure, there is a trend towards intensification of aquaculture production in freshwater aquaculture systems. Intensification of aquaculture production can help increase production to meet growing demand for fish. Farmed freshwater fish in many cases is and will be an essential source of animal protein for consumers in both rural and urban areas. Opportunities and constraints of intensification of freshwater aquaculture systems need to be explored, with a view to providing appropriate technical guidance for sustainable intensification of food production using such systems.

During efforts to assist sustainable intensification of food production through aquaculture, consideration must be given to understanding of the role of aquatic resources (aquaculture and inland fisheries) in the livelihoods of the users of water resources. While adequate evaluation of the impact of the activity on other water users need to be considered, communities should be developed to effectively and equitably manage the process (fishing, income, agreement on ownership, access). Development of technical criteria for management (inputs, stocking, feeding, water management, allowable fishing methods etc.) is considered equally important.

For the purpose of this Expert Consultation, intensification of food production through aquaculture is not considered in the narrow context of increase production of fish from a unit area of water. Intensification essentially means an increase in the output of a system per unit input. This therefore relates to all of the resources that constitute a production or farming system. As such, quantitative measurements for intensification would include productivity (kg ha^{-1}) of a water body, efficiency of water use (kg fish m^{-3} of water used), fish catch per unit effort (CPUE), invested and economic indicators (profit margin, cost of production, income/profit per unit of water used ($/$m^{-3}$). More qualitative indicators relate to socio-economic criteria such as number of households sustained, diversity of livelihoods strategies and reduced vulnerability.

The FAO Fisheries Department promotes analyses and consultations on the Sustainable Intensification of Food Production through Aquaculture within Low-Income Food-Deficit Countries. As part of this initiative, an Expert Consultation was held on 16–19 October 2001, in Bhubaneswar, India, to review the technical aspects of Sustainable Intensification of Food Production through Aquaculture in the countries of South Asia. The Expert Consultation, which mainly discussed freshwater aquaculture production in countries of South Asia, will benefit planners and policy-makers, technical specialists and primary producers of this Asian region as well other regions. The Expert Consultation focused on major issues related to intensification, particularly on (i) water use and environment, (ii) nutrition and feeding, (iii) diseases and health management, and (iv) seed resources. The FAO, the Central Institute of Freshwater Aquaculture (CIFA, Bhubaneswar, India) and the Network of Aquaculture Centres in Asia-Pacific (NACA), carried out this activity as a cooperative effort.

The overall goal of the Expert Consultation was to facilitate the preparation of Draft Technical Guidelines on Aquaculture Nutrition and Environmental Health Management for the Sustainable Intensification of Food Production through Aquaculture in Low Income Food Deficit Countries (LIFDCs) in South Asia. The Expert Consultation helped in consolidating the information, experiences, ideas and findings related to intensification of freshwater aquaculture systems with focus on nutrition, disease and health management and environmental management. The Expert Consultation brought participation and contributions of major stakeholders, including producers, national aquaculture experts and government planners and policy-makers.

Venue, Dates and Participation

The Expert Consultation was held from 16 to 19 October 2001 at Mayfair Lagoon Hotel, Bhubaneswar, India and was attended by 26 participants. The work programme for the consultation and list of participants are given in Appendixes A and B.

Consultation Agenda, Procedure and Conduct

Following the opening ceremony, involving welcoming remarks from the FAO (Dr R. Subasinghe), the NACA Coordinator (Mr P. Bueno) and the Deputy-Director General (Fisheries) of ICAR (Dr K. Gopakumar), the introduction and objectives of the Expert Consultation were presented.

There followed presentations of country papers by Bangladesh[1], Bhutan, India, Myanmar, Nepal, Pakistan and Sri Lanka, each followed by discussions.

After completion of the presentation and review of country papers, Dr Y. Ayyapan presented the Synthesis Paper prepared by CIFA. The full synthesis paper is given as Appendix C. Presentations were also made on major issues (i.e. nutrition and feeding, diseases and health management, and water use and environment) related to intensification of freshwater aquaculture.

The FAO also introduced experiences from a recent FAO workshop in China that developed Technical Guidelines for Aquaculture Intensification in China.

Following these various presentations, and discussions, the participants spilt into Working Groups to discuss the major issues concerning intensification. The terms of reference for the Working Groups are provided in Appendix D. The reports from the working groups are given below.

[1] Where authors of the country papers were not present, the papers were introduced to the participants, who were invited to study the written papers in detail and ensure the salient points were considered in discussions and working groups.

Working Group Reports

Group 1 – Water and Environment

Composition: Dr Jayasekera, Dr S. Adhikari, Dr K. Kumar, Dr N. Kutty
Moderator: Dr Silvarajan
Rapporteur: Dr Simon Funge-Smith

The aim of this working group was to discuss water resource issues relating to the intensification of food production through aquaculture and culture-based fisheries.

Background

South Asia has extensive freshwater resources in the form of large and small water bodies, man-made reservoirs and irrigation tanks. There are also groundwater resources exploited through tube-wells, rivers and streams. South Asia also has extensive irrigation systems. High population densities in some of the south Asian countries mean that there is competition for these water resources for agricultural irrigation, drinking water supply, sanitary use, livestock watering, hydroelectric power generation and fisheries. The multiuse of water from such bodies requires that development of fisheries and aquaculture that utilizes these resources must be integrated into existing usage.

Within fisheries and aquaculture there are occasional conflicts between those who fish water bodies and those who would stock. Frequently a group that will undertake aquaculture in a water body is a subgroup of the larger community that utilizes the water resource. This raises the question - who benefits from the intensification/development of aquaculture and culture-based fisheries?

Several communities or groups often utilize large water bodies. Such large areas make usage difficult to enforce and regulate and there are a range of problems associated with the manner in which the fisheries are stocked and exploited. There are many small water bodies in the subregion, many of which are used for water storage and are connected to irrigation systems. The patterns of ownership, utilization and management are diverse, but these bodies may be characterized as having a more limited number of resource users who may belong to the same geographic community.

There are quite few extensive irrigation systems in the region and one challenge is to add value per cubic meter of water used. Aquaculture in such extensive irrigation systems has potential both in integration of fish culture into irrigated agricultural land and also in the development of fishing in water storage structures. Irrigation systems are comprised of a number of water user groups, which may cover more than one community. This raises many issues on how intensification can be promoted in an equitable way, to cover both fisheries and aquaculture.

The use of irrigation water for aquaculture may be a significant opportunity alongside other agricultural cash crops. Comparisons of value of crop per unit water used may favour aquaculture in some cases, although this comparison is rarely done. Such aquaculture production might be relatively low, but may represent a significant source of protein or supplementary income to the families involved.

Individually owned aquaculture operations are also numerous in the region and some have potential for intensification. Increased investment or more efficient recycling of on-farm resources must meet increasing input requirements for these ponds. In some areas tube-wells are increasingly used to access groundwater for agriculture and aquaculture. This may lead to excessive extraction and depletion of the resource. This is particularly apparent for crops that have high water demand and in such cases, aquaculture may have the potential to use less water. Diversion of stream or river water for aquaculture may impact downstream users both in terms of flow and quality. However, aquaculture has significant potential in mountainous and hilly areas, particularly when integrated with water storage.

The working group discussions were based around a series of issues and were taken in the context of several categories of waterbodies - large reservoirs, medium communal water bodies, irrigation systems and individually owned ponds. The issues that were covered for these resources were: ownership, communities and the resource, management of the resource, weaknesses, government strategies and legislation and opportunities for intensification. The findings and discussions for each issue are enumerated below.

<u>Ownership</u>

Reservoirs and Large Water Bodies

- Large scale hydropower, irrigation and drinking water reservoirs are state owned.
- Water discharge is managed by the requirements for drinking water, irrigation and electricity generation.
- Fisheries departments do not have authority for making water management and use decisions.

Community Water Bodies/Tanks

- Community tanks may be owned by community or government department, often the irrigation department.
- The water bodies can be operated by the community or leased to individuals/groups.
- Although the government department or community owns tanks, exploitation for fisheries is discouraged if close to a temple.

Irrigation Reservoirs and Systems

- Irrigation reservoirs and distribution systems are often owned by the irrigation department.
- Operation and maintenance is slowly being decentralized in selected systems (in some cases in response to donor initiatives).

Individually Owned Ponds

- Tube-wells and groundwater are individually owned and controlled.
- Groundwater may be owned by the state.
- Policies vary on utilization.
- This might be extracted for irrigation and for aquaculture.
- Excessive abstraction may cause problems with salination of aquifers, reduction of flow, lowered water tables and other issues.

<u>Communities and the Resource</u>

Reservoirs and Large Water Bodies

- There are access issues; multiuser fisheries predominate and responsibility/ownership may involve several authorities.
- Access for fishing may be controlled, but extremely difficult to control.
- Reservoirs located in wildlife areas require several permits for access.
- Where there is a strong good community, there are greater opportunities for aquaculture and culture-based fisheries.

Community Water Bodies/Tanks

- Increasing use of tube-wells (due to favourable loans plus subsidized electricity for tube-wells for small farmers) in irrigation command areas reduces demand for irrigation tank water. This reduces the conflict between agriculture and aquaculture. The income generated from the tank fishery can be used to maintain the tank.
- The standing water in the tank is necessary for recharging the tube-wells through percolation. Systems such as this should be prioritized for aquaculture/fisheries development.
- Occasional conflicts occur between social groups using the reservoir (farmers and fishers) relating to water quality.
- Temple tanks and holy tanks (bathing, lotus production, etc.) cannot be used for other purposes.

Individually Owned Ponds

- Social issues relating to desire to culture fish in a pond vs. pond owner's not accepting lower caste groups' involvement.

Management

Reservoirs and Large Water Bodies

- Cost of stocking is handled by the state.
- Little correlation exists between stocking and recapture (except where large fingerlings are used).
- Communities stock their reservoirs and collect annual inland fisheries license. A proportion of the value of the catch is paid to the community fund (e.g. practice in Sri Lanka).
- Fees are collected from fishermen's cooperative.
- Common landing site for control of landings and ability to exact community/government fee. Fishers do not sell on this market, prices outside are better and illegal fishers will also not land.

Community Water Bodies/Tanks

- Traditionally controlled and serviced by a small group. The integration into a greater common area has led to a breakdown in the community structure and productivity of the systems.

Irrigation Reservoirs and Systems

- Decentralized management should be emphasized (i.e. transfer of responsibility to water user groups as has occurred in Punjab and Andhra Pradesh in India).

Individually Owned Ponds

- Household ponds used for irrigated gardens and fish may be stocked.
- Annual harvest and wild recruitment is typical in the traditional system.
- Stocked with hatchery fingerlings and intensified management is possible if aquaculture does not conflict with other uses of the water.

Weaknesses

Reservoirs and Large Water Bodies

- Large deep reservoirs can have inundated forest, which may cause problems with fisheries using large gears, and therefore fishing is limited.
- Oxygen may be an issue due to stratification.

- Poaching by non-licensed fishers poses a problem.
- Low productivity in such water bodies.
- There is limited access near hydropower structures.
- Excessive fishing pressure or illegal fishing over-exploits fish populations causing fishery decline.

Community Water Bodies/Tanks

- Culture may be perennial or seasonal.
- Affected by enrichment and eutrophication, uncontrolled use of pesticides and chemicals (sewage disposal, agricultural run-off), macrophyte infestations and silt loads.
- Lack of drainage in low lying areas.
- Poaching in community ponds.
- Widely dispersed and poorly protected by locally responsible authorities and community.
- Deteriorating physical infrastructure due to lack of maintenance and due to emphasis on major and medium irrigation systems - this requires capital reinvestment for rehabilitation.

Irrigation Reservoirs and Systems

- Dominant use of water resource by agriculture.
- Water systems are mainly geared for paddy production, so water supply for fisheries and aquaculture is never guaranteed.
- During paddy drying season, there may be insufficient water for fish culture.
- Drying down of small reservoirs for sand removal impacts fisheries.
- Water user groups are unable to effectively police water management in the system to adequately guarantee water.
- Lack of coordination between irrigation and fisheries authorities.
- Surplus water only discharged for use in aquaculture.
- Uncertainty of supply for aquaculture.
- Water logging and salinization.
- Water distribution is unequal due to infrastructure, dereliction or management.
- Irrigation water may even not be used for aquaculture as legislated in some countries.

Individually Owned Ponds

- Short culture season as some ponds are not perennial.
- Silting up and shallow of ponds common, and thus, require frequent excavation.
- Water supply may not be available, thus, limiting level of intensification.
- Effluents may impact local water resources (uncommon).
- Pollution related impacts likely to occur through agricultural run-off impacts water quality and fish health.
- Water usage for bathing and drinking purposes limits aquaculture potential.

Government Strategies and Legislation

Reservoirs and Large Water Bodies

- Promotion of community-based fish culture.
- Government will not stock large reservoirs since they consider fish as self recruiting.

Community Water Bodies/Tanks

- Promotion of community based fish culture.
- Income generating shrimp culture requires tax breaks, import tax breaks, credit support.
- Free seeds are initially given to fish farmer development agencies.
- It may not be possible to lease a water body or part of it for aquaculture purposes. In some cases this may be legally allowed but practically impossible due to multiple authorities.

Irrigation Reservoirs and Systems

- There is a general lack of policy for utilization of irrigation reservoirs and command systems for fisheries and aquaculture.
- Ponds are individually owned.
- Free seeds are initially given to fish farmer development agencies.
- Loans may be available for aquaculture but poor uptake.
- NGOs promote small-scale fish culture in rural areas, but fingerlings are not free.
- Agriculture is less attractive for income generation with respect to fish culture.

<u>Opportunities for Intensification</u>

Reservoirs and Large Water Bodies

- Some underutilized water bodies offer potential for enhanced fisheries.
- Improved management of natural fish stocks as well as monitoring and regulation of artificial stocking for further development of culture-based fisheries will enhance reservoir fish production.
- Stocking using larger fingerlings will enhance production.
- Government stocking programmes (i.e. input side of enhancement) desirable, however, harvest side may not be adequately addressed and sustainability will require cost recovery systems.
- Fishers may be individuals or cooperatives, frequently relatively new (10 years) and thus, lack cohesion, experience and technical knowledge. Strengthening these groups could enhance management and sustainability of the enhanced fishery.
- Use of cage culture for seed production (for stocking larger reservoirs) and for grow-out (floating and stake) desirable.
- Commercial species are most likely to be viable and this may limit entry to the activity due to high start up and operational costs.
- Use of pen culture (major carps) recommended.
- Green-water culture in cages (and some pens) is not possible and will require more complete feeding.
- Water quality impacts likely to occur in shallow waters; eutrophication, static water and thermocline effects may increase temperature and limit oxygen.
- Poor citing (due to requirement for guarding, access to market, landing, etc.) often leads to excessive cage density resulting to rapid disease transmission and localized water quality impacts.
- Although high production density is achieved in the cage, it is small when taken on the overall area of the water body.

Community Water Bodies/Tanks

- Small size and community owned, therefore community culture is possible, especially where the grouping is strong.
- In other cases, the community will lease out to an individual or group to manage.

- Not a technology transfer issue but more of a community or group strengthening requirement.
- Improvement of the fishery directly impacts the resource users (~80 percent which are mostly small to medium farmers).
- Seasonal bodies are easier to manage due to ability to harvest everything.
- Stocking is undertaken by community groups, government or private groups.
- A wide variety of cost recovery mechanisms (e.g. country-specific or may even be particular to a water body or community) exist and there is considerable potential for transfer of these to those who lack experience.
- Cost recovery by government is not always effective due to factors such as poor control, poaching and illegal landing.
- Wealthy farmers prefer individual operation, thus communal operation may be less popular.
- De-silting and management of the tank are needed for rehabilitation and may be offset through fisheries development. There are compensatory gains as the excavated silt (mostly sand) could be used for substituting the river sand whose utilization for construction purposes is now restricted.
- Opportunities and demand exists for mini-power generation units at minor dams/waterfalls.

Irrigation Reservoirs and Systems

- Where there is a continuous discharge, aquaculture is possible.
- Irrigation canals are not used for aquaculture but only for short-term crops (e.g. tilapia, nursery operation).
- Appropriate for air breathing species.
- Salination and water logging reduces agricultural value in irrigation systems, thus, making aquaculture a good opportunity in this environment.
- Integration of aquaculture and crops possible.
- There is pressure for resource generation and financial sustainability of irrigation tanks and systems (i.e. inability of state to maintain operation).
- Fisheries development offers opportunity for irrigation department to collect additional revenue for maintenance of infrastructure.

Individually Owned Ponds

- Fluctuation and uncertainty of income from agriculture lead to increased financial risks, thus, alternative sources of income generation such as aquaculture becomes attractive.
- Additional income and employment generation for fishermen/fish farmers generate increasing interest in alternative species, i.e. diversification for improved income generation.
- Individual ownership in most cases facilitates management, therefore, increased productivity is merely a case of technology transfer.
- Stocking increases production.
- Diversification towards carnivorous species desired, but lack of feeds is a limiting factor.
- Lack of pellet/formulated feeds limits production opportunity.
- Use of wastes such as offals are underutilized, although there may be social issues related to the acceptability of this practice.
- Stocking of the freshwater prawn (*Macrobrachium rosenbergii*) in small reservoirs, rivers and ponds desirable as well as introduction of freshwater pearl culture.
- Potentials for integration of aquaculture into water treatment and wastewater treatment exist, where such integration might include the use of aquatic macrophytes.

Conclusions and Recommendations

- Considerable potential exists for the intensification of the multifarious water bodies and resources of south Asia. However, there are also considerable constraints to the development of these resources, many of which are not well understood or are not immediately apparent.
- Aquaculture requires ownership and a degree of control of the 'property'. Culture-based fisheries require systems for management of fishing efforts and re-investment or recovery of stocking costs. Since intensification requires various inputs, investment of resources is unlikely if a direct benefit is not perceived. Large water bodies have multiple-users and stocking efforts often fail due to unsustainable stocking and cost recuperation coupled by the lack of management of fishing activity. Smaller aquaculture systems suffer from theft (in rice fish ponds away from home, cages in reservoirs) and may need security, thus affecting site-selection for aquaculture operations and may limit individual's ability to adopt the activity.
- Any effort to intensify aquaculture must take into consideration the wider issues of how aquaculture will affect others and there will be situations where intensification is not suitable. Appropriate aquaculture initiatives can alleviate poverty through enhancing fisheries yields, increased efficiency of resource use and opportunities for diversification and income generation. However, it also has the potential to increase poverty through equity issues such as loss of access to fishing areas, exclusion of the poorest from community fish ponds, loss of drinking sources, water quality and conflicts over water supply.
- The issues which mainly relate to intensification of water bodies and to a lesser extent to household ponds, are primarily socio-economic in nature. All relate to the ways in which aquaculture is integrated into the wider community and environment and these are frequently overlooked due to the sectoral nature of the institutions that deal with water and fisheries.

Information Issues Relating to Management of Inland Fisheries and Aquaculture

- There is a serious lack of information on carrying capacities of reservoirs. Characterization of water bodies suitable for aquaculture and fisheries development to allow prioritization of aquaculture and fisheries development is required. Synthesis of available information is necessary.
- There is a need for separation of wild fish production from that of stocked fisheries in collecting statistics of production.
- Riverine areas not brought under the survey/management of the fisheries departments.
- Collection of data on rivers flowing through the district and the irrigation canals from the dams to the field, for diversifying aquaculture and other uses are necessary.
- Improved collection of statistics on culture-based fisheries production and yields (fish catch) from all water bodies are necessary in order to have more accurate production estimates.
- There is a need for updated inventory/details on water resources with respect to suitability and allowed areas for fish culture. The following are important considerations:
    - Policy may restrict use of water resources for fisheries and aquaculture.
    - Proper allocation of water use for different sectors is necessary.
    - Information on sector-wise utilization of quantities and economics of water used from the available sources is inadequate.
    - Evaluation of the available statistics of water utilization and related costs for drinking, home use and irrigation (agriculture) necessary.
    - Need for collecting information on the quantities of water used by the other sectors and also respective opportunity costs involved on an annual basis.
    - Adequate monitoring system, both communal and individual, for water usage is required.

Institutional Issues

- Clear policies for aquaculture or fisheries development in water bodies are currently inadequate or in some cases, do not exist, thus, immediately constraining any initiative. Reservoir and irrigation system policies and operations need to be more adaptive to the requirements of fisheries and aquaculture. Awareness building in the other sectors (e.g. planners, forestry, irrigation, power generation) at all the relevant levels, on the potentials of stocking is necessary.
- Different sectoral policy use/authority involving usage of such water resources is a serious limitation to effective aquaculture and fisheries intensification. There is a potential for cross-sectoral body to discuss the issues of management for multipurpose water bodies (large and small). Such bodies could be formal or informal and operate from national to local level.
- Interdepartmental competition/intersectoral rivalry in water use and management of reservoirs is an important issue (e.g. a single dam with 5 stakeholder authorities (e.g. Irrigation/Agriculture Departments, Fisheries and Forestry (wildlife) Departments, Water Authority (drinking water supply), Electricity Board (power supply/generation) and the Tourism Development Corporation).
- Clear ownership or rights to access limits the ability of individuals or groups to invest their resources is lacking. Therefore, establishing ownership and right (priority) for use of water bodies like dams, irrigation tanks, etc. are necessary. The current trend to decentralize management to water user groups requires a strengthening of their ability to interact with each other and with other relevant government institutions.
- The key to management of a water body lies in understanding the variety of other social issues, which frequently impact fisheries and fish culture production, and the development of mechanisms for their resolution.
- Provide incentive, as a direct benefit to user groups to improve their resources, through re-investment of revenues generated from tank operations back to the tank system instead of being taken by state governments.
- Assessment of the applicability, transferability and potential for sustainable resource utilization of existing management initiatives/mechanisms developed by users of water resources should be undertaken.
- Motivating agencies at local level need to be established/developed.
- Fish losses occur in reservoirs and stocked water bodies as a result of:
    - violation or disregard of dead storage level/mandatory minimum level as fish refuge during low water period;
    - evacuation of the Walayar reservoir in India in 1999, under the pretext of irrigation but apparently for the clandestine removal of sand, resulted to the complete loss of both stocked and natural fish stock; and
    - illegal/unauthorized fish capture, fish landing, and poaching.
- The lack of basic support facilities to start-up culture-based fisheries and aquaculture is a special problem for individual farmers who have limited credit access for basic inputs such as nets, pumps, and seed for stocking, etc.
- Opportunities exist for the integration of aquaculture and agriculture, to diversify the species produced and to increase profitability, through the development of fish culture within existing agriculture systems, particularly those that have existing water resources.
- While technologies for culture of commercial species (e.g. freshwater prawn (*Macrobrachium rosenbergii*), snakehead (*Channa* spp.), catfish (*Clarias* spp.)) exist, entry costs to these activities are high and this opportunity may not be available for many farmers.

Principles for Water Use and Aquaculture

Some principles for responsible water use for aquaculture that integrate the requirements of different stakeholders are listed below:

- add value to water;
- use water efficiently to maximize its potential;
- aquaculture should respect other users as water is a common resource;
- water quality should be maintained to the highest quality for common use of all;
- aquaculture should endeavour to improve water quality;
- equitable access to water and fisheries should be ensured;
- intersectoral coordination should be promoted, particularly at the local level (i.e. district and community levels).

Case Studies Based on Background Material and Working Group Discussions

India

Favourable loan conditions coupled with subsidized electricity for water abstraction, have promoted tube-well construction and reduced the conflict between water requirements for agriculture and aquaculture. Income can be generated through the development of the fishery in the tanks supplying the command area, and such income from the tank fishery can be used to maintain the tank. Two important features of this system are: (a) water levels are maintained in the tank to support the fishery; and (b) water demand is lowered through the use of tube-wells. The standing water in the tank is necessary for the recharging of groundwater that supplies the tube-wells through percolation. Proper identification of locations for such systems and subsequent prioritization of those sites are needed for aquaculture/culture-based fisheries development.

Kerala, India

A large area (e.g. 124 000 ha) is not currently used for fish culture because of high yielding varieties of rice production and the associated use of chemicals and pesticides. Rice cultivation in such areas is not particularly profitable. One crop of fish as practiced in Kuttanad in South Kerala is a good alternative. Rice-fish culture could also be practiced, particularly since paddy farmers are using organic manure, other bio-fertilizers and bio-pesticides resulting from increased awareness on the harmful effects of chemicals and pesticides (e.g. Endosulphan organochlorine pesticide, currently causes considerable destruction of the plantation crop ecosystem in North Kerala). In Chittoor, farmers have abandoned sugarcane cultivation. Aquaculture integration, thus, offers potential solutions to these environmentally-unfriendly and unprofitable agricultural production systems.

Punjab, Pakistan

Although rapidly expanding activity in many regions with low rainfall, fish farming is relatively new. This is particularly true in situations where large-scale management of flowing water resources for irrigation tended to reduce the productivity of existing fisheries. In arid, semi-arid and sub-humid regions, water loss to the atmosphere consumes much of the water allocated to fish ponds. Reducing crest width and pond shape may substantially reduce this loss and the quantity of water required for pond fish culture. Depending on pond size and location, savings of up to 37 percent of total water requirements may be achieved by adopting a square design and minimising crest width. Analysis of the relative water requirements for different types of agriculture and aquaculture could lead to more diversity in crop production, greater availability of animal protein and more efficient multiple water-use options.

Orissa, India

In Orissa, the state government drafted a policy to transfer authority for reservoirs of more than 24 ha water area from the Water Resources Department to the Fishery Department in order to better exploit freshwater fisheries potential of reservoirs. Fishing rights in 80 of 129 of the state's reservoirs will be initially transferred followed by a complete transfer of the remainder of the reservoirs, if the scheme proves successful. Fishing rights to the reservoirs would not be auctioned to individuals or private commercial interests but will be made available to people living near the reservoir, irrespective of whether they are traditional fishermen or not. Management will be conducted through fishing cooperatives.

The Fishery Department will be empowered to register the cooperatives. Fishing cooperatives will be required to deposit Rs. 100 per hectare in order to fish the reservoir. Twenty percent of this amount goes to the Water Resources Department for maintenance of the reservoir; 80 percent goes to the Fish Farmers Development Agency (FFDA). The FFDA will utilize the funds to supply fish fry for stocking and for use by fish farmers. With regards to the threat of theft, fisheries extension officers will have the power to initiate appropriate action whenever theft cases are reported to them.

Group 2 – Nutrition and Feeding

Members:	Dr P.K. Mukahopadhyay, Dr S.N. Mohanty, Dr S.S. Giri, Dr P.V. Rangacharyulu, Dr B.N. Paul
Moderator:	Dr S. Ayyappan
Rapporteur:	Mr Pedro Bueno

The aim of this working group was to discuss issues related to nutrition and feeding, including feed manufacturing, feeding practices, and other related issues to be considered during the intensification process to improve production, reduce environmental impacts, and make the intensification process sustainable.

Species

In South Asia, there is scope and good potential for culturing species other than carps. These are seen to provide food and increase farmers' incomes. These include seabass and reef fishes such as grouper, milkfish, catfishes (Pangasiids and Clariids), trout, masher, murrels, featherbacks, perch, hilsa, silver barbs, giant freshwater prawn, and others. Further research and development on the breeding technology, feed and nutritional requirements for most of these species are necessary before widespread culture. As most of the breeding technologies are available elsewhere, research and technology adaptation from other countries will fill the technological gaps for these species.

Species selection criteria and users

Criteria	Users
Herbivorous fish (low in food chain)	Resource poor farmers
Carnivorous fish (high in food chain)	Resource rich farmers
Grazers and strainers	Fertilized pond culture

Suitability of aquaculture practices in relation to feeding habit

Type of aquaculture	Suitable species
Monoculture	Carnivore species
Monoculture	Omnivore species
Polyculture	Herbivores species
Polyculture	Herbivores and omnivores

An important consideration is to intensify the production of the traditional food fish species such as carps in South Asia.

The yield gap for carps in India is wide: (a) experimental farm level - 15 MT/ha l; (b) pilot farm - 10 tonnes/ha; (c) well managed farm - 6 tonnes/ha; and (d) national average - 2 tonnes/ha. Improved nutrition, mainly through provision of supplementary formulated feed, can bridge a big part of this gap. A related issue would be standard nutrient composition for each growth stage of the fish for cost-effective use of feeds.

Feed (for carps and other food fish species)

An important research issue concerns supplementary and formulated (complete) feed compositions to support various levels of intensification and various species being farmed or promoted for aquaculture.

Extension issues to be considered are:

- transfer of feed formulation to the local feed industry (private, farmer cooperatives;
- quality assurance;
- reliability of feed supply for intensive systems of species that depend mostly on artificial feed; and
- transfer of techniques to farmers.

Market and Distribution

For India, in particular, an important policy issue is finding suitable nationwide arrangement in the establishment of feed production units to supply feed to the farmers. An assumption is that a good and sustained demand for commercially formulated feed would encourage commercial feed enterprises to set up business. However, there should also be a vigorous effort from the government to develop and promote farm-made feeds, and to assist farmer cooperatives/associations in establishing feed plants to serve their needs. Another important role for the government is the development of an efficient marketing system for feed to make them readily available to farmers at an affordable price.

There is also need to rationalize the levels of feed manufacturing to cater to various aquaculture systems through:

- formulated feed manufacturing, to be located centrally, for intensive systems that rely solely or heavily on formulated feed;
- community feed mill for semi-intensive systems that depend significantly on artificial feed; and
- farm-level aquafeed production for semi-intensive production systems.

Economics of Current Production Systems

The traditional composite carp system requires low operating cost, it is often done in undrainable lands, therefore, the land rent is low. While carp prices remain low, and margins are narrow, the demand is seen to be sustained. Such traditional system will enable the farmers to continue to make money, although profitability is low, from carp farming. If carp production is intensified, this would require supplementary (even complete formulated) feed where the cost of feed will be 50–60 percent of the total input cost. If this pathway to intensification is followed, a critical need will be to improve efficiency of feed utilization, and finding and making widely available alternative local ingredients.

Another pathway is developing and promoting integrated systems. Carp aquaculture could remain as the main farm enterprise and integrated with the production of cash crops, food crops, chicken, livestock (e.g. Bengal goat), and agroforestry). A third pathway is promotion of polyculture systems of carps (as the main species) and other higher value species (e.g. freshwater prawn).

It is also important to develop multipurpose uses for water. In India, a follow-through system (6 litres/sec) has been developed for carps (initial trial used rohu) that produced 1.5–2.0 kg/m^2 of water over a three month period. Water is supplied by gravity and re-used for agriculture. In this trial system, water was used to irrigate paddy but it could very well be used for other purposes. Formulated pellet was used that yielded a Food Conversion Ratio (FCR) of around 2. It was formulated at the CIFA laboratory using standard ingredients available in local markets. This could be applicable to hilly areas (e.g. trout farms in Nepal which discharges used water into a field of crops and orchard) and diverted streams.

Likely Impacts of Intensification

The following are important considerations with respect to likely impacts of intensification.

Environmental

- Pollution of water can occur in confined environment if stocking density is increased and this could be mitigated with better nutrition, less wastage and efficient use of feed through:
    - proper feeding regime (better dispensing system);
    - improved feed quality (lower FCR);
    - optimized feed utilization;
    - stock manipulation (appropriate biomass control);
    - recycling of farm resources (including feed resources) to improve farm sustainability; and
    - use of biofilters (plant and animal) to improve water quality as well as add to farm production.

Economic

- Adoption of integrated systems for more cost-effective utilization of water and land, on-farm resources (manure, farm by-products), as well as farm labour (family and hired) is essential.

Technical

- Provision of credit for initial investment to farmers who would like to adopt integrated farming systems is important.
- Development and transfer of management skills to operate integrated farming systems;
- adoption of better management skills in feeding intensive monoculture of high value species (i.e. *Macrobrachium*, *Clarias*, etc), or polyculture with other high-value species such as *Macrobrachium* are necessary.
- Development of appropriate feeds for the concerned culture systems is required.

Strategies to Enable Intensification of Feed Industry

- A good market for formulated feeds and incentives from the government would encourage expansion of the aquafeed industry. This, however, depends on a sustained demand from aquaculture, which is in turn reliant on the profitability of using formulated feed.
- Standardization of manufacturing processes is essential.
- Quality assurance is necessary.

Competition with Other Animal Feeds and Human Food

Important issues include:

- efficiency in feed conversion;
- substitution of feed ingredient;
- use of non-traditional feed ingredients; and
- recycling of by-products as well as waste materials.

Opportunities for Non-Conventional Feeds

- Large number of feed ingredients has been identified and their nutrient compositions have been assessed. However, there is need to further study the effects of using them in terms of their attributes such as anti-nutritional factors, digestibility and nutrient bio-availability.

Feed Additives

- Non-hormonal growth enhancers are encouraged.
- Antibiotics should not be used.
- Better understanding of attractants, binders and probiotics is necessary.
- Better understanding of vitamin and mineral additives is essential.

Aquafeed Manufacturing Practices

There are standards set by the Bureau of Indian Standards. It is necessary to ensure that good practices are promoted and the standards are followed, in consideration of the following:

- quality control of ingredients and finished product;
- appropriate labelling with respect of nutrient composition, shelf-life, and optimal water stability; and
- proper advice on use of feed.

Dietary Nutrient Requirements of Cultured Species

- A good understanding of micronutrients, vitamins and minerals for cost-effective dietary formulation is essential.

Larval and Postlarval Nutritional Requirements

Better understanding of the following aspects of larval and postlarval nutritional requirements is necessary:

- technology for larval feed production (e.g. micro-encapsulation);
- physiology of digestion and feeding behaviour of prawn, catfish and grouper; and
- nutrient requirements of recruit species.

Nutrient Loads and Losses to the Environment

The following are important considerations with respect to maximizing nutrient retention efficiency:

- increasing stability; and
- increasing bio-availability of nutrients.

Nutritional Requirements of Broodstock and Stocking Material

It is necessary to have a good understanding of the following:

- increase fecundity;
- multiple breeding (performance of broodfish during spawning and post-spawning phases);
- seed quality from multiple breeding; and
- requirements of carp fingerlings during stunting and stocking.

Major Issues

- Aquaculture is dependent on agricultural and fishery resources for fertilizers and feed inputs.
- There is increased competition between users of the limited agricultural and fishery resources.
- The costs of feed ingredients and farm inputs are increasing.
- Decreasing or static market costs for the major cultivated finfish and crustacean species are important factors.
- Impacts of intensification of aquaculture production on the aquatic environment are a major risk.
- Choice of farming system affects sustainable and fish production.
- Availability and utilization of quality feed ingredients are essential requirements.

Strategies and Recommendations

- Aquaculture production can be increased by maximizing the role of natural food organisms through the use of improved pond management (i.e. fertilization, substrate enhancement, and water management techniques).
- Aquaculture of filter feeding/herbivorous and omnivorous fish should be promoted to make the efficient use of natural pond food organisms and use of locally available agricultural and animal by-products and wastes.
- Aquaculture production can be enhanced by adopting location-specific polyculture technology in semi-intensive farming systems.
- Identification of conventional and non-conventional feed ingredients/alternative protein sources for aqua-feed production should be encouraged.
- Research to verify the existing information-base supporting the commercial production of aquafeed for finfish and crustaceans should be undertaken.
- Research on the role of natural food organisms in semi-intensive farming systems should be promoted.
- Development of improved feed management strategy in semi-intensive and intensive farming systems should be undertaken.
- Integration of aquaculture with agricultural production systems should be promoted.
- Development of improved on-farm feed formulation and feed manufacturing techniques for the production and use of farm-made aquafeeds by small-scale farmers should be promoted.
- Evaluation of on-farm fertilizer and feeding regimes and strategies employed by farmers for the major cultivated finfish and crustacean species should be undertaken in order to identify gaps in knowledge as well as constraints.
- Development of regional information centres and networks on aquaculture nutrition and feeding should be encouraged.

Group 3 – Disease Control and Health Management

Members: Dr B.K. Misra, Dr R.K. Dey, Dr B.K. Das, Dr P. Swain
Moderator: Dr M. Reantaso
Rapporteur: Dr R. Subasinghe

The aim of this working group was to discuss issues related to undertaking appropriate health management measures during the intensification process to reduce the risks of diseases and disease outbreaks in aquatic production systems for better productivity.

Background

The working group examined the relevant information provided by the seven countries in the country status reports. The working group was of the opinion that all aquaculture systems are prone to diseases and health problems. The traditional extensive systems are less prone to diseases but, semi-intensive or intensive systems, particularly ill-managed systems, have the highest risk of disease incursions. Thus, health management should not be addressed on the basis of systems.

Disease outbreaks generally occur through environmental changes/degradation, poor nutrition, proliferation of resident pathogens, and through the introduced pathogens resulting from movement (introductions/transfers) of animals (seed/broodstock).

There are many pathogens of concern in the subregional countries, but it is important to categorize and prioritize "important pathogens" to be considered for prevention and control. Unknown aetiology, rapidity of spread, economic loss and severity are considered criteria for categorizing diseases.

The approach for reducing the risk of disease outbreaks should be to avoid pathogens, improve management through better management practices, control of resident pathogens, prophylaxis, and overall prevention. Subasinghe *et al*. (2000)[2] identified the requirements for an effective health management programme which covers all levels of aquaculture activity (i.e. production, farm, district, provincial level, national and regional/international levels). The success of such a broad-ranging programme relies on a continuum of open communication and information exchange flowing in all directions. The requirements are:

- strong, healthy juvenile/seed, proper nutrition, appropriate waste management, optimum water quality, and regular monitoring at the production level;
- good record keeping to include all aspects of farm operations is essential at the farm-site level; and
- good planning and siting of aquaculture farms, efficient extension services, farmer cooperatives, health management training for local fisheries officers are essential at the district/divisional/provincial levels.

[2] Subasinghe, R.P., Bondad–Reantaso, M.G. & McGladdery, S.E. 2001. Aquaculture development, health and wealth. *In*: Subasinghe, R.P., Bueno, P., Phillips, M.J., Hough, C., McGladdery, S.E. & Arthur, J.R. (eds.). *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, Bangkok, Thailand. 20–25 February 2000. FAO, Rome, Italy and NACA, Bangkok, Thailand.

At the national level the requirements are:

- resources to support one or more team(s) of health professionals and specialists with a solid communication infrastructure linking national and farm level expertise, and with access to information exchange and technology;
- national policy directives/regulations and legislation covering: (a) diagnostic services, (b) disease management and control plans (including contingency plans for emergency disease outbreaks), (c) surveillance and reporting systems, (d) health management and extension services training and education, and (e) public awareness programmes for policy-makers, farmers, national and field officers, and market consumers;
- a system to establish good communication links in order to provide appropriate consultation with stakeholders (e.g. farmers, industry, academe, research institutes, other interested groups); and
- enhanced awareness, participation and cooperation in regional/international programmes and political commitment to implement aquatic animal health agreements and respond to changes at regional/international levels.

At the regional/international levels, a regional mechanism should be cooperatively established for building joint strategies and approaches on:

- standardized techniques for disease diagnosis and screening for specific pathogens;
- codes of practice for reducing aquatic animal health risks;
- responsible and transparent reporting systems;
- accreditation of regional aquatic animal health reference laboratories; and
- mechanisms for regular monitoring and evaluation of regional/international agreements.

The group recognized the efforts of FAO and NACA and the progress made during past few years in developing and building consensus on the Asia Regional Technical Guidelines on Health Management for Responsible Movement of Live Aquatic Animals (FAO/NACA, 2000). The group strongly recommended that the relevant provisions should be implemented as early as possible to assist the responsible intensification process.

A recommended approach to address the above needs is the development of National Strategy on Aquatic Animal Health Management. In developing and implementing the National Strategy, it is recognized that the countries within the sub-region have different levels of expertise, capacities, infrastructure, and socio-economic status. The importance of learning from the lessons learned by countries in the sub-region was also realized. The components of the National Strategy are:

- legislation/regulatory frameworks/conducive policy;
- coordination of activities at local, national and regional levels;
- identification of important pathogens to be dealt with;
- adequate institutional resources;
- good diagnostics;
- disease surveillance and reporting;
- early warning systems and contingency planning;
- human and institutional resources improvement/capacity building; and
- private sector (all stakeholders) participation in implementation.

Policy and Legislation

Appropriate policies and legislation and effective enforcement are necessary for a successful aquatic animal health management programme. The following are important considerations in order to achieve this:

- integrate aquatic animal health management into national aquaculture development plans and as appropriate, designate responsible authorities and agencies with appropriate mandates, responsibilities and competency to deal with aquatic animal health matters;

- establish National Aquatic Animal Health Committees with clear terms of reference and action plans;
- identify and designate national/local aquatic animal health centres for health support services (e.g. national or state-level referral laboratories for specific diseases, etc.;
- facilitate appropriate legal framework and regulations for health certification, disease reporting, early response (warning) to disease emergencies, disease control programmes, registration of farms and hatcheries, accreditation of hatcheries for live aquatic animal control and health assurance;
- encourage national institutions and other stakeholder dialogues and consultation; and
- develop mechanisms for long-term adoption of policies and regulations and enforcement of legislature.

Quarantine and Health Certification

It is important to ensure that national policies are consistent with international obligations (e.g. trading obligations such as WTO/SPS Agreements) and to improve national status as a responsible partner in international trade. It is also important that national trading and movement of animals are conducted in a responsible manner to reduce the risks of disease incursions. Therefore, it is necessary to consider the following:

- review external requirements and conditions for domestic and international movement of live aquatic animals;
- international and domestic health certification requirements based on risk assessments to reduce risks of spreading diseases to new areas and preparation of supporting technical implementation guidelines;
- upgrade of facilities and appropriate training of staff at national, regional, provincial and local levels;
- enhanced coordination and communication between different state authorities at central to district, provincial and local levels;
- capacity building at the farmer level, and provincial authorities and research institutes;
- awareness-building on concepts of Import Risk Analysis (IRA);
- create an enabling institutional environment to deal with health certification and quarantine;
- establish procedure for registering of health certification authorities and/or persons; and
- establish networking and publication of a directory of competent authorities/persons within the subregional countries.

Disease Surveillance, Monitoring, Early Warning and Contingency Planning (Disaster Management System)

It is essential to: (a) establish an effective programme to detect disease outbreaks, as early as possible, (b) monitor existing disease problems, and (c) implement control and/or eradication strategies. These could be achieved through:

- improved participation of subregional countries to the Asia-Pacific Quarterly Aquatic Animal Disease Reporting System being implemented by NACA/FAO and the Office International des Epizooties (OIE) through assistance to capacity building on diagnostics, surveillance, etc.;
- field-level dissemination of Level I diagnostics (FAO/NACA 2000)[3] and implementing farm level surveillance;
- training on epidemiology, pathology and participatory approaches to disease assessments; and
- establish a national early warning system and contingency plan.

[3] FAO/NACA. 2000. Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals. FAO Fisheries Technical Paper No. 402. Rome, FAO. 2000. 53p.

Diagnostics, Therapy and Control

Delivery of an effective aquatic animal health diagnostic and advice services to farmers and improving aquatic animal health certification is essential. The following are important considerations:

- different levels of diagnostics as outlined in the Asia Technical Guidelines on Health Management;
- development of cost effective rapid diagnostic techniques;
- standardization of diagnostic techniques and national level inter-calibration exercises;
- standardization and validation of diagnostic techniques and networking among the subregional countries and laboratories;
- enhancement of laboratory facilities and expertise;
- in-house training for field laboratory officers at appropriate research institutions;
- collaboration between terrestrial and aquatic animal health services;
- long-term capacity building and educational programmes;
- regulation of veterinary drug use; and
- development of national veterinary drug licensing, registration and inventory programmes.

Aquatic Animal Health Information Systems

It is necessary to consolidate information on aquatic animal diseases. This could be achieved by:

- development and establishment of an aquatic animal health information system - mechanics, over-all coordination, requirements, linkages;
- integration of such systems into field extension services;
- training on database management, data analysis and computer skills;
- institutional strengthening for handling information and data; and
- participation of subregional countries in FAO's Aquatic Animal Pathogen and Quarantine Information System (AAPQIS).

Awareness, Extension Education and Communication Programmes

Increasing awareness on aquatic animal health issues, and improving linkages and communication between farmers, service providers, provincial officers, extension staff, national and international agencies are essential. These could be achieved through:

- development and provision of educational and training resources to farmers and the general consuming public;
- development of university-level training on aquatic animal health management (i.e. inclusion in fisheries and veterinary medicine curricula);
- on-site demonstration/education/training programmes;
- establishment of effective extension services through delivery of farm-level health management extension materials, and effective problem solving skills;
- promotion and delivery of effective health management practices and harmonized advice through various entry and control points (e.g. fry producers/ suppliers, fry traders, farmer networks, NGOs, extension officers, universities, etc.);
- building strong linkages between farmers, diagnosticians, researchers and policy-makers and improving communication at all levels (i.e. national, provincial and district levels);
- encourage, establish, and implement technical cooperation programme among farmers (e.g. selfhelp programmes); and
- increase awareness on concepts such as import risk analysis, contingency planning and zoning.

Research and Development

The following are important considerations:

- prioritize research areas in aquatic animal health management based on identified needs;
- evaluate the practical application of researches conducted by research institutes, universities;
- undertake more problem-solving research;
- emphasize on traditional disease control methods such as herbal remedies, etc.;
- effective dissemination of research findings;
- conduct on-farm intervention trials with farmers;
- integrate research output and finding mechanisms to use research output as basis for policy decisions on health management;
- basic knowledge on aquaculture and aquatic animal health should be a pre-requisite for engagement in research, extension, and advice on aquatic animal health management;
- improved aquatic animal health facilities of both government and research institutions;
- explore possibilities of industry participation in research where research institutions conduct industry-led, timely, problem solving research with financial and other assistance from the private sector; and
- establish a mechanism for registration and licensing of aquatic animal health professionals.

Resources and Funding

Generation of finances from the government (and other possible external sources) to support the different components of the National Strategy (within the short- and long-term time-frame) and also technical and financial support from regional and international donor agencies is essential. It is important to encourage project proposal development by the national institutions for external funding while influencing increased state commitment. Mechanisms for generating financial support from the private sector should be identified and implemented and important lessons learned should be shared among regional countries.

Regional and International Linkages

In order to enhance national capacities on aquatic animal health management, regional and international linkages should be strengthened through regional activities that will promote:

- regional cooperation and approaches to disease control programmes for shared watersheds;
- sharing of information and experiences;
- standardization of techniques for disease diagnosis, etc.; and
- cooperation in the adoption of regional and international agreements and standards on aquaculture health management.

Major Issues and Recommendations

- Diseases have become a primary constraint to sustainable aquaculture production and product trade and will remain a key issue during the process of intensification.
- Specific examples on the impacts of transboundary aquatic animal diseases on international trade, as well as socio-economic and biodiversity implications are available and these should serve as important guide to regional countries.
- Different measures are needed to deal with diseases of fish and shellfish in terms of international codes, regionally oriented guidelines, national programmes and legislation, technology for diagnostics, therapy and information communication.
- Approaches to aquatic animal health management should cover generic (e.g. good husbandry, prevention and control), systems health management and epidemiological approaches (e.g. disease surveillance and reporting systems).

- Aquatic animal health management programmes carried out in different countries are different in terms of efficacy of disease prophylaxis/control and pathogen detection/disease diagnostics, national legislation, obligations to international agreements and other regional codes, and the effectiveness of programmes on education, training and extension services.
- Health management problems do pose risks to rural small-scale aquaculture, and there is a need for special consideration of this aquaculture sector.
- There is a need for effective communication at all levels of the production system
- Identification of the roles of the private sector (e.g. aquaculturists, industry associations, cooperatives, etc.), professional societies, diagnosticians and researchers, in education, research, training and other related extension services for effective health management are important.
- State sector participation and enhanced contribution and commitment to health management are vital.
- Over the past few years, particularly in Asia, understanding and knowledge on health management of aquatic animals increased through strong awareness building among countries and involved stakeholders and this should be continued
- The implementation of the Asia Regional Technical Guidelines on Health Management for Responsible Movement of Live Aquatic Animals which will positively assist health management process during intensification.
- National Aquatic Animal Health Management Strategies, based on the needs of the country, considering the above issues, should be developed and implemented.

Group 4 – Seed Resources

Members: Dr R.K. Jana, Dr Swar, Dr Karma, Dr R.N. Mandal, Mr C.D. Sahoo and Ms A. Antony
Moderator: Dr Swar
Rapporteur: Dr R.K. Jana

Seed Production

The ready availability of good quality fish seed plays a vital role in sustainable development of aquaculture. In many cases, while potentials for intensification of aquaculture exist, the unreliable or seasonal supply of fingerlings presents a major constraint. Fingerling prices may be high in situations where there is high demand and limited supply. The quality of fingerlings is also typically low in such situations, since farmers will buy and stock any fish that they can obtain.

Choice of species is another limitation to intensification. As farmers seek to diversify out of traditionally cultured species, the fingerlings of more commercial species may not be available locally. In south Asia, the lack of seed is currently limiting the expansion of culture of certain carnivorous species such as *Clarias* spp. and *Channa* spp. and freshwater prawns (*Macrobrachium rosenbergii* and *M. malcolmsonii*).

Fairly well-developed technologies for mass production of the Indian and Chinese carps exist in the countries of south Asia. These methods, while robust but not highly efficient, are relatively well adapted to the environmental and economic conditions typically encountered in south Asia.

The working group concluded that ensuring greater availability of high quality fish seed is dependent upon different factors as discussed below.

Local production of fish seed is an important goal. This requires the creation of an enabling environment for private sector hatcheries such as:

- development of markets (establishment of fishing groups for stocking water bodies, extension and technology transfer to pond farmers);
- fingerling trading and transportation;
- good quality broodstock (both genetic and nutritional);
- support to health management;
- access to finance;
- access to technical knowledge; and
- portable or mini-hatcheries for farmer-based seed production.

Hatchery hygiene is typically poor and water supplies in small-scale hatcheries are usually reliant on surface water. Such water has already passed through fishponds prior to use in the hatchery. Poor water quality in the hatchery immediately reduces fertilization and hatching efficiency. The steps required to improve water quality are various and may not be economically viable in many cases. Simple actions include: (a) use of settling ponds or water improvement ponds, (b) water storage in reservoirs that do not have stocked fish, (c) use of fine mesh screens, (d) mechanical filtration, and (e) simple recirculation.

Improvement in nursery management is also necessary. Considerable mortality of seed from hatchlings to fry stage is a common problem encountered and is the result of poor management. Reduction of this mortality can be achieved through sufficient feeding, exclusion of predatory/wild fish, frogs and insects from the nursery pond, and effective fertilization for natural food production.

Intensive stocking of fingerlings in restricted holding conditions leads to stunting problems. There are management issues concerned with cannibalism and this system could be improved further. Extending the period of availability of fish seed could be ensured by prolonging the breeding season. Re-maturation and multiple breeding of broodfish are management related actions, but do relate to available resources (especially feed quality and water area) at the hatchery.

Wild fish are commonly used for improving the genetic quality or rectifying in-breeding. This should not be relied upon for the maintenance of long term genetic quality; the maintenance of aquaculture stocks should be a long-term goal.

Pure line fish seed should be maintained by controlled breeding techniques using as hypophysation. Records must be maintained for these lines. It is important to keep fish at a number of locations to ensure that the stock is not lost completely as a result of mortality from disease or environmental problems.

Uncontrolled hybridization between carp species should be avoided at farm level.

Major Recommendations of the Consultation

The following recommendations were discussed and agreed during the final session of the Expert Consultation.

General Recommendations

1. Review of policies, regulatory frameworks and institutional arrangements on water use for aquaculture and culture-based fisheries in medium and large water bodies was considered to be of high priority and timely for the efforts in assisting the intensification process. Therefore, the Expert Consultation recommended that appropriate country case studies/reviews be soon conducted by FAO in collaboration with NACA, and a South-Asia Subregional Workshop be subsequently conducted. It is also recommended that relevant divisions of the FAO Agriculture Department (AGLW - Agriculture, Land and Water Division) be consulted during the process. The participant from Nepal offered to host such a workshop.

2. Screening and mapping of locally available non-conventional feed sources, with emphasis on replacement of fish meal in aquatic feed was also recommended. Providing adequately nutritious feed at affordable cost is of primary importance to intensification of aquaculture and sectoral sustainability. Recognising this importance, the Expert Consultation requested FAO and NACA to initiate an activity (e.g. a baseline survey) towards evaluation and conducting an inventory of non-conventional feed resources in South Asia.

3. Under the broad umbrella of aquatic animal health management, the Expert Consultation felt that there is a strong need for introducing novel concepts of disease control, particularly for diseases of trans-boundary importance, to the relevant policy-makers and regulators of the sub-region. Recognising this need, the Consultation recommended that FAO and NACA organise a subregional training programme on import risk analysis (IRA), early warning systems, and contingency planning on aquatic animal health management. The Consultation expressed the need for increased awareness amongst policy-makers relating to the issues of international trade, particularly required under WTO-SPS agreement, and recommended that a subregional training programme be formulated and conducted.

Specific Recommendations

The Expert Consultation formulated more detailed recommendations that would support sustainable intensification of fish production in South Asia in specific areas as enumerated below.

Reservoirs, Large Water Bodies and Irrigation Tanks

1. Identify practical examples of comanagement of water bodies with culture-based fisheries, recorded case studies of community management/comanagement mechanisms.
2. Based on recorded case studies, prepare guidelines for the development and application of comanagement and culture-based fishery technologies in common resource water bodies.
3. Reservoirs/water resource development should include appropriate fisheries within environmental impact assessment (EIA); implementation of the recommendations resulting from the assessment should be implemented.
4. Case studies of cage culture (involving several countries) should be gathered to provide examples and strategies that create positive social and economic impacts, with suitable

environmental mitigation measures. Demonstrate and promotion of environmentally acceptable cage culture practices should be undertaken.

5. The participants suggested development of local design demand feeders for cage culture/pond culture.

Small Scale Aquaculture and Resource Poor Farmers

1. Guidelines for aquaculture development should be developed that specifically focus on resource poor farmers.
2. Localized feed production for aquaculture should be promoted.

Support to Health Management

1. Establishment of local primary health centres/aqua-clinics to support small-scale aquaculture.
2. Promotion of one-stop aquaculture-clinics/aquaculture-shops.

Policy Related Issues

1. A policy study on the effects of differential tariffs for agricultural and aquacultural feedstuffs should be undertaken.
2. Comparative evaluation and water budgeting for aquaculture systems and in comparison to agricultural usage should be undertaken.

Appendix A: Expert Consultation Agenda

Tuesday, 16 October 2001

1. Opening Ceremony
2. Introduction and Objectives of the Consultation
3. Country Paper Presentations
   - Bangladesh
   - Bhutan
   - India
   - Nepal
   - Sri Lanka
4. Technical Guidelines (Chinese experience, as related by FAO).

Wednesday, 17 October 2001

5. Presentation of Synthesis Paper and Discussion of Major Issues Related to Intensification.
   - Nutrition and feeding.
   - Diseases and health management.
   - Water use and environment.
   - Perspectives from the point of view of government planners and policy-makers, technical experts, producers and others.
6. Presentation of Global Perspectives Followed by Discussions.
   - Nutrition and feeding.
   - Diseases and health management.
   - Water use and environment.
7. Discussion on Preparation of Draft Consultation Recommendations and Draft Technical Guidelines Including Formation of Working/Drafting Groups.
8. Working Groups.
   - Working Group 1: Water and Environment
   - Working Group 2: Nutrition and Feeding
   - Working Group 3: Diseases Control and Health Management
   - Working Group 4: Seed Resources

Thursday, 18 October 2001

8. Working Groups (Continued).
9. Plenary Discussions of Working Group Findings.
10. Working Groups Incorporate Comments and Finalize Their Work on Draft Recommendations and Draft Guidelines.

Friday, 18 October 2001

11. Plenary Discussions and Finalizing of Draft Recommendations and Draft Guidelines.
12. Presentation and Adoption of Consultation Report.
13. Closing Ceremony.

Appendix B: List of Participants

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Appendix C: Synthesis Report

Synthesis Report prepared for the FAO/CIFA/NACA Expert Consultation on the Intensification of Food Production through Aquaculture in LIFDC Countries

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Introduction

Due to rapid urbanization and industrialization of developing countries, the available agricultural land and water areas have been greatly reduced. The growth of population is inversely proportional to reduction of these resources. To cope up with the situation, there is a need to develop technologies that can provide scope for enhancing production levels from an available unit area. The production technologies pertain to the monoculture and polyculture of cultivable species under extensive, semi-intensive, intensive/super-intensive levels as well as raising fish using running water facilities, integrated farming, cage and pen culture practices, etc. Technologies for many of these systems are already available but may need suitable modifications to suit local conditions. In some cases, standard technology packages have yet to be developed using the components of genetics and biotechnological tools.

The genetic potentials of many economically important species have yet to be fully tapped in these countries. In India there has been an initiation of conservation and preservation of wild fish populations. With regard to aquaculture genetics, methodologies have been already developed for genome manipulations and selective breeding of carps. Development of planned and systematic breeding programmes could help in production of good quality fish seed with traits showing high survival, better growth and increased resistance to disease and other adverse environment factors.

The classical selective breeding and the modern genetic and chromosomal engineering or a combination of these technologies may form a potential support to the farming systems to reduce the culture period and cost of production, thereby making it a sustainable and profitable endeavour.

Based on information from country status papers, fish culture practices followed by participating countries are more or less the same and mainly based on extensive, semi-intensive and, to some extent, intensive systems. Integrated farming developed in China is not common or practiced on a large-scale in some countries of the region.

The recommendations for intensification of culture of food fishes should be based on the nature of water bodies available in a country. Water bodies existing in participating countries are in the form of ponds, tanks and reservoirs. Except for Bhutan, where the mountain nature of land restricts fish culture, enough water bodies of different categories exist, in countries like India, Bangladesh, Pakistan and Sri Lanka, which are suitable for aquaculture purposes. The information provided in the status papers also suggests that: (a) the various aquaculture systems followed are more or less the same; and (b) cultured species mostly include the Indian and Chinese major carps besides the local varieties.

While recommending the technologies and protocols for intensification of aquaculture, it is important to take into account the criteria (e.g. type of water bodies available and their nature) and the category of farmers (e.g. resource rich, marginal, poor, etc.).

Nature of Water Bodies Available for Culture

Reservoirs

Fish farming is practiced in reservoirs which are formed from to dam construction across rivers and those found in urban/rural areas. These are generally categorized (based on water area) as large (above 5 000 ha), medium (1 000–5 000 ha) and small (up to 1 000 ha) reservoirs.

Ponds for Table Fish Raising

- Large ponds (above 10 hectares)
- Small ponds (below 10 hectares)

Ponds for Seed Raising

- Perennial
- Seasonal
- Irrigation ponds

Available Culture Practices

- Extensive
- Semi-intensive
- Intensive
- Super-intensive
- Integrated farming
- Cage-culture
- Pen-culture
- Paddy cum fish culture
- Flow-through or running water facilities

Recommendations

Technologies

Recommended technologies suitable for different water bodies are described below.

i) **Reservoirs (riverine)**
Depending on the fertility (natural productivity) and type of food available, the species to be stocked need to be selected. The ratio of species also depends on the type of food available in the ecosystem. Apart from direct stocking and rearing, reservoirs, due to their large area and high water depth, may serve as one of the most ideal environment to develop cage culture systems, more or less along the lines of cage culture of Atlantic salmon and rainbow trout in Norway.

ii) **Small Reservoirs**
Though not very common, there exist (in some places in India and possibly in other participating countries) relatively large tanks with good catchment area which are usually termed as reservoirs for storing water either for irrigation purpose or for drinking. If it is for irrigation purpose, fish culture can be taken up in these water bodies at an extensive level.

iii) **Ponds Above 10 ha**

These large-sized water bodies may be suitable for intensive and super-intensive fish rearing. In such bodies, average depth is between 2–3 meters, hence, high stocking density is possible. For intensive culture using high stocking densities, heavy input (e.g. fertilizers, feeds, aeration, etc.) becomes one of the important aspects of the technology package, not only for activating the metabolic rate in the fish but also for relatively rapid mineralization of the unutilized feed items and to maintain the oxygen level in the medium. These types of ponds are mostly suitable for resource rich farmers.

iv) **Ponds below 10 ha**

These water bodies may be suitable for undertaking semi-intensive farming as these are relatively easy to manage. These are also suitable for middle-income farmers.

v) **Ponds/Tanks**

Some perennial or even seasonal type of water bodies fall under this category, with water spread of at least one ha. These water bodies can be used for fish culture by applying extensive culture technologies. This system will be quite suitable for marginal or even resource poor farmers.

Ponds or tanks which are around 0.5 ha or less and seasonal in nature can be used for rearing fry/fingerlings for culture purpose. This can be taken up in rural areas as employment generation and poverty alleviation programmes to raise two to three crops of fry/fingerlings.

vi) **Cage/pen culture**

Reservoirs are well suited for cage culture. Other larger water bodies like *bheels* in Assam and some lakes may be suitable for pen culture in an enclosed area.

Suitable Candidate Species

Depending on the preference of the consumer of a country or in a particular region of the country, the candidate species for culture have to be selected and the type of water bodies also have to be taken into account. The following are important considerations:

- Reservoirs and other larger water bodies are suitable for carp culture or large catfish culture.
- Medium water bodies may be well suited for culture of carps, prawns (fish-cum-prawn), small size catfish like *Clarias batrachus*, *Heteropneustes fossilis,* etc.
- Seasonal or other small size ponds may be much suitable for spawn rearing or culture of minnows such as *Amblypharyngodon* sp., *Puntius* sp. *Gobids,* etc., species which have shorter life cycles and at the same time relished by the rural poor. Almost all these species form a part of the daily meal among the rural people in these countries. However, these species are not cultured in a regular and systematic manner as no proper technologies are yet developed. They are naturally available in ponds and other water bodies and are harvested to meet the local demands. Development of systematic culture technology for these species is needed.

Other species of fish suitable for culture in smaller ponds are the murrels or snakeheads belonging to the family *Chennidae* (formerly *Ophiocephalidae*), consisting of only one genus, *Channa.* Four species are common: (a) *C. marulius*, (b) *C. striatus*, (c) *C. punctatus,* and (d) *C. gachua*. These are highly preferred food fish especially among the rural people in India.

Murrels are mostly bottom living fish. They burrow into the upper layer of the mud in the pond and can remain there for considerable time. They are very strong and hardy fish and can remain alive out of water for considerable time, making them available for sale in live condition like catfish, and thus attract customers.

Presently, the problem posing the culture of these species is mainly the availability of seed in sufficient quantities and proper feed (mostly high animal protein feed).

Constraints to Development of Aquaculture

Availability of Seed

The first and foremost constraint in aquaculture farming is the availability of adequate quantity of pure seed of the desired species.

Transport

Once the seed is available, then the next constraint is its transportation. Most fish farms are usually located away from the hatchery site. Obtaining carp seed, is not as difficult as obtaining seeds of other cultivable species like the catfishes, minnows, shrimp/prawn as the production of seed of these species is low.

Food and Feeding

Appropriate feed for various stages, from eggs to fry, is one of the most essential aspects in up keeping of sustainability of production. The cost of feed ingredients is increasing, adding to the cost of production. It is therefore essential to develop affordable and efficient feeds. Feed being one of the main inputs in intensive farming, which plays a major role when considering the viability and sustainability of the aquaculture industry in an eco-friendly manner.

Available Feed Inputs and Future Guidelines

Present Status in Various Countries

Consequent to several nutritional studies in India (and elsewhere), feed formulations for different culture species of fish and shellfish have now been made possible. However, in most south Asian countries, farmers still use their own farm-made feeds due to non-availability of prepared balanced dry pellet feeds. Most often, fishmeal or any other animal protein is incorporated in order to improve the biological value of different plant feeds. In Sri Lanka, for example, feeds consisting of local ingredients like rice bran, fishmeal and *"coconut poonac"* are used to support subsistence level of carp farming. The feed scenario for freshwater giant prawn in the country underwent a transformation to the use of pellet feed comprising 20 percent sprat heads, soybean powder and egg mixture, 29.5 percent rice bran, 10 percent wheat flour, 0.5 percent vitamins and minerals. Chicken feed is also used for small-scale prawn farming. A diet containing 20 percent protein was used for cage culture of tilapia on experimental basis.

In Myanmar, feed made up of cake-bran mixture is used by farmers. Egg yolk or egg custard is used for catfish fry rearing in addition to the use of *Moina* and *Artemia* nauplii. Pellet feeds manufactured by a government feed mill are also reported to be used in catfish farming.

Farmers of Bhutan use wheat bran, rice bran, kitchen wastes, etc. as feeds. Attempts are made in government fish farm to use other ingredients like mustard oil and soybean cakes in addition to wheat bran for carp broodstock management including grass carp which are also feed with plant feeds. Use of starter feed and formulated feed (prepared from oil cakes and soybean) is limited to government farm in Bhutan. Although 83 fish feed ingredients of both plant and animal origins are identified in Bangladesh, supplementary feeding using cake-bran is still the trend. This kind of feed is sometimes fortified with growth promoters, salts, minerals and vitamins for gonadal development in brood fish as reported in some hatcheries in Bangladesh. The feeds incorporated with fishmeal or dried blood meal containing 25–30 percent protein are used in seed rearing practices. Improved feed scenario with formulated feed containing 30–40 percent protein, 30–35 percent carbohydrate, 5–7 percent fat and 1–2 percent vitamins and mineral premix has been reported for shrimp/prawn farming to a limited extent.

It is evident from the foregoing account that feeding using improved supplementary feed or balanced feed to intensify production levels of fish and prawn is yet to take up a momentum and efforts are required to standardize aquaculture feeds for every growth stages of candidate species.

Future Guidelines and Recommendations for Feeds

Based on the experience and studies conducted at CIFA and elsewhere, the following guidelines may be considered for effective feed and feed management. The artificial feeds of carp and prawn should contain 25–30 percent protein, 8–10 percent lipid, 25–26 percent carbohydrate and 3.5–4 kcal/g gross energy with P/E ratio of 88–113 (mg/kcal energy) and also 1–2 percent vitamins and minerals especially when feed pelletization is contemplated. Protein levels in catfish diets are kept as high as 30–40 percent, which could be significantly reduced by providing them adequate quantity of lipid as much as 30 percent. The ten essential amino acids and the two essential fatty acids (n-3 and n-6) need to be balanced in feed formulation. In prawn diets, 0.25–0.5 percent sterol and cholesterol are required.

Feeds should be prepared using locally available ingredients of both plant and animal origin. For the commonly used blood meal, available ingredients like rice bran wheat bran, groundnut oil cake, soybean meal, fish meal, meat meal, silk worm pupae and several other indigenous materials may be used for this kind of feed depending upon their availability in a locality and costs. Particle and pellet size feeds are important considerations and should be adjusted according to the size of fish and prawn. Larval diet should reflect the biochemical composition of zooplankton/*Artemia* for their amino acids, molecular weight and essential fatty acids with proper particle size. It is further suggested to use probiotics and phospholipid compounds in carp larval diets.

Improved supplementary/balanced artificial feeds should be made available in conjunction with adequate natural food supply. Plankton production can be increased using suitable fertilization packages at regular intervals. This is most important for extensive farming where plankton is the only source of nutrients and energy. For semi-intensive systems, supplementary feeds need not necessarily be nutritionally balanced but should be adequate to supplement the deficiencies. Feeding of single ingredient as supplementary feed is not beneficial. Understanding that interactions between natural fish food supply and artificial feeds economize feed cost and greatly influence the dietary utilization is essential. Feeding of formulated diet along with natural food supply in semi-intensive systems helps in increasing the production level beyond 3–4t/ha/yr.

A large proportion of alternative protein sources should be used for preparation of freshwater fish and prawns feeds. It is important to consider the formulation of less-expensive feeds to support sustainability of aquaculture. The information generated also needs to be disseminated to the private sector for commercial production, and subsequently made available to farmers and entrepreneurs at affordable prices.

Use of locally available ingredients (e.g. plant materials) for feeds should be encouraged in order to lessen dependence on expensive feeds such as fishmeal. Feed ingredients and formulated feeds have a reported of up to a maximum of 3–4 months under tropical conditions depending on the variety used; vitamin pre-mixes are preserved for a maximum period of 6 months under cold conditions.

Feeding Practices

Carp

Finely powdered feeds are used for both seed and small fry; granules for bigger fry. Dry pellets, when used, are grounded or crushed. In advanced laboratories or hatcheries, automatic feeders are used at desired intervals. A feeding frequency of 30 min to 1 hour interval, commonly practiced in hatcheries, is reported to yield good results in terms of high growth and better survival. In grow-out ponds, feed doughs or dry pellets using feeding basket suspended in ponds are commonly used. Feeding twice a day (morning and evening before sunset, in equal amounts) was found to be beneficial. The table below shows the feeding requirements used for different stages of carp.

Table 1. Feeding requirements of different stages of carp.

Carp Seed-Fry (culture period of 15 days)	Fry-Fingerlings (culture period of 90 days)	Grow-out (culture period 10–12 months)
4 times of initial body weight (first week) 8 times of initial body weight (second week)	6–8% of biomass (first month) 5–6% of biomass (second month) 3–4% of biomass (third month)	2–3% of biomass (first month) 1–3% of biomass (from second month onwards)

Magur

The magur eggs are reared for 12–14 days indoor with mixed zooplankton, *Artemia* nauplii, molluscan meat, tubifex and egg custard as larval feed. Egg custard is supplemented with vitamins and minerals. No feed is provided until 4th day of hatching and as soon as yolk absorption starts small quantity of feed is given. Larval feeds are provided from 5th day onwards.

Initial feeding starts with feed particle/organism of 20–30µ and the size is increased gradually to 50–60µ for one week old fry. Bigger-sized fry are removed and shifted to other containers. Unutilized feed and excreta of fry need to be removed through 50 percent water exchange with constant aeration. Fry which are 10–12 days old are stocked in large containers using appropriate density, and fed with reduced quantity of *Artemia nauplii* supplemented with zooplankton, Tubifex, molluscan meat or fish flesh for 10–12 days. Advanced fry and fingerlings are fed artificial feed comprised of finely minced trash fish/molluscan meat and rice bran (1:1 ratio) or any other formulated feed at 5–10 percent of body weight, daily during morning and evening hours.

Prawn

It is observed that prawn larvae of different stages require 5–50 brine shrimp nauplii (2–10 nauplii/ml) and should be provided with feed at the rate of 50–150 µg/day/larva. The feed quantity depends on feed utilization by the larvae and is decided by the hatchery operator through visual estimation. In the event of over-feeding, it is necessary to exchange 70–90 percent of the culture water.

Table 2 . Level of acceptance by different larval stages to different types of diet.

	Larval diet	Level of acceptance
I. Principal		
1.	*Artemia* sp. Nauplii	Highly acceptable to all larval stages
2.	*Tubifex* spp. cut pieces	Good acceptance
3.	*Acetes* spp. Suspension	Good acceptance
4.	Freshwater mussel (*Lamellidens* spp.)	Good acceptance of gonad and foot tissue
5.	Mussel meat + egg custard + milk powder + vitamin mineral mix	Active feeding by zoea IV to zoea XI
6.	Fish flesh + egg custard + wheat flour + milk powder + vitamin mineral mix	Active feeding by zoea IV to zoea XI
II. Secondary diets		
7.	Mushroom (cut pieces)	Active feeding by zoea IV to zoea XI
8.	Soya products	Active feeding by zoea IV to zoea XI
9.	Freshwater snails	Gonad tissue only
10.	Marine bivalves (*Perna* sp; *Anadora* sp.)	Gonad tissue only
11.	Stomatopod meat (*Squilla* sp.)	Moderate acceptance of the tissue suspension
12.	Earth worm (cut pieces)	Active feeding by zoea VI to zoea XI
13.	Fish flesh	Good acceptance
14.	Hen's egg (custard)	Good acceptance

For feeding the prawns in grow out ponds, feeds are provided at 5–10 percent of body weight, and pellet size 2–3 mm in diameter. In polyculture of carps and prawn, feeds are provided at 2–5 percent of body weight. Artificial feeding normally starts after seven days of stocking. About 60–65 percent of the ration should be provided during night hours. In grow-out, feeds are provided along the water edges of pond or simultaneously in check-trays suspended in water 2–3 m away from the pond dikes. The feeds may also be provided using feeding trays/baskets suspended in water at least at 6–7 positions in the ponds, depends on the size.

Health and Environment Monitoring

Monitoring of health and environment in aquaculture is important, particularly in intensive/super-intensive systems, in order to harvest healthy crops with high survival and optimum growth. Due to heavy inputs of feed and fertilizers, diseases occur more frequently in intensive culture systems. The following measures are suggested for health and environment monitoring.

Health

Diseases have, during the last decade, become significant constraints for successful aquaculture and hampered production and trade of the aquaculture sector. Extensive farm level survey conducted by NACA in 16 countries of the Asia-Pacific region suggested that diseases and related problems have probably caused annual losses of more than US$ 3 billion/year. Besides this negative economic impact, pathogen transfer and subsequent disease outbreak in natural aquatic ecosystems have caused significant impact on aquatic biodiversity.

Disease Emergence in Various Types of Culture Systems

In the traditional or extensive system of fish/prawn culture, less disease outbreaks occur because of low stocking density and absence of any inputs. In semi-intensive, intensive and super intensive systems with very high stocking densities and high input of supplementary feed and fertilizers, outbreaks of infectious diseases and occasional appearance of non-infectious diseases caused by environmental deterioration and nutritional deficiencies are reported.

Occurrences of Diseases in the Participating Countries

Bangladesh

A number of diseases are of major concern to fish growers. These include infections by protozoan and metazoan parasites, bacteria and fungi. However, most serious losses have been caused by Epizootic Ulcerative Syndrome (EUS) which appeared first in 1988. EUS caused severe losses in total fish production, drastic reduction in market prices and also consumer rejection. Some wild species of fish may be under pressure of extinction due to EUS. More recently, the frequency of EUS is reported to have decreased. Shrimp disease such as White Spot Disease (WSD) is also a serious problem in brackishwater. Ectoparasites such as *Argulus* and *Lernaea* cause serious disease problems particularly in broodfish.

Bhutan

No information is available about the types of fish diseases occurring in ponds or tanks and their management strategies practiced although culture of indigenous warm-water fish species have been undertaken by the National Warm Water Fish Culture Centre (NWWFCC) under Gelephu Integrated Area Development Project (GIADP).

Pakistan

No major disease problems were reported from farms in Pakistan until 1996 when the first outbreak of EUS was confirmed and heavy mortality occurred in the Punjab province. Isolated cases of fish diseases caused by protozoan and metazoan parasites, fungi and bacteria have been recorded.

India

Two of the most serious diseases creating concerns and constraints in the aquaculture sector of the country are EUS and WSD. EUS affected a wide variety of fishes both in the wild and cultivated conditions throughout the country from 1988 until present. WSD affected brackishwater prawns from 1993 onwards. Various stages of carp and catfish culture are affected by various diseases such as: (a) bacterial diseases (e.g. bacterial septicaemia, columnaris disease, fin and tail rot, edwardsiellosis; (b) fungal diseases (e.g. saprolegniasis, achlyasis, branchiomycosis; (c) parasitic diseases (e.g. ichthyophthiriasis, trichodinosis, myxoboliasis, dactylogyrosis, gyrodactylosis, argulosis and lernaeasis).

Although there are no reports of any serious disease outbreaks in the mature freshwater prawns (*M. rosenbergii* and *M. malcolmsonii)* several diseases caused by viral, bacterial, fungal, parasitic, ectocommensals, nutritional and environmental deterioration have been reported. In hatchery and in grow-out systems. These include larval mid-cycle disease (MCD), bacterial necrosis, exuvia entrapment disease, epibiont fouling disease and black spot disease.

Sri Lanka

EUS was first observed to occur in 1987 in natural water bodies affecting a wide variety of fishes of which *C. striatius* and *C. punctatus* were the most severely affected ones. The disease spread to almost all natural water bodies including every small stream causing heavy mortalities in natural fish population. In culture practices, parasites (e.g. *Piscioodinium* sp., *Cryptobia* sp., *Trichodina, Scyphidia, Ichthyophthrius, Myxobolus, Dactylogyrus*, Digenian metacercariae, *Lernaea, Ergasilus, Synergassilus)* have been reported to cause frequent losses. Bacterial disease in *Catla catla* and mrigal fingerlings in ponds and gill rot in grass carp brooders have been reported causing severe losses; while fungal disease caused by *Saprolegnia* sp. has been reported in *Labeo rohita* .

Remedial Measures (Preventive/curative)

Good husbandry management
The most effective and recommended procedure for controlling disease is good management of ponds. Good water quality, appropriate feeding, reducing stress, etc., are important components of good management.

Disinfection of ponds[4]
Drainable ponds should be thoroughly dried and exposed to sunlight for about 10–15 days. In non-drainable ponds, bleaching powder (Calcium hypochlorite 50 ppm) should be applied in order to get rid of all unwanted fishes, molluscs, tadpoles, crabs, etc. It also serves as disinfectant for soil and water.

Disinfection of materials and equipment
Net, gears, plastic wares, 'hapas', and other materials should be thoroughly cleaned and sun-dried or immersed in concentrated solution of disinfectant like potassium permanganate before and after use.

Proper Feeding
Good quality supplementary feed in optimum quantity is essentially to maintain and raise a healthy crop of fish.

Separation of Year Class Fish Population
Older fish may serve as carriers of disease causing organisms. To avoid such risks the best course is to separately maintain older fish.

Immediate Removal of Dead/Diseased Fish From Pond
Dead or moribund fish should be immediately removed from ponds.

Chemoprophylaxis[5]
Use of chemotherapeutants for prophylactic treatment is an effective measure against bacterial diseases. Dips, baths and oral routes of administration and pond treatments are commonly practiced. Oral administration of therapeutants is also applied in prophylactic treatments for systemic infections.

Occasional application of potassium permanganate (2–3 ppm) is recommended. Dip treatment in 500–1 000 ppm of potassium permanganate ($KMnO_4$) solution for 60–120 sec before releasing fish back in ponds is a very effective prophylactic measure. Dip treatment in 2–3 percent common salt solution for seeds before stocking is a very inexpensive prophylactic measure against a wide range of parasitic and microbial diseases.

Immunoprophylaxis
Immunization programme is an emerging and important measure for preventing communicable fish diseases. Vaccines against some of the bacterial pathogens of fish (e.g. *Aeromonas salmonicida, Yersinia ruckeri, Vibrio anguillarum)* and a parasite *Ichthyophthirius multifilis* and several viral pathogens are now commercially available in some developed countries.

[4] Care must be taken when using chemicals for disinfection of ponds and equipment to reduce adverse environmental and human health impacts of such applications.
[5] Chemoprophylaxis and therapy must be conducted following expert advice. Care must be taken not to apply any banned or unregistered chemotherapeutics and to reduce potential adverse environmental and human health hazards.

Curative Measures

Epizootic Ulcerative Syndrome (EUS)
A number of chemicals and chemotherapeutics have been tried to control EUS with inconsistent results. However, lime (CaO) at 600kg/ha/m of water in 3 equal parts at 5–7 days interval was found extremely effective against the disease in India. A chemical preparation named "CIFAX" and an herbal treatment using turmeric in combination with lime were also found highly effective against the disease.

White Spot Disease in Shrimps
A number of chemicals, antibiotics and immunostimulants are reported to have been used to control the disease but results are highly inconsistent.

Bacterial Diseases[6]

Bacterial Hemorrhagic Septicaemia

- Evidence of using streptomycin at 20–25 mg/kg body weight or in combination with penicillin (20 000 1.U/kg body wt.) through injection.
- There are incidences where terramycin in feed at 75–80mg/kg body wt with feed for 10–12 days.

Columnaris Disease

- Dip treatment in 500 ppm potassium permanganate ($KMnO_4$) for 1–2 min
- Oxytetracycline at 50 mg/kg body wt. with feed for 10–12 days.

Fin and Tail Rot

- Treat fish with oxytetracycline mixed with feed at 50 mg/kg body wt for 10–12 days.

Edwardsiellosis

- Treat fish with oxytetracycline mixed with feed at 50 mg/kg body wt for 10–12 days.

Vibriosis in Prawns/Fish

- Sulphamerazine at 8–12 mg/45.3kg of fish /day for 3 days with feed is used.
- Oxytetracycline at 70–80 mg/kg body wt/day for 3 days with feed is used.

Fungal Diseases
Fungal diseases such as saprolegniasis, achlyasis and branchiomycosis in carp and catfish and also fungal infections in prawns are cured by:

- Bath treatment of 250 ppm formalin[7] for few minutes
- Pond treatment of 15–25 ppm formalin

Protozoan Diseases
Protozoan parasites like *Ichthyophthirius multifilis, Trichodina, Cyclochaeta* can be controlled in ponds by a combined treatment of malachite green (0.1 ppm) and formalin

[6] Use of antibiotics to control/treat disease must be done following accurate diagnosis and under expert advice. Banned or unregistered antibiotics must not be used. When antibiotics are used, care must be taken to allow appropriate time before harvesting to reduce potential residues in flesh. Repeated use of antibiotics results in development of resistant strains and accumulation of residues in the sediment. Proper procedures must be used during application of antibiotics.

[7] Extreme care must be taken when using formalin to reduce possible human health, food safety, and environmental impacts.

(25 ppm). However, use of malachite green is banned and this procedure should not be used any more.

Since no chemotherapy is available for the myxosporidian parasites like *Myxobolus, Thellohanelus* and microsporidian parasites, fish ponds should be disinfected with 50–60 ppm bleaching powder (Calcium hypochlorite) before stocking

Helminth Diseases
Infections by the monogenean trematodes *Dactylogyru*s an*d Gyrodactylus* in carps and catfish can be controlled by dipping the infected fish in 2–3% common salt and also application of 0.25ppm malathion (an insecticide) in ponds.

Crustacean Diseases
The two most serious and frequently occurring crustacean parasites namely *Argulus* and *Lernaea* in major carps are controlled by 0.25 ppm malathion application in ponds in 3 equal weekly portions. Use of pesticides for controlling fish diseases is discouraged and should be avoided. Possible human health and environmental implications of such uses must be duly considered.

Nutritional Disease
Scoliosis and lordosis, diseases caused by vitamin C deficiencies, are often encountered during culture operations of carps and catfish. Incorporation of optimum levels of vitamin C in supplementary diets is the remedial measure for such diseases. Liver lipid disease in *Catla catla* due to rancid feed intake is cured by providing fresh feed with high protein content (about 22%).

Losses Due to Diseases

- There are no reliable estimates of economic loss due to diseases and related problems in the participating countries of this workshop, with the exception of Sri Lanka who reported (Balasuriya & Jayasekera 1990) the following loss estimates:
- >Rs. 1 M losses in 1988 and 1989 due to EUS;
- Rs 4 M losses due to Myxobacterial gill rot disease in *Catla catla*

Guidelines/Recommendations for Tackling Disease Problems in Aquaculture Practices of the Participating Countries

- Diagnostic facilities for timely and precise identification of various disease problems may be established and strengthened by adopting recently developed quick diagnostic procedures (PCR techniques, dot-blot and immunoflourescent techniques).
- Prophylactic and preventive measures against commonly occurring diseases in fish/prawn should be standardized and strictly adhered to during culture practices.
- As far as possible curative treatment of diseases through chemicals, insecticides, antibiotics, etc. should be avoided and injudicious application of these chemical should be strictly prohibited.
- Studies and researches on application of indigenously available plant and herbal materials as substitutes for chemicals treatment for controlling and managing disease should be encouraged.
- Scientists and technical personnel involved in disease investigations should be continuously trained.
- Quarantine and health certification programmes should be introduced through governmental legislation in all participating countries in order to prevent the entry and spread of diseases/pathogens from one region to the other that may result from introducing exotic varieties from other countries.

- Regular exchanges of scientific information on disease among fish disease specialists and technical personnel of participating countries should be ensured through workshops, seminars, symposia and networking, etc.
- Epidemiological studies and reliable statistical data about losses due to diseases should be meticulously undertaken by participating countries.

Environment

Present Status in Participating Countries

Bangladesh

In Bangladesh, typical freshwater food fish production systems are extensive and semi-intensive polyculture systems with supplementary feeding and fertilization and management. Rice bran, wheat bran, mustard oil cake, sesame oil cake, etc. are some of the important feed ingredients widely used in the country. Both inorganic (chemical), organic and compost are used to economize the cost and to maintain balance with supplementary feed. The inorganic fertilizers used are N-P-K, urea, TSP and MP (Murate of Potash), SSP; organic fertilizers include cow dung, poultry droppings and compost. Expensive commercial artificial feeds are not yet in use. The uncontrolled use of pesticides and chemicals may cause irreparable damage to the environment. The newly constructed ponds and other water bodies are treated with extended doses of organic fertilizers to prevent resist seepage problems. As the culture system is still dominated by extensive or semi-intensive methods, husbandry practices are employed to maintain fish health.

Regular water exchange, bio-filter, water treatment, feed quality assurance, aeration and other quality attributes are maintained for health management. The overgrowth of plankton is controlled by restricting the use of fertilizers and growth enhancers. The application of lime at monthly interval (at varying dose from 0.25 kg to 1.0 kg/ha) prevents the outbreak of common fish diseases.

To ensure production of fish food organisms, both organic and inorganic fertilizers are used. Fertilizers are applied 5–7 days after lime treatment. Application, in one ha pond, of 1 200–2 500 kg cow dung, 700–12 000 kg poultry litters, 2 000–3 000 kg compost, 25–30 kg urea, 10–15 kg MP can enhance the production of plankton (e.g. *Cladocera*, copepod, etc.) growths within 10–15 days of fertilization. The use of 1 kg/ha mustard oil cake accelerates rotifer growth. Mustard oil cake, rice bran, wheat bran, fish meal, dried blood meal, etc. are used as supplementary feed for carp seed rearing. The mixture of the ingredients applied as supplementary feed can ensure 90 percent survival of seed until fry level. The mustard oil cake, with small amount of urea and mixed with rice bran or wheat bran, is soaked in water for 1–12 hr before application in pond. During the initial 5 days, the use of only mustard oil cake results to better seed production of carp.

The production inputs *viz*., spawn, feed, fertilizer, etc. need operational capital. Lack of sound financial management among operators limits intensified seed production practice. The use of different chemicals, insecticides, pesticides during pond preparation phase, clearing out of predatory fish and other animals, combating insect infestation and disease control in production phase have negative impacts on environment.

Bhutan

The mountainous nature of the land has restricted fish cultivation in large scale. Fish culture system mainly depends on organized farming along with supplementary fertilization and feeding. Water bodies have very low alkalinity and hardness, therefore it will respond positively to lime. The pond is disinfected using chemicals such as $KMnO_4$. The culture system is mainly extensive/semi-intensive.

Sri Lanka

In integrated fish farming and culture of freshwater prawn, use of cow dung, lime and feed are generally practiced. Feeding is done with chicken feed by broadcasting three times a day. Cow dung application at higher doses is reported to cause gill rot disease.

Pakistan

Freshwater fish culture in the country is mainly semi-intensive. Before stocking the fry, 0.25 ppm Baytex or other organophosphate pesticides are generally used. Feeding is usually done 2–3% of the body weight. Ammonium sulphate is used as fertilizer. Nothing has been mentioned regarding other fertilizers. The basis of ammonium sulphate has not been mentioned. Ponds are limed and manured properly.

Ideal Environmental Parameters and Guidelines for Their Management for Sustainable Fish Culture

Environmental parameters play vital roles in aquaculture and its sustainability. If the parameters become adverse, the fish/prawn in the culture systems become stressed, they subsequently succumb to diseases. The water quality parameters of significance to fish/prawn health in tropical climate are described below.

Water Quality Management

Dissolved Oxygen

The optimum dissolved oxygen (DO) content of pond waters should be in the range of 5 mg/l to saturation level for good growth of fish. Below are some guidelines for dissolved oxygen for fish health management:

- 5.0 mg/l - optimum for normal growth and reproduction in tropical waters;
- 1.0–5.0 mg/l - may have sub-lethal effects on growth, feed conversion and tolerance to disease;
- 0.3–0.8 mg/l - lethal to many species if sustained for a long period.

Oxygen depletion in water is rectified by the following aeration methods:

- **Manual.** In this method, water surface is splashed with bamboo sticks. This helps in dissolving atmospheric oxygen in water.
- **Mechanical.** A diesel water pump is operated through method. Water is pumped out and simultaneously sprayed in again into the water body. This helps in dissolution of atmospheric oxygen.
- **Aerators.** Aerators are mechanical floating devices. Their rotating blades churn the water helping in dissolution of atmospheric oxygen in water. Depending upon the concentration of oxygen in waters, the number and placement of such aerators are determined.

Other steps taken to control the oxygen level are:

- Care should be taken to feed fish in the afternoon or evening in heavily stocked pond systems as oxygen requirement in fish after feeding increases and dissolved oxygen is minimum in pond during early morning.
- Organic manure application in a water area should be done carefully as organic material consumes oxygen during decomposition. Therefore, the quality of manure to be applied without the risk of oxygen depletion can be calculated taking into consideration the availability of dissolved oxygen during the 24 hr period.
- During collapse of phytoplankton bloom, decomposition occurs and in the process oxygen requirements of micro-organisms increase. Thus, special care has to be taken during this time.

- Special care has to be taken as fish more oxygen are required with increasing temperature.

Ammonia

The total ammonia concentration in water comprises two forms, namely:

NH_3 = unionized ammonia (Free ammonia) and NH_4^+ = Ionized ammonia

They maintain equilibrium as per the equation: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

The un-ionized ammonia fraction is more toxic to fish and the amount of the total ammonia in this form depends on the pH and temperature of the water. As a general rule, the higher the pH and temperature, the higher is the percentage of the total ammonia present in the toxic un-ionized form. Below are guidelines for un-ionized ammonia level in fish health management:

- 0.02–0.05 mg/l - safe concentration for many tropical fish species;
- 0.05–0.4 mg/l - sub-lethal effects depending on the species; and
- 0.4–2.5 mg/l - lethal to many fish species.

There are a number of measures to maintain safe ammonia concentration in pond water. Normally at high dissolved oxygen and high carbon dioxide concentration, the toxicity of ammonia to fish is reduced. Some recommended measures to reduce the effects of ammonia are:

- Aeration will increase the dissolved oxygen concentration and decrease the increasing pH thereby reducing toxicity.
- Healthy phytoplankton populations remove ammonia from water. Care should be taken while using fresh manure with high ammonia content. The manure should be dried to allow ammonia gas to escape before application to the pond.
- Biological filters may be used to treat water for converting ammonia to nitrite and then to harmless nitrate through nitrification process.
- A high quality feed that contains no more nitrogen (crude protein) and phosphorus than actually needed by fish should be used in ponds and also over-feeding should be avoided.
- Excessive liming should be avoided as it raises pH and high pH favours ammonia toxicity to aquatic animals.
- Water exchange can reduce ammonia concentrations in fish and prawn ponds. From both economic and environmental perspectives, water exchange should only be used when necessary.
- Formalin can be used to remove ammonia from fishponds.

Nitrite

Nitrite is an intermediate product in the biological oxidation of ammonia to nitrate, a process called nitrification. In most natural water bodies and in well maintained ponds, nitrite concentration is low. In water bodies with high organic pollution and low oxygen concentration, nitrite concentration may increase. Guidelines for nitrite value in fish health management are as follows:

- 0.02–1.0 mg/l - sub-lethal level for many fish species;
- 1.0–10 mg/l - lethal level for many warm water fish species.

Measures to maintain safe nitrite level in water are:

- Correct stocking, feeding and fertilization practices should be maintained. The ponds should be kept well oxygenated.

- Bio filtration is done through special filters by which biological conversion of nitrite to harmless nitrate occur.

Temperature

Temperature sets the pace of metabolism by controlling molecular dynamics (diffusibility, solubility, fluidity) and biochemical reaction rates. Under favourable conditions, the optimum temperature range for many coldwater and warmwater fishes are 14–18°C and 24–30°C, respectively. Water temperatures can be adjusted to optimum levels in controlled system such as hatcheries. It is difficult to adjust water temperature in large water bodies. Operation of aerator during calm and warm afternoon helps to break thermal stratification by mixing warm surface water with cool subsurface water. Planting of trees on pond banks to give shade will reduce stratification but at the same time, reduces the beneficial effects of wind mixing and restricts solar energy for photosynthesis.

Turbidity

Turbidity in culturable water is the resultant effect of several factors like suspended soil particles, planktonic organisms, humus substances produced through decomposition of organic matter, etc. Turbidity is measured by secchi disk visibility. Optimum secchi disk visibility in fish ponds is considered to be 40–60 cm. Turbidity resulting from plankton is generally desirable. Guidelines for suspended soil particles value in fish health management are:

Up to 10 000 mg/l	Freshwater carps, *Tilapia* sp. and catfishes are tolerant to this level, however, the effect will depend upon the nature of the suspended particles.

Pond waters turbid with suspended soil particles can be controlled by application of 500–1 000kg/ha organic manure, 250–500 kg/ha gypsum or 25–50 kg/ha alum.

Hydrogen Sulphide

Freshwater fish ponds should be free from hydrogen sulphide (H_2S). Hydrogen sulphide is produced by chemical reduction of organic matter that accumulates and forms a thick layer of organic deposit at the bottom. Unionised hydrogen sulphide is toxic to fish, but the ions resulting from its dissociation are not very toxic. Guidelines for hydrogen sulphide value in fish health management are:

- 0.01–0.5 mg/l - lethal to fish and any detectable concentration of hydrogen sulphide in water creates stress to fish;
- 0.1–0.2 mg/l - prawn lose their equilibrium and create sub-lethal stress;
- 3 mg/l - prawn die instantly.

Measures to rectify increase in hydrogen sulphide levels include:

- frequent water exchange to prevent building up of hydrogen sulphide in the water body;
- when pH of water is increased by liming, the toxicity of hydrogen sulphide decreases; and
- potassium permanganate (6.2 mg/l) can be used to remove hydrogen sulphide (1 mg/l) from water.

pH

pH is a measure of the hydrogen ion concentration in water and indicates how much acidic or basic the water is. Water pH affects metabolism and physiological process of fish. pH also exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility. Guidelines for pH value in fish health management are given in Table 3 below:

Table 3. Effects of different pH levels.

pH	Effect
4	Acid death point
4–6	Slow growth
6–9	Best for growth
9–11	Slow growth, lethal to fish over long period of time
11	Alkaline death point

Measures for rectifying alkaline and acidic water bodies are provided below.

Alkaline Waters
- Rapid fluctuations in pH caused by excessive phytoplankton populations may be rectified by ensuring good water management. Water body should have an alkalinity of more than 20 mg/l as $CaCO_3$.
- Application of acid forming fertilizers.

Acidic Waters
- Calcium carbonate ($CaCO_3$), calcium hydroxide ($Ca(OH)_2$), calcium oxide (CaO) or dolomite is used to rectify the acidic water bodies depending upon the pH.
- Salt water like sea water may be flushed through water bodies of coastal farms to neutralize acidity.

Alkalinity
Alkalinity refers to the concentration of bases in water and the capacity of water to accept acidity, i.e. the debuffering capacity. In most waters, bicarbonates and carbonates are the predominant bases. Guidelines for alkalinity in fish health management are:
- 300 mg/l - create stress to fish;
- 20–300 mg/l - ideal for fish;
- <20 mg/l - create stress to fish.

High alkalinity can be rectified by treatment with lime.

Total Hardness
Contents of alkali earth metals, mainly calcium and magnesium constitute the total hardness of a water body. Guidelines for hardness value in fish health management are given below:
- 20 mg/l - satisfactory for pond productivity and helps protect fish against harmful effects of pH fluctuations and metal ions;
- <20 mg/l - creates stress to fish.

Measures for rectification of low hardness:
- Ponds with low hardness can be treated with lime for rectification.

Carbon Dioxide
Carbon dioxide is present in the atmosphere in very small quantity. For this reason, in spite of its high solubility in water, its concentration in most water bodies is low. It occurs in water in three closely related forms, namely: (a) free carbon dioxide, (b) bicarbonate ion (HCO_3^-), and (c) carbonate ion (CO_3^{2-}). The amount of each form presents, depends on the pH of water. For example, in neutral or acidic waters high concentrations of free carbon dioxide, i.e. the toxic form is frequently found. Guidelines for carbon dioxide value in fish health management are:

- 12–50 mg/l - sub-lethal effects include respiratory stress and development of kidney stones (nephrocalcinosis) in some species;
- 50–60 mg/l - lethal to many fish species with prolonged exposure.

Measures for controlling high carbon dioxide concentration include:

- repeated aeration of water;
- increasing the pH of water by hydrated lime can control high carbon-dioxide concentration. Experiments have shown that 1.0 mg/l of hydrated lime can remove 1.68 mg/l of free CO_2; and
- phytoplankton population and the organic loading in a water body should be regulated by correct stocking, feeding and fertilization.

Bottom Soil Management

Role of bottom soil in determining productivity of a pond is well documented. Production of various primary food organisms depends largely on the availability of different nutrients. Dynamics of availability of most of these nutrients, in turn, is determined by the condition prevailing in the bottom soil. Considering this significance, bottom soil is designated as the chemical laboratory of a pond. However, suitable soil quality problem is common in aquaculture ponds, and therefore, many methods are used for the purpose of improving pond soils.

<u>Soil Texture</u>
Many important physico-chemical properties affecting the fertility of fish ponds are influenced to a great extent by the relative proportion of the different size fraction of the soil. An ideal pond should not be too sandy to allow leaching of the nutrients or should not be too clayey to keep all the nutrients adsorbed in it. When the pond is constructed on sandy soils, then heavy doses of organic manure application is essential to control seepage loss of water. In general, the dose of raw or composted farmyard manure varies from 10 000–15 000 kg/ha/yr.

<u>Soil Acidity</u>
Soil may be acidic, alkaline or neutral. The ideal range for fish pond soil is pH 6–8. Water passing over acid soil tends to be acidic with low alkalinity and hardness. High concentration of metal ions particularly aluminium and iron also may be present. Acidic ponds do not respond well to fertilization.

Liming is the only way to improve water quality with acid soils. Recommended rate of application of lime at different soil pH has been given under the section on fertilizer schedule for fish ponds.

<u>Acid Sulphate Soils</u>
Acid sulphate soils from mine spoils and coastal mangroves tide swamps contain high levels of pyrite (FeS_2, 1–6 percent). As long as sediments containing pyrite are submerged and anaerobic, they remain reduced and there is little change. However, as they are drained and exposed to the air, oxidation results and sulphuric acid is formed.

Sulphuric acid reduces the pH of the water when pond is filled. In ponds, problems with acid sulphate soils usually originate in pond dikes. Pond bottoms are usually flooded and anaerobic, so sulphuric acid does not form. However, dikes dry and sulphuric acid formed during dry period enters pond in run-off water after rains. Acidity on dikes can be controlled by liming (0.5–1.0 kg/ m^2) and establishing good cover with an acid resistant grass species.

A procedure for rapid reclamation of ponds with acid sulphate involves drying and filling of the soil to oxidize pyrite, filling the pond with water and holding till water pH drops to

< 4 and then draining the pond, repeating the procedure until the pH stabilizes at a pH >5, followed by liming the pond with 500 kg of calcium carbonate/ha.

Bottom Soil Oxidation

Dissolved oxygen cannot move rapidly into water-saturated soil, and pond soil becomes anaerobic below a depth of few mm. Aeration and water circulation are beneficial in improving bottom soil oxygenation, but the surface layer of soil may still become anaerobic in intensive fish culture ponds. When the redox potential is low at the soil surface (anaerobic conditions), hydrogen sulphide and other toxic microbial metabolites diffuse into the pond water. Sodium nitrate can serve as a source of oxygen for microbes in poorly-oxygenated environment; the redox potential will not drop to a level enough for the formation of hydrogen sulphide and other toxic metabolites.

Some Other Environmental Parameters

Nutrient Removal

It is possible to precipitate phosphorous from pond water by applying sources of iron, aluminium or calcium ions. These ions precipitate phosphate as insoluble iron, aluminium or calcium phosphates. Alum (aluminium sulphate) and ferric chloride are commercially available sources of aluminium and iron, respectively. Alum is cheaper and more widely available than ferric chloride. Gypsum (calcium sulphate) is a good source of calcium, because it is more soluble than liming materials. Treatment rates of 20–30 mg/l alum and 100–200 mg/l gypsum have lower phosphorus concentration in pond waters. Alum is acidic and more suitable for use in waters with 500 mg/l of total alkalinity and above. Gypsum is better for use in low alkalinity waters.

Phytoplankton Removal

Algaecides are used to reduce the abundance of phytoplankton in intensive fish culture ponds. Copper sulphate pentahydrate ($CuSO_4.5H_2O$)[8] is recommended for reducing phytoplankton abundance and the abundance of blue-green algae in particular. The usual recommendation is to apply a dose of copper sulphate equal to 1/100 of the total alkalinity. The best approach to phytoplankton control is to regulate nutrient inputs by moderate stocking and feeding rates, but it may be feasible to use alum or gypsum to precipitate excessive concentrations of phosphorus.

Sanitation of Ponds (Chlorination)

Hypochlorus acid and hypochlorite (free chlorine residuals) are the chlorine products which are used for disinfecting pond water. However, chlorination of water containing fish or prawn is both dangerous and unbeneficial. It is possible to sterilize bottoms of empty ponds and water in newly filled but unstocked ponds by applying chlorine products. When this is done, enough chlorine should be applied to overcome the chlorine demand and provide 1 mg/l or more of free chlorine residual. The residuals will detoxify naturally in a few days so that ponds can be stocked safety.

Water Exchange

There are reasons to exchange water in specific instances, such as to reduce salinity, to flush out excessive nutrients and plankton or to reduce ammonia concentrations. However, daily water exchange usually does not improve water quality in ponds, and pumping costs are a liability. Ponds are highly efficient in assimilating carbon, nitrogen and phosphorus inputs, which are not converted to fish or prawn flesh, but if water exchange is great, these substances are discharged from ponds before they can be assimilated. Thus, the pollution potential of aquaculture ponds increases as a function of increasing water exchange. From

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[8] Use of $CuSO_4$ in plankton removal is discouraged as excessive use of the chemical could cause human health and environmental problems.

both economic and environmental perspectives, water exchange should only be used when necessary.

Fertilization of Nursery, Rearing and Stocking Ponds

Natural or inherent fertility of nurseries often remain unsatisfacotry due to deficiency of one or more of the nutrient elements in soil and water including other environmental conditions. Correction of deficiencies by application of manures or fertilizer containing these deficient nutrients in suitable form and in optimal amount is necessary to accelerate biological production. Accordingly, to facilitate effective control or manipulation of environmental condition, small ponds either seasonal or having shallow depth, are preferred for nurseries.

Use of Organic Manures

Both organic manures and chemical fertilizers are widely used for improving productivity of nurseries. Cow-dung is the most widely used organic manure compared to others and applied at the rate of 5 000 to 15 000 kg/ha in one instalment well in advance, preferably a fortnight prior to stocking with spawn. The amount is reduced to 5 000 kg/ha when *mohua* seed cake is used as a fish toxicant in nurseries with shallow water depth. Sometimes, to hasten the process of decomposition of added manures, nurseries are limed at 250–350 kg CaCO3/ha after the application of manure. In other cases, , spaced manuring with cow-dung at 10 000 kg/ha 15 days prior to stocking followed by subsequent application of 5 000 kg/ha seven days after stocking have been practiced for sustainable production of zooplanktons in nurseries. When more than one crop is raised, nurseries may be manured with cow-dung at 5 500 kg/ha immediately after the removal of the first crop. Besides cow-dung, a combination of mustard oil cake, cow-dung and poultry manure using the ratio of 6:3:1 at 1 100 ppm has been used for the culture of desirable species of zooplankton for carp.

Inorganic Fertilizer

Inorganic fertilizers containing a fixed percentage of individual nutrient element or a combination of more than one element are also able to enhance biological production in nurseries. A ratio of nitrogen to phosphorous of 4:1 (N:P) is considered most effective for increased production in nurseries. Weekly application of N:P:K mixture in the ratio of 8:4:2 is suitable for increased production of fish food organisms. Use of N:P:K in the ratio of 18:8:4 at 500 kg/ha after liming at 200 kg/ha is quite effective in enhancing the production of slightly acidic and unproductive soils used for nurseries.

Nitrogenous fertilizers containing different forms of nitrogen (e.g. amide, ammonium-cum-nitrate and ammonium) are suitable for management of nurseries. These three forms of fertilizers (e.g. urea, calcium ammonium nitrate and ammonium sulphate) are effective for slightly acidic to neutral, moderately acidic and alkaline soils, respectively and the rate of 80 kg N/ha is most suitable for rearing of rohu in nurseries.

Organic and Inorganic

Combined use of both organic and inorganic fertilizers are also suitable for increased production of either fish food organisms or fry. The combination of mustard oil cake and N:P:K (ratio of 6:8:4) on equivalent nutrient basis at 12 kg N/ha is suitable. However, on equivalent basis (N:P:K) organic manure (cow-dung) is most suitable for management of carp nurseries.

Rearing and Stocking Ponds

Since acidic pond soils reduce the microbial activity and availability of nutrients to pond water, either native or when added externally, application of lime is the first step of management for all stages of fish culture. Liming raises the soils pH to a desirable level (near neutral) and establishes a strong buffer system in the aquatic environment.

Liming stimulates the microbial decomposition of organic matter, supplies Ca to the pond, increases HCO_3^- content in the pond and maintains sanitation in the pond environment. Generally, ground limestone is extensively used and spread over the dry bed to ensure the complete benefit or broadcast over the water surface in a single dose at least 15–20 days before stocking. On the basis of soil pH, specific dosages of lime are usually applied to ponds as described below. Besides initial application, some compensatory applications of lime in the range of 100–200 kg/ha may also be made in the stocking pond from time to time to neutralize acidity developed through application of acid farming inorganic fertilizers and organic manure and also when fishes are diseased or distressed.

Table 4. Specific dosage of lime applied to different pond conditions.

Soil pH	Soil condition	Dose of lime ($CaCO_3$ kg/ha)		
		Sandy soil	Medium	Clay soil
4.0–5.0	Highly acidic	1 000	2 000	3 000
5.0–6.0	Moderately acidic	600	1 200	1 800
6.0–6.5	Slightly acidic	500	1 000	1 500
6.5–7.5	Near neutral	200	400	600

In India, organic manure is more commonly used than inorganic fertilizers. A variety of agricultural wastes, cow-dung, poultry droppings, pig manure, bio-gas slurry, etc. can be used as organic manure. In rearing ponds, application of raw cow-dung or bio-gas slurry is observed to give better results. Depending on the organic carbon content of pond soil in rearing pond, application of raw cow-dung or bio-gas slurry in the range of 3.0–7.0 or 5.5–12.0 t/ha, respectively; and addition of 5.0–15.0 or 10.0–30.0 or 2.5–5.0 t/ha/yr of cow-dung, bio-gas slurry, or poultry droppings, respectively, in stocking ponds give good results. In rearing ponds, 50 percent of the total requirement is usually given 15–20 days prior to stocking of fry and the remaining portions in two equal monthly splits during the entire rearing period. In stocking ponds, on the other hand, 20 percent of the total requirement is applied initially and the rest is given in equal monthly splits. But if the ponds are treated with *mohua* seed cake to eradicate unwanted fishes, the initial application of the organic manure can be dispensed in both culture systems.

Efficiency of N-fertilizer in enhancing the productivity of pond depends largely on their forms. The commonly used N-fertilizers are urea, ammonium sulphate and calcium ammonium nitrate. Among these forms, urea is suitable for slightly acidic to neutral soil, ammonium sulphate for alkaline soil and calcium ammonium nitrate for acidic soil. Depending on the available nitrogen content of the pond soil, application of 50–70 kg N/ha (i.e. 108–152 kg urea/ha; 200–280 kg calcium ammonium nitrate/ha; 250–350 kg ammonium sulphate/ha) in rearing ponds and 75–150 kg N/ha/yr (i.e. 163–326 kg urea/ha/yr; 300–600 kg calcium ammonium nitrate/ha/yr; 375–7 500 kg ammonium sulphate/ha/yr) in stocking ponds give good results. The fertilizer should be applied in equal monthly splits alternately with organic manure with a fortnight interval.

Single super phosphate (SSP) is most commonly used as phosphate fertilizer in fish ponds. Depending on the available P_2O_5 content of pond soil, application of 25–50 kg P_2O_5/ha (i.e. 156–312 kg SSP/ha) and 40–75 kg P_2O_5/ha/yr (i.e. 250–468 SSP/ha) in rearing and stocking ponds, respectively, give good results. To get better utilization efficiency, P-fertilization should be applied at weekly intervals and the first instalment is to be given 7 days after initial organic manuring.

Muriate of potash (KCl) and sulphate of potash (K_2SO_4) are commonly used as potassium fertilizers in fish ponds. Application of 10–20 kg K_2O/ha (i.e. 16–32 kg KCl/ha or 20–40 kg K_2SO_4/ha) and 25–40 kg K_2O/ha/yr (i.e. 41–66 kg KCl /ha or 52–83 kg K_2SO_4/ha/yr) in rearing and stocking ponds, respectively, give good results. The fertilizer should be applied in equal monthly splits. In order to avoid depletion of oxygen, application of manure and fertilizers are to be suspended, if thick green or blue-green blooms develop in the pond..

Conclusion

As all the participating countries are developing in nature, many similarities can be expected in socio-economic pattern. The country status papers indicate that the species cultured in these countries and the aquaculture systems practised fall under some or all systems discussed earlier. Farmers are also, more or less under similar categories as previously mentioned, i.e. resource rich, middle and marginal or resource poor categories.

Fish culture technologies so far developed or available and under practice are mainly based on management considerations of species cultured, stocking density, health and environment monitoring. These have demonstrated higher production levels to the level of 10–15 t/ha/yr with carps. However, further improvement in the production, as rightly felt by the aquaculture scientists, depends on the development of technologies that can provide sustainable higher yields and that which are cost effective and environmental friendly.

One of the potential means to develop such technologies is to exploit the genetic potentials of the candidate species which are hitherto not properly tapped. Several genetic techniques are available and some of them (e.g. selective breeding) have already demonstrated their potential for producing genetically improved strains, with better survival and growth, strong resistance to disease and adverse environment, etc. All these traits help in enhancing production of high quality products. Use of genetically improved strains may also bring down the requirement of feed as their efficacy in converting the feed to fish flesh is usually much better than the normal individuals. This in turn brings down the cost of production and also may reduce the culture period due to their faster growth. Lower inputs of feed and fertilizers also make the technology environmental friendly. Genetic technologies may be particularly useful in intensive or super-intensive systems. Other technologies, purely management in nature, may be quite suitable for smaller ponds/tanks and seasonal water bodies. Integrated farming practices may also be suitable for extensive and semi-intensive systems.

The immediate need, in most of the participating countries for aquaculture practices, appears to be the availability and supply of fish seed particularly to farmers in the rural and remote areas where transportation of the seed is a problem as well as financial assistance for procuring inputs (e.g. feeds and fertilizers). Feed is one of the most important aspects in enhancing production in aquaculture. Urgent attention is required to develop suitable feed formulations and feeding methods. As already pointed out, while considering nutritional aspects, besides effective formulation of feed items, it is also important to identify cheap, effective and easily available ingredients. Fish health management is one of the most important managerial aspects for successful aquaculture since optimum survival of stocked populations and harvesting of good quality fish products depend on disease-free and healthy conditions of fish/prawn during culture periods. Regular monitoring of health and pond environment is highly essential for sustainability.

Making use of all the readily available water bodies is also one of the most important aspects in aquaculture for the over-all increase in the fish production of a country. In bigger countries like India, regional preference for a particular variety or type of fish also exist. In some states like West Bengal, Orissa or some of the eastern regional states, more people prefer Indian major carps and some other small varieties. In states like Punjab, consumers prefer fish with fewer bones, such as catfish or pomphret. In southern India, beside carps, murrels (Channidae) are preferred. In Karnataka State, *Cyprinus carpio* and *Catla catla* are preferred among other carp species. Similar preferences might also be present in other participating countries. Therefore, depending on the consumer preference, the species to be cultured can be selected and their farming should be encouraged and developed.

In order to further develop aquaculture in South Asia, technology exchange programmes along with human resource development are very important considerations , where countries like India and Bangladesh can play an important role. Networking of people and enhanced exchange of knowledge and experience should be encouraged. A focal station, either in India or in Sri Lanka, may be selected for updating database available from different countries and make them available or accessible to all countries.

Considering the present practice of aquaculture and economic status of the aquaculturists in the participating countries, emphasis may be given for low and medium input technologies and appropriate measures for transfer of technologies to the grass root levels. In this regard, necessary emphasis should be given for rural development having aquaculture as the main thrust area and judicious use of resources like water. Employment generation and poverty alleviation also can be incorporated in programmes for aquaculture development in the region. Since some of the countries in the region have already developed irrigation systems for supply of water for agriculture and allied activities, it would be a very useful and effective if water is used in an integrated way for multiple uses, employing flow-through system of aquaculture, horticulture along with agriculture.

Appendix D: General Working Group Guidelines and Suggested Outline for Country Papers and Presentations

General Working Group Guidelines

Water and Environment

The working group should review the current water and environmental management practices employed for the major food fish species (by farming system and province/region), including existing related guidelines/legislation, current issues and constraints, and future directives.

It is expected that the group will discuss and describe the perspectives, regarding the water and environmental aspects of aquaculture, of the following groups:

(i) the Government;
(ii) technical experts on water and environmental management (e.g. public sector, university, research institute, etc.); and
(iii) aquaculture producers.

Nutrition and Feeding

The Nutrition and Feeding group should review the current feeding practices employed for the major food fish species (by farming system and province/region), including existing related guidelines/legislation, current issues and constraints, and future prospects.

The group is expected to describe the perspectives of the different groups:

(i) technical experts on nutrition and feeding (e.g. public sector, university, research institutes, etc);
(ii) commercial feed manufacturers;
(iii) dealers/producers of locally available major feed ingredients for farm-made feeds (e.g. de-oiled cakes and brans of rice, wheat, etc.); and
(iv) aquafarmers/ producers.

Disease Control and Health Management

The group should discuss and describe the current diseases and health management practices employed for the major food fish species (by farming system and province/region), including existing related guidelines/legislation, current issues and constraints, and future prospects.

This group should review the diseases control strategies and health management situation, from different perspectives:

(i) the Government;
(ii) technical experts on health management (e.g. public sector, university, research institutes, etc.); and
(iii) aquaculture producers.

Seed Resources

The group should discuss and describe the current situation on seed resources available for the major food fish species (by farming system and province/region), including existing related guidelines/legislation, current issues and constraints, and future prospects.

This group should review the diseases control strategies and health management situation, from different perspectives:

(i) the Government;
(ii) technical experts on hatchery/seed management (e.g. public sector, university, research institutes, etc.); and
(iii) aquaculture producers.

General Discussions

All the groups are furthermore expected to discuss and describe the following broad issues relevant to the group's subject:

- policy and legislation;
- awareness, extension education and communication programmes;
- research and development;
- resources and funding; and
- regional and international linkages.

Suggested Outline for Country Papers and Presentations

Overview of Freshwater Aquaculture Food Fish Production in Your Country

This section should cover the following areas:
- national/ provincial government policy plans and targets;
- anticipated and perceived constraints;
- production methods, levels and trends;
- current government support on financing, inputs, market, extension, research, training, etc.; and
- future prospects and outlook.

Main Areas of Interest

There should also be a section on each of the main areas namely: (i) water and environment; (ii) nutrition and feeding; (iii) disease control and health management; and (iv) seed resources.

Summary and Recommendations

In this section, the authors would provide a summary of main technical issues, including opportunities and constraints of intensification of freshwater aquaculture production in their country. Recommendations for future actions should be formulated, based on consideration of perspectives and expectations by government planners and policy-makers, technical specialists, and aquaculture producers.