ISSN 0859-600X

Volume XIII No. 3 July-September 2008

AQUACULTURE ASIA

Carp culture in Andhra Pradesh

Impacts of climate change

Selection for feeding efficiency

Nai Lagoon, Vietnam

Prawns in Bangladesh

Mussels and water quality


Back to Nature
Algine based complementary feeding stuff for fish
1 kg
AquaVac™
Ergosan™
Algae-Based Complementary Feeding Stuff for Fish
Intervet
Schering-Plough Animal Health
For naturally healthy solutions contact our specialists:
spaquaculture@spcorp.com

Aquaculture Asia
is an autonomous publication that gives people in developing countries a voice. The views and opinions expressed herein are those of the contributors and do not represent the policies or position of NACA.

Editor
Simon Wilkinson
simon@enaca.org

NACA
An intergovernmental organization that promotes rural development through sustainable aquaculture. NACA seeks to improve rural income, increase food production and foreign exchange earnings and to diversify farm production. The ultimate beneficiaries of NACA activities are farmers and rural communities.

Contact
The Editor, Aquaculture Asia
PO Box 1040
Kasetsart Post Office
Bangkok 10903, Thailand
Tel +66-2 561 1728
Fax +66-2 561 1727
Email:
magazine@enaca.org
Website http://www.enaca.org

Printed by

Scand-Media Co., Ltd.

AQUACULTURE ASIA

Volume XIII No. 3 **ISSN 0859-600X**
July-September 2008

The Aquatic Commons

As Editor of this magazine and the NACA website, I have long been a fan of 'open access' publishing, that is to say, making publications available for free, to whoever wants them. If you have information you want to share then in these days of the internet it makes sense to put it online where 1.4 billion people can find it, particularly since this can be done at virtually no expense. Compare this to traditional 'print' publishing, where you might produce a few thousand paper copies of a publication at considerable expense, and once they have been distributed, they are gone.

This (near) freedom of access to information made possible by the internet is turning traditional 'user pays' and subscription-based publishing models on their head, and is forcing publishing houses and media outlets to look at alternative business models. Initiatives such as Google Books and the Public Library of Science (www.plos.org) are great examples of how information can be made available to the general public for free, and yet remain financially viable. Happily, there is now an online facility available for sharing publications on fisheries and aquaculture. It's called the Aquatic Commons. It is entirely free, institutions can contribute (and store) their own publications there if they want to, and it will be maintained as an archive over the long-term, free of charge.

The Aquatic Commons is essentially a digital library covering the marine, estuarine /brackish and fresh water environments. It covers all aspects of the science, technology, management and conservation of these environments, their organisms and resources, and the economic, sociological and legal aspects. The library contains a growing collection of published and unpublished research, organizational publications, and other scholarly materials contributed by researchers, librarians, and their institutions. It was established by the International Association of Aquatic and Marine Science Libraries and Information Centers (IAMSLIC) and has been in steady development over the last two years, based on the free e-Prints software developed by the University of Southampton and managed by the Florida Center for Library Automation.

The purpose of the Aquatic Commons is to facilitate the exchange of scientific research related to the marine/aquatic environments by providing a searchable, web accessible repository for digital documents, in a range of digital formats. It also has a specific mandate to offer 'repository services' to institutions that do not have the IT capacity of funds to establish their own digital libraries. Put simply, participating institutions can upload their publications into the Commons, which will then maintain them online indefinitely on the institution's behalf, as a public service. A long-term goal of the repository will be to assist in providing access to legacy collections that have never been easily accessible to researchers and to provide access to the grey literature produced as the technical series of smaller research units in universities, governmental, and non-governmental agencies. I encourage you to take a look at the Aquatic Commons for yourself, and to consider lodging your own publications in there, for both for posterity and the benefit of others. You can access it at:

http://aquacomm.fcla.edu/

Simon Wilkinson

AQUACULTURE ASIA

In this issue

Sustainable aquaculture

Page 3.

Genetics and biodiversity

Page 22.

Research and farming techniques

Page 27.

Asia-Pacific Marine Finfish Aquaculture Network Magazine

Page 41.

Page 52.

Peter Edwards writes on

Rural Aquaculture

Dr Edwards is a consultant and Emeritus Professor at the Asian Institute of Technology in Thailand where he founded the aquaculture program. He has over 30 years experience in aquaculture education, research and development in the Asian region. Email: pedwards@inet.co.th.

Comments on possible improvements to carp culture in Andhra Pradesh

Introduction

In February I took up the kind invitation of Dr Ravi RamaKrishna, Senior Scientist at the Fisheries Research Station in the West Godavari district of Andhra Pradesh, to visit the 'fish bowl' of India in the Kolleru Lake area of the State. The local carp production system has become well known within India as well as abroad. See previous articles in this magazine: Nandeesha, M.C. (2001). Andhra Pradesh farmers go in to revolutionary carp research. Aquaculture Asia 4(4):29-32; and RamaKrishna, R. 2007. Kolleru carp culture in India: an aquaplosion and an explosion. Aquaculture Asia Magazine 12 (4): 12-18.

Our intensive four day study tour involved visits to fish farms and formal meetings with individual farmers in Mallavaram village in West Godavari district and Bhujabalapatnam village in Krishna district, cooperative fish farmers in Prathikollanka village, in West Godavari district, all by Kolleru Lake; to carp hatcheries and nurseries in the Kaikaluru area of Krishna district; and to fish farms and informal meetings with individual farmers towards Gudivada in Krishna district where a second phase of carp culture development has taken place. At the end of the tour I was only too pleased when asked to comment to a group of about a dozen farmers belonging to the Delta Fish Farmers Association. And I repeat here what I said to the farmers at the start of our final meeting, that four days was hardly sufficient time to fully appreciate the most impressive but complex aquaculture system I had been shown but that at the very least my comments should stimulate further debate about how to resolve some of the problems and how the system might evolve in the future.

Farmer checking the amount of natural food in fish pond water.

Overview of the system

The technology of the current system of Indian major carp culture in Andhra Pradesh has been mainly developed by local farmers as described in the article by Dr. Nandeesha. It is a simplified two-species system in which rohu is dominant with 80-90% of the fish biomass and with catla a very profitable 10-20%. Production may be described as semi-intensive and indirectly integrated. It is a 'green water' system with mainly local off-farm inputs: chicken manure (and chemical fertilizers); supplemented with farm-mixed de-oiled rice bran and oil cake.

Feedlot chicken manure en route to the farm.

A well fertilized 'green water' pond.

Delivery of de-oiled rice bran to the farm.

Sustainable annual production is 3-4 tonnes/acre (7.5-10 tonnes/ha) although 5-6 tonnes/acre (12.5-15 tonnes/ha) have been achieved but at increased risk of fish mass mortality. Last year 5,000-6,000 farmers produced a total of 450,000 tonnes of fish from 60,000ha of ponds.

Farmers reported that they are experiencing problems, especially increasing cost of production, mainly due to rising cost of fertilizers and supplementary feed; and weather related fish mass mortality. The main problem is the fall in dissolved oxygen (DO) in the rainy season in particular but also during cloudy weather in general and during cool season fog. Water quality problems also occur during the hot season from April to June when there is limited water availability, especially with high density culture, which may cause disease. The farmers also recognized the need for change, especially to farm new species for domestic and possibly export markets.

Comments on the system

The following account is based on a final oral presentation to the Delta Fish Farmers Association and the written comments subsequently sent to them.

1. Water quality

The main cause of adverse water quality in the ponds is a decline in night-time DO due to excessive growth of phytoplankton. This can be addressed in part by a lower intensity of culture, already recognized by the farmers who now aim for a more sustainable maximum annual production of 10 rather than 15 tonnes/ha; and/or use of pond aeration as practiced by some farmers. Water quality can also be improved by more efficient use of fertilizers and supplementary feeds as discussed below.

A farm worker suspending supplementary feed-filled sacs from a rope in the pond.

2. Fertilizers

A major factor in profitable carp culture is use of fertilizers to produce natural food as is well appreciated by the farmers. However, pond fertilization research carried out elsewhere could improve local practice. Both organic and chemical fertilizers can be used effectively to fertilize fish ponds. It is not true that both organic and chemical fertilizers are required for phytoplankton production as believed by some farmers. To be most effective, fertilizers need to be used frequently, preferably weekly in small doses. The reason that some farmers believe that chemical fertilizers cannot be used alone is their usual 1-2 monthly frequency of application is too long to sustain adequate phytoplankton growth.

Sacs perforated with small holes are used to hold supplementary feed.

It is also not true that organic is cheaper than chemical fertilizer based on the weight of the major nutrients of nitrogen and phosphorus contained in the fertilizers. Inorganic fertilizers also require less labour and lead to less build up of pond sediment which can also adversely affect water quality.

A farmer was concerned that use of only chemical fertilizers may lead to mineral deficiency but there are adequate micronutrients in fertilized and supplementary-fed ponds.

Another farmer reported that he preferred cattle manure to poultry manure as the former produces only methane and not ammonia. Poultry manure is a much better fertilizer than cattle manure as the former has a higher nutrient and lower organic matter content. Thus poultry manure would produce more phytoplankton and less pond sediment than cattle manure on a unit weight basis.

Farmers asked about toxic levels of ammonia but there is no need for concern in fertilized fish ponds as phytoplankton use ammonia as a source of nitrogen; DO will become critical before ammonia. Reported total ammonia levels in local ponds of 2-3 mg/l are not excessively high; although the toxic form of ammonia, un-ionized

Farm workers mixing de-oiled rice bran with oil cake as a supplementary feed.

ammonia, increases relative to ionized ammonia with rises in pH and water temperature during the day, ammonia levels fall to low levels in productive fish ponds as they tend to be removed from the water by phytoplankton during intensive photosynthesis.

Farmers believed that less fertilizer is required in West Godavi than in Krishna district as the former has richer soil than the latter. While this might have been true when fish culture began, it is unlikely to be so today as the fertilizer effect of the two dimensional pond sediment is minor compared to that of the three dimensional water column which requires a relatively high level of intentional fertilization for productive fish culture.

3. Liming

Farmers traditionally lime ponds to reduce CO_2 in the water which they believe would otherwise be toxic to the fish. However, highly productive alkaline fish ponds have carbon in the form of bicarbonate rather than toxic CO_2 in the water. Furthermore, lime will precipitate phosphorus and thus make fertilization less effective so it should not be used other than in pond preparation. Lime is used to increase the pH of acidic soil as well as to disinfect the soil between crops of fish.

Farm workers with rohu.

4. Supplementary feed

The greatest impact on current practice would be made by improving supplementary feeding. The two main feeds are de-oiled rice bran (12% protein) and groundnut cake (40% protein), mixed together and placed in the pond in suspended sacks with holes through which the fish feed. Cotton seed cake is also widely used and if both are used they are usually mixed at a ratio of 1:1. However, the high average food conversion ratio (FCR) of 3:1 (range 2.5-3.5:1) indicates a low supplementary food conversion efficiency. Observation revealed considerable physical loss of feed through the sack holes to which may be added loss of feed nutrients due to leaching as well as handling losses. This is confirmed by comparison of the FCRs for floating pellets of about 1.5 and sinking pellets of about 2.0 in clear water systems, and 1.0 in experimental fertilized ponds with a commercial pellet used as supplementary feed (see section 6).

Trials should be carried out to compare the present bag feeding method with minced moist feed, broadcast or placed on feeding platforms. Farmers said it would not be possible to produce dry feed on-farm in the quantities required. However, ways to reduce feed wastage do need to be explored.

Farm workers preparing quicklime for spreading on the pond surface.

Supplementary feed may be readily lost through the holes when the fish are feeding on the feed mix as suggested by lifting the sac.

Only rice bran is fed until the fish reach 300-350 g after which oil cake is added to give a feed mix of 80-90% rice bran and 10-20% oil cake with an approximate mash protein content of 18%. However, some farmers use oil cake from the start of the grow-out cycle.

Eight to ten 25 kg sacks are used per acre giving a feeding rate of 40-100 kg/acre/day as each sac is filled with 5-10 kg of mash according to one farmer. Farmers never give feed by estimating the fish biomass in the ponds as they believe that fish increase in size by the same weight increment each day irrespective of fish size. Another farmer reported that for the first month fish are fed 20-30 kg/acre/day and then from the second month until harvest at month 12 are fed 50-60 kg/acre/day which corresponds to the rate reported by the first farmer interviewed.

There was a need to explain to the farmers that:

- Fish only grow quickly on phytoplankton alone when they are small. As they increase in size they need more food to maintain their growth rate as the surface area of their gut declines relative to their total body volume as they increase in weight. This means that current farmer practice of only feeding rice bran initially is probably wise.

- However, as the fish grow larger they need increasing amounts of supplementary feed so the current practice of maintaining only two feeding rates is inefficient. The bigger a fish, the faster it grows; but to maintain growth as close as

Close up of rohu.

Close up of catla.

A recently introduced species, silver striped catfish.

Feral Mozambique tilapia.

practical to its genetically maximum rate requires increasing amounts of feed.

- The fish also need to be fed a diet with more protein as they get larger. One farmer reported that he used more oil cake, at a ratio of rice bran to oil cake of 2:1 i.e., 33% oil cake rather than the usual 10-20% oil cake in the feed mash, and got improved production. Another farmer stated that carp do not require a diet with a protein content beyond 16-18% protein but giving larger fish a supplementary diet with this relatively low protein content will slow down their growth. It is not the protein content of the feed that is critical but the total amount of protein in the diet – and as the fish grow larger they require a correspondingly larger amount of protein. Thus, the proportion of oil cake in the diet should be increased with time as the fish grow, possibly up to about 30% protein in the mash. Feeding a mash with a lower protein content means that either the fish get insufficient protein or that they need to eat much more feed with a lower protein content, even if they were able to do so, which would have a greater adverse impact on water quality through increased production of faeces.

Fish nutrition specialist colleagues advised me that it is better to feed a fish twice than once/day in terms of fish feeding efficiency. However, as the difference in growth rate may only be small, it may not be economic to feed fish more than once a day due to increased labour costs.

Fish should be fed when the DO in the pond water has risen due to phytoplankton photosynthesis. Thus, fish should not be fed soon after dawn but commencing at 8-9 am at the earliest.

5. Pelleted feed as supplementary feed

According to a farmer, the traditional method of feeding costs R20-22/kg of fish production compared to R28/kg with commercial pelleted feed so he asked why spend more? With a farm gate price of carp of R40/kg, the profit with commercial pellets would be only R12/kg compared to R18-20/kg with traditional feed he explained. However, use of pellets would require less labour, would improve the water quality as feed conversion would be more efficient, and fish growth and production would be increased. While the capital invested in fish culture would be higher and the profit margin per kg of fish produced possibly lower with use of pelleted feed, the profit per farm would be higher due to increased fish production per unit area of fish pond. Thus, it is not true that increased use of feed will lead to loss of money if feeding efficiency, water quality, fish growth and production are all increased. This is supported by the experience of a farmer in Prathikollanka Cooperative who reported that use of pellets at 1.5% fish body weight/day was very profitable in a poultry manured pond. However, he stocked large 400 g fingerlings and rohu attained 1.3 kg and catla 2.4 kg in only 4 months. It is recommended that use of pellets be investigated, at least for fattening fish in the latter half of the grow-out phase.

Considerable expense is involved through installation of nylon string to protect small fish from bird predation.

6. Chemical fertilizers and commercial pellets as supplementary feed

It may be possible to increase sustainable production by use of commercial pellets as supplementary feed in chemically fertilized ponds. Experiments with monoculture of tilapia in Thailand produced about 20 tonnes/ha with a FCR of only 1.0 in the 'green water' ponds. Ponds were fertilized weekly. Feeding at 50% feed satiation with pellets of 30% protein content began when fish reached 50-100 g and continued daily until harvestable size of 500-600 g. This experiment showed the effectiveness of proper supplementary feeding in a fertilized pond.

7. New species

Farmers expressed interest in improved and new species. Seed quality of carps was reported to be low due to inbreeding but an improved strain of rohu has been developed by a Norwegian funded project. About 250-300 local farmers were already using the improved rohu, available from Farm Pallewda, Krishna district, a Multiplier Centre, which grows 30% faster and therefore shortens the culture period by 2 months.

An estimated 10-15% of local farmers stock silver striped catfish (Pangasianodon hypophthalmus) in either polyculture or monoculture with production in monoculture of 20-25 tonnes/ha. Market accessibility and price are low at R35/kg compared to R45/kg for rohu and catla. It is unlikely that local farmers will be able to compete with Vietnam in export of this catfish as it currently produces over 1 million tonnes and has established markets but they should be able to compete with Bangladesh and Burma where catfish production is increasing and may already be being exported to Kolkata.

Although tilapia is considered as a "weed fish" at present, selling at only R5/kg, it has potential if a market can be developed. As one farmer stated, "tilapia is more delicious than rohu and catla" so it is highly likely that tilapia will be increasingly accepted in Indian markets. Nile tilapia, in contrast to the feral Mozambique tilapia present in the area, has potential to become a major commodity for national Indian markets as well as for export from the country.

Local farmers need to develop Nile tilapia culture if they are to compete on the Kolkata market as Bangladesh and Burma have already imported quality tilapia seed and hatchery technology from Thailand. Quality seed of various Nile tilapia strains may be obtained from Nam Sai Farms, Thailand. I recommended that a delegation of local farmers visit Nam Sai Farms, website www.tilapiathai.com, and later confirmed that the farm is willing to host a small delegation from Kolleru and to also take them to visit local farms and markets for tilapia and other species, including silver striped catfish.

Other possible culturable species are seabass, walking catfish and snake-head, all traditionally fed on high-protein trash fish diets. Snakehead has been bred in Thailand and successfully fed on dry commercial feed.

Visiting a large cooperative fish pond with the farmers. The writer (centre left), Dr. RamaKrishna (centre right).

Dr. RamaKrishna introducing the writer to a final meeting at the Delta Fish Farmers Association.

Dr. RamaKrishna introducing the writer to the members of a fish farming commune.

8. Pond size

According to the farmers, "bigger is better" for pond size, with average grow-out pond size of about 20 acres (8 ha) and optimum size considered to be at least 25-50 acres (10-20 ha). Some ponds exceeded 100 acres (40 ha). While Indian major carps may grow best in large ponds, Chinese farmers reported to me in the early 1980s that ponds of 0.2-0.3 ha were best for highly productive Chinese fertilized and supplementary fed polyculture, an order of magnitude smaller than a similar semi-intensive system.

Local farmers reported better unit area production, more water surface area per farm and need for fewer watchman with larger than smaller ponds. However, large ponds must be more difficult to manage, especially with intensified production. It is recommended that optimum size of ponds be reconsidered.

9. Stunted yearlings

The system as developed by the farmers consists of two stages of 10-12 months each: production of 100-250 g yearlings in which 2.5 cm fingerlings are stocked at 4-5/m^2; and

grow-out in which yearlings are stocked at about 0.4/m^2 until rohu reaches marketable size of 1.5 kg and catla 2.3 kg. A partial harvest may take place after 8 months.

Most farmers believe that, irrespective of stocking density and feeding, carps grow slowly in their first year and only grow quickly in their second year. The two-year cycle with the area of grow-out to nursery ponds of about 4-5:1 on most farms has evolved based on a belief for the need to stunt carps in their first year.

While compensatory growth of stunted fish has been reported in the scientific literature, it may be more profitable to redesign the system around optimizing fish growth at all times within the carrying capacities of well fertilized and fed ponds, as there would be better use of pond space and a shorter time to produce marketable size fish,. This is supported by the experience of a farmer who said that it is possible to grow rohu to marketable size in 1 year with food of adequate amount and quality. Research on growth rates of carps of different sizes and ages, with bio-economic modeling is recommended. Farmers expressed concern that reducing the length of the fish culture by providing more growing space for smaller fish would lead to more bird predation. Currently stunted fish are protected from bird predation by nylon string mesh.

10. Pond additives

Farmers commonly use commercial mineral supplements, especially when fish are stressed; these are unlikely to be needed in fertilized 'green water' ponds with abundant natural food.

The need for bromine as a "water sanitizer" to reduce bacteria is probably also unnecessary.

11. Pond effluents

Farmers reported no adverse impact of discharged pond effluents on Kolleru Lake, a Ramsar site. Effluent quality could be improved by reduced use of manures and improved supplementary feeding practices. Furthermore, discharge of sediment-rich effluent could be reduced by simple pond draining procedures and by being treated by sedimentation in on-farm drainage canals before being discharged to the lake.

12. Farmer seminar

I also recommended that current farmer experience be documented through questionnaires and subsequently discussed at a seminar. Several farmers are continuing to experiment so it would be invaluable to benefit from their experience over the past three decades. It appears that several of my suggestions for possible improvement of the system have already been tested by small numbers of farmers. Dissemination of improved farmer practice could lead to major benefits for other farmers who continue to farm fish in the local traditional way.

Aquaculture and environmental issues in the region of Nai Lagoon, Ninh Hai district, Ninh Thuan province, Viet Nam

Nguyen Van Quynh Boi
Aquaculture Faculty – Nha Trang University, Viet Nam, e-mail: nvqboi122@yahoo.com

During recent years, aquaculture in Viet Nam has grown rapidly in terms of area, type of culture, productivity, yield as well as economic results. For diversification purposes, many species have cultured at different localities. However, spontaneous development without adequate planning, management controls or awareness of environment conservation have led to problems such as conflicts among users, environmental degradation and outbreaks of disease, resulting in difficulties for aquaculture development in general.

Nai Lagoon located in the northeast of Phan Rang city, belongs to the administrative area of Ninh Hai district, Ninh Thuan Province. Nai Lagoon supplies aquatic resources that form the basis of the livelihoods of most of the people living around it. Like other coastal lagoons, due to the heavy pressure of livelihood activities, particularly aquaculture, Nai Lagoon has been at risk of gradual degradation of its environmental quality and resources, thereby compromising the livelihoods of local communities.

Under these circumstances, sustainable aquaculture development together with coastal ecosystem and environment conservation, based on the involvement of local communities, as adopted by many countries and local governments throughout the world, appears vital.

In order to develop community-based environment conservation at Nai Lagoon, it is necessary to understand the status of aquaculture and relevant problems. This paper focuses on aquaculture development and environmental issues at Nai Lagoon in recent times.

Methodology

Rapid Rural Appraisal (RRA) methods and questionnaire surveys were used to collect data from targeted households of five communities around the lagoon. RRA method was applied to obtain general information on the study area and to direct the questionnaire survey. Information in the questionnaire survey focused on culture status (cultured species, type, area and economic performance), environmental issues emerging during recent years and orientation for sustainable aquaculture. The number of aquaculture households randomly interviewed was selected based on the relative ratio of households growing different species. The number of interviewed households is shown in Table 1.

Interview with a farmer.

The study attempted to assess the current situation of aquaculture in the region of Nai Lagoon in terms of cultured species and economic performance. Social assessments were undertaken in order to understand awareness, attitudes and opinions of aquaculture households about fisheries extension activities and environmental issues. Data was analysed for each item using MS Excel software.

In addition, secondary data was summarised in order to understand natural conditions, social-economic situation, environmental issues, mechanisms for aquaculture management and orientation of aquaculture in the region of Nai Lagoon.

Results and discussion

Overview of natural conditions of Nai Lagoon

Nai Lagoon is a coastal bay about 700 ha in area. The maximum depth of the lagoon is about 2.5 m depending on tide. Tidal amplitude fluctuates from 0.7 to 2.5 m. Rainfall is rather low, usually around 700 – 800 mm with the wet season from August to November, often flooding at this time causing losses for shrimp farmers. The lagoon often features a strong current throughout the wet season and salinity may fall. The volume of fresh water annually supplied to Nai Lagoon ranges from 350 to 400 million m^3. However, seventy percent of the volume often reached for three months of rainy season. For that reason, fresh water supplied for agriculture and shrimp culture was limited in dry season leading to many difficulties for these activities.

The lagoon is connected with the sea by a narrow canal (Ta Khac Thuong et al, 2001) of 2 km in length, 3-5 m in depth and 100-400 m in width. However, the canal has filled up somewhat leading

Table 1. Number of aquaculture households interviewed.

Cultured species	Number of households	Ratio (%)
Black tiger shrimp	30	43
Seaweed	15	22
Crab	10	14
Molluscs	8	11
Marine fish	7	10
Total	**70**	**100**

Table 2. Area and yield of shrimp culture at Nai Lagoon.

Year	Area (ha)	Yield (Tonnes)	Productivity (tonnes/ha)
1992	469	620	1.32
1995	552	523	0.94
1998	548	947	0.57
1999	607	1,183	1.95
2000	673	1,412	2.1
2002	898	1,162	1.29
2003	898	1,143	1.27
2004	773	2,221	2.87

(Source: Reports of 2004 and 2005, Provincial Fisheries Department of Ninh Thuan province).

Table 3. Some species cultured at communes around Nai Lagoon.

Commune	Cultured species					
	Black tiger shrimp	Swimming crab	Snail (*Babylonia areolata*)	Blood cockle	Seaweed	Fish
Khanh Hai	+				+	
Tri Hai	+	+			+	+
Ho Hai	+	+			+	+
Tan Hai	+		+	+		
Phuong Hai	+	+			+	+

Table 4. Economic results of each species culture activities.

Cultured species	Culture period (months)	Profit (VND/ha/month)
Babylon snail	4	74,116,750
Black tiger shrimp	4	41,562,500
Fin fish	8	16,250,000 – 17,500,000
Seaweed	5	2,111,000
Swimming crab	12	1,300,000 – 1,500,000

to a decrease in water exchange and increased sedimentation within the lagoon.

Overview of social – economic situation of communities around the lagoon area

According to the administrative division, five communes of Tan Hai, Ho Hai, Phuong Hai, Tri Hai and Khanh Hai belonging to Ninh Hai district are located around Nai Lagoon. The total population of these five communes was around 64,300 people accounting for 54% of the district population. Up to December 2004, the population density was at 423 people/km^2, which is rather high in comparison to district population density (215 people/km^2) (Provincial Fishery Department of Ninh Thuan province, 2004). The population is biased towards young people with more than 50% under 18 year old, a high birth rate (crude birth rate was about 3%) and number of people per household (average of 6-7). Moreover, the local unemployment rate is high at more than 30%. In recent years, literacy standards have improved but are still at low levels in comparison to urban areas. Resolving the unemployment problems, increasing living standards and improving the lagoon environment are challenges for the local government. In recent times, livelihood activities of most local people were mainly based on resources of Nai Lagoon such as shrimp culture, aquatic resource exploitation, and salt production. Nai Lagoon is the largest area for aquaculture in Ninh Thuan province with around 900 ha of pond area.

Recent situation of aquaculture in the region surrounding Nai Lagoon

Aquaculture at Nai Lagoon started in 1980 mainly with extensive systems. The main products were marine fish and sand-shrimp (*Metapenaeus* sp.). The area of aquaculture increased to 80 ha with the introduction of black tiger shrimp culture in 1987 using improved extensive systems. In 1993, the Peoples Committee of Ninh Thuan Province issued a policy to develop infrastructure for 500 ha of aquaculture in the region and aquaculture activities changed from this time. After 1995, culture techniques changed to semi-intensive type with large investments of seed, shrimp feed, equipment and application of technological advances. The year 2000 was the peak of shrimp culture activities of Ninh Thuan Province in general and Nai Lagoon in particular in terms of productivity and economic performance. Aquaculture has stabilized at around 900 ha of pond area at present.

However, due to failure of black tiger shrimp culture in recent years, other species have been farmed instead. Up to July 2005, there were 120.5 ha used for culturing other species with 267 participating households. Of these, the area used for seaweed culture (*Kappaphicus alvarezii*) was largest (133.8 ha). In fact, most of households were at the stage of looking for suitable alternative culture species. Species cultured in the area are summarized in table 3.

Basing on surveyed data, economic performance calculated for one ha showed that high profit were associated with the farming of black tiger shrimp, babylon snail, finfish and seaweed.

The results of culture (table 4) have shown that culture of snails, shrimp and fish can give high profit. In fact, shrimp farming was high-risk activity so snail and finfish have been the new trade-off for culture activity at the lagoon. However, the main difficulty has been the lack of culture technique for these species for farmers, especially for babylon snail. Therefore, the Fishery Extension Center of Ninh Thuan province should in future seek to assist farmers in this regard, together with capital provision policy.

Black tiger shrimp culture (*Penaeus monodon*)

Together with high profit, the area used for shrimp culture has increased. Over the period from 1989 to 1999, shrimp culture area increased by 105.74% (an average of 10.57% annually). However, in the period from 2000 to 2005, the area used for shrimp culture has decreased. The ponds remain, however the area actually used has fallen from 898 ha (2003) to 773.2 ha (2004), to only 325 ha in 2005 (Fishery Department of Ninh Thuan province, 2005). While area under culture was still increasing in 2002 the productivity and yield had begun to fall, with yield down 250 tons and productivity falling by 800 kg/ha, reaching a low of just 1,270 kg/ha in 2003. This was one reason for the rapid subsequent decline in culture area and switch into other species by many farmers; another reason was that farmers lacked capital to continue shrimp farming.

Seaweed culture (*Kappaphicus alvarezii*)

In 2003, with assistance from the Provincial Fishery Department of Ninh Thuan, the Peoples Committee completed preparation of a project to provide opportunities for employment and "hunger eradication - poverty alleviation" for shrimp farmers around Nai Lagoon. The area planned for seaweed culture was 20% total area of Nal lagoon (from 160 to 200 ha) (People Committee of Ninh Hai district, 2004). Seaweed culture was piloted in a 4.8 ha area at Khanh Hai Commune, increasing to 37.8 ha in 2004 and 133.8 ha in 2005.

Seaweed was farmed using the method of a single line stretched over the lagoon bottom. This method was popularly applied and evaluated as having advantages over other methods. Seaweed was often cultured from May to September and from October to March of following year in areas of water exchange with salinity of 28 – 30 ppt, less waves and no direct influence by fresh water. However, in the sub-crop season, weather was often unstable and floods, storms and high temperatures had some negative impacts the development of seaweed culture.

Table 5. Assessing extension activity in the region of Nai Lagoon (n=70).

Item	Opinion	Ratio (%)
Aquaculture workshops		
Participating	40	57
Not participating	30	43
Results		
Good	28	40
Fair	7	10
Bad	5	7
No opinion	30	43

Table 6. Decreasing environmental quality – causes and solutions (n=70).

Item	Opinion	Ratio (%)
Environmental quality		
a. Good	1	1.4
b. Acceptable	6	8.6
c. Bad	63	90
Cause of pollution		
a. Freely discharging waste	43	61
b. Lack of treatment systems	2	5.7
c. Low awareness of culturists	13	19
d. Other	10	14.3
Way of improvement		
a. Seed testing before stocking	2	3
b. Improving pond environment	2	3
c. Enhancing community awareness	52	74
d. Other	14	20

Swimming crab culture (*Portunus* spp.)

Swimming crab culture has not been widely developed due to lack of seed. However, difficulties in shrimp culture have led some households to use their shrimp ponds for swimming crab culture. Most of these households were poor. In addition to swimming crab culture, their livelihood activity was fishing in the lagoon so they could catch natural seed to supplement during culture cycles. Other households could buy seed from fishers. For that reason, most of interviewees (90%) revealed that seed quality was not good and rather scarce. In general, swimming crab culture at the Nai Lagoon was mainly "harvesting and stocking in rotation".

Most cases of swimming crab culture were carried out at Hon Thien – Ho Hai commune. Culture area in 2004 was only 6.3 ha with 16 households and average culture area was 0.35 ha/household. Culture density was rather low at the average of 1.32 inds/m^2 with average seed size of 20 – 30 individuals/kg. Productivity of swimming crab culture at Nai Lagoon was about 1.16 tons/ha/year.

Mollusc culture

Due to problems encountered with shrimp culture, the Fisheries Department proposed diversifying culture species in order to improve the culture area environment and develop sustainable aquaculture. As new species, snail and blood cockle were reared.

Babylon snail farming (*Babylonia areolata*): Babylon snail was a cultured species of economic value, especially for export purpose. In 2003, the Fishery Extension Center of Ninh Thuan Province carried out snail culture successfully in earthen ponds. From this time, it started to be reared by farmers. Crops started from February to June and from September to December. The price of seed was rather high and all households revealed this to be the main difficulty. At the present, six households conduct snail farming in ponds at Tan An village - Tri Hai commune with total area of 2.8 ha. Furthermore, nine households culture snail in the lagoon area (cage culture) at Khanh Hai commune. However, all of these households have suffered high mortality rates without identified reasons. The potential problem of snail rearing was fresh feed. This could easily pollute the lagoon environment if snail culture further develops.

Blood cockle culture (*Arca ranosa*): Since 1997 some farmers started blood cockle culture in the littoral area of the lagoon but results were not good. Up to June, 2005 there were only two households conducting blood cockle rearing at Hon Thien, Ho Hai commune with 2 ha pond area and 0.5 ha littoral area (fence culture). The culture period lasts for seven months (from August to April of the following year). However, due to high mortality rate without known reasons, yield only reached 0.4 tons/ha. In recent times, there has been no hatchery seed so wild seed of blood cockle caught from the lagoon was used. Due to overexploitation, natural seed of blood cockle became gradually scarce, negatively affecting natural resources of blood cockle in Nai Lagoon. Together with the development of seaweed culture, waters area used for exploiting blood cockle seed was narrowed leading to conflict between the two activities. According to the policy of Provincial Fishery Department, the area of blood cockle culture should not be increased due to low economic performance and environmental impact of the waste from blood cockle farming.

Fish farming

Fish farming was one option to diversify culture species in order to reduce the dependence on shrimp culture activity with negatively environmental impacts. Fish farming at Nai Lagoon started from 2004. Cultured species included sea-bass (*Lates calcarifer*), snapper (*Lutjanus* spp.) and tilapia (*Oreochromis* spp.). The culture season of fish depended on seed availability. Moreover, the Fishery Extension Center of Ninh Thuan Province has piloted model of co-culture of black tiger shrimp and milkfish in order to improve environmental conditions and enhance economic performance. Fish farming helped to provide more jobs, increased income for farmers, and improve pond environment. According to farmers, the economic performance of fish farming was positive. However, data was limited for detailed analysis.

Environmental problems caused by aquaculture activities at Nai Lagoon

In recent time, problems of environmental pollution and degradation at Nai Lagoon were at alarm levels. Of these, waste from culture activities was the most important problem that needed to be solved. Negative factors for the environment of Nai Lagoon from aquaculture activities included:

Chemicals

For aquaculture production, all households used chemicals for a variety of purposes including cleaning the pond bottom, water quality management and sterilization, probiotics and tonics. These chemicals affected not only the ecosystem in culture pond but also natural ecosystem when they were released into outside environment.

Organic wastes

Large amounts of dissolved and solid wastes generated from aquaculture activities have been mentioned in a number of documents. So far, in general, aquaculture systems in the region have developed spontaneously without planning. Hence, there was lack of dedicated systems for water supply-discharge. Therefore, water discharge was loaded into the lagoon without any treatment, leading to pollution of the lagoon. Some parameters were higher than regulated criteria for aquaculture such as dissolved oxygen, NH_3, biological oxygen demand and total bacterial counts. For that reason, there should be necessary measures to control these wastes. In recent time, in order to avoid environmental pollution caused from low quality feed, the Fishery Extension Center and Fishery Department has often tested feed samples from shrimp feed services. In addition, fisheries extension programs were undertaken to educate farmers about feeding rates and regimes. The seaweed culture program was also one of solutions for this problem.

Fisheries extension activities and awareness of local people about environmental issues

Yearly, under guideline of the Provincial Fishery Department, the Fishery Extension Center collaborating with District People Committee, Commune People Committees, and shrimp feed agents organised aquaculture workshops.

Above, below: Shrimp ponds in the Nai Lagoon area.

However, survey results showed that only 57% of aquaculture households did attend. Forty percent of interviewees evaluated the workshops as helpful. By this way, they learned culture techniques such as feeding methods and disease prevention. However, 7% of interviewees thought that fishery extension activities did not have any effect.

Assessing environmental quality, 90% interviewed opinions showed that it was bad but 1.4% thought that it was good. According to aquaculturists, causes of pollution were freely discharging waste (61%), low awareness of local people (19%), lack of waste treatment systems (5.7%) and other causes such as unplanned development and unsuitable time culture. In order to improve environmental quality, they suggested to enhance community awareness. Seventy four percent interviewed opinions thought that responsible culturists should not discharge waste freely, particularly in case of infected shrimp ponds by disease.

At present there are some communes (Luong Cach, Tri Thuy) that have introduced fees for environmental cleaning. However, the fee for aquaculture activity was not applied due to lack of policy. Environmental fees might be new for local managers and farmers.

However, it could be a useful tool to regulate local economic development if it were used in the right way. According to our survey, 63% of interviewees agreed that it is necessary to apply an environmental fee. The basic issue was to identify appropriate sum of money and use the fee for right purpose. For aquaculture, environmental fee policy aims at ensuring the fairness between resource users and others. This fee could be calculated based on profit from aquaculture activity. This fee also forbids resource users to be responsible for their activities. In case of disease breaking out, this fee would be the fund to help farmers to resolve the problem.

Mechanisms for management of aquaculture activity

Among authorities/offices at any level

Aquaculture activity was under direct management of the Provincial Fishery Department, the Fishery Extension Center and Aquatic Resources Preservation Office (responsible for culture techniques, environmental conditions and disease warnings), the Provincial Peoples Committee (generally promulgating policy, planning development and regulating management) and the District and Commune Peoples Committees (implementing guidelines).

In principle, aquaculture ecosystems are the un-detachable part of aquatic ecosystem that are not only directly related to but also affected by terrestrial ecosystems. Thus aquaculture is affected by other economic activities, especially agriculture. However, the connection among economic branches was still loose and not decentralized completely. The Provincial Fishery Department was responsible for aquaculture but canal and irrigation systems are under management of the Provincial Department of Agriculture and Rural Development. Under this circumstance, the Fishery Department was only in charge of professional techniques so it could not manage wastes from agricultural activity (mainly fertilizers and pesticides). Moreover, at district and commune levels, there was not any office responsible for aquaculture so management activities were ineffective. Trying to resolve these issues, the Fishery Department of Ninh Thuan Province established Ninh Hai Station of Aquaculture Management in order to better manage aquaculture activity at the district level.

Among farmers conducting aquaculture

Before 2004, all localities around the lagoon established aquaculture self-management groups in order to control environmental cleaning and disease warnings. On a voluntary basis, each group had 10 - 15 members including the head. Each group organized monthly meetings to inform members about the aquaculture situation and so that they could help each other with capital and techniques. However, by 2005 only two communes had maintained this activity, Ho Hai and Phuong Hai, due to lack of activity expenditure, manpower, mechanism and experiences. In fact, management mechanisms were only applied for shrimp and seaweed culture but most farmers did not believe in this type of management due to ineffective activity of the self-management groups. When farmers had problems such as disease they tried to solve themselves. For that reason, authorities should improve activity of self-management groups.

Orientation of aquaculture at Nai Lagoon in future

According to the aquaculture planning project of Ninh Thuan Province, the aquaculture area around Nai Lagoon will be decreased by 200 ha. Khanh Hai and Tri Thuy communes will not continue aquaculture but will develop eco-tourism instead. Aquaculture area for the whole region of Nai Lagoon will be 750 ha including 650 ha (500 ha water surface equivalently) of Phuong Hai, Ho Hai and Tan Hai communes conducting semi-intensive culture and 100 ha of Khanh Hai commune conducting eco-tourism aquaculture.

One crop per year of black tiger shrimp will be conducted and the remaining crop will be other species. In recent times, there have been two types of rotation culture: shrimp – fish (often tilapia) and shrimp – seaweed. However, the rotation culture of shrimp – seaweed has been ineffective in the lagoon region due to poor development of seaweed in ponds. It may be useful for the Fishery Extension Center to carry out more research to improve this model. In addition, shrimp and milkfish co-culture models have been experimented with. The success of this model would enhance income and improve pond environments. However, methods and ratio of co-cultured species should be researched in order not to affect shrimp as the main culture species (due to competition of milkfish with shrimp about feed). Babylon snail, tilapia, snapper, grouper may provide alternatives to black tiger shrimp. It is clear that the culture model of these species should be further researched to develop sustainable aquaculture. Depending on location and condition of each locality, farmers should be encouraged to culture suitable species.

In order to realize the above mentioned orientations, it is necessary to develop infrastructure and integrated management policy among production branches as well as levels. Additionally, the support and participation of local people should be encouraged.

Conclusion and recommendations

Based on survey results, the following conclusions can be made:

- In recent times, the main cultured species in region of Nai Lagoon was black tiger shrimp.
- Aquaculture is the main livelihood activity of many local households. However, most of them have low technical qualification so culture activity is based on their experience.
- In general, aquaculture activities have not been planned and wastes have not been adequately controlled. Together with low awareness of farmers, these have resulted in degradation of the natural environment, leading to losses for farmers.
- Management activities have generally been ineffective. Aquaculture training has not been considered as good by all farmers. Management mechanisms at different levels have been limited. The activity of self-management groups has not been effective.

In order to sustain aquaculture in the region of Nai Lagoon, some recommendations are proposed:

- Applying waste water treatment systems for aquaculture and restoring mangrove forest in the vicinity of the lagoon to assist with assimilation of nutrients.

- Planning of culture area, conducting rotation aquaculture and co-culture, and carrying out culture activities in suitable season-crops could facilitate sustainable production.

- Further research on culture species to find suitable species for this locality.

- Organisation of frequent aquaculture workshops in order to improve technical skills and environmental awareness of farmers.

- Application of environmental tax/fees on aquaculture activity to assist with prevention, remediation and fund response to emergencies such as disease outbreaks.

References

Ngo, T. A. 2005. Impact assessment of commercial shrimp culture on Nai Lagoon environment. Master Thesis. Aquaculture Faculty, University of Fisheries – Nha Trang.

Fishery Department of Ninh Thuan province, 2004. Situation of aquaculture development and results of fishery extension activities in the period of 2000 – 2005.

Fishery Department of Ninh Thuan province, 2005. Assessment of implementing yearly plan of 2004, line and duty of 2005 yearly plan. Summary report.

Nguyen, T. N. and Nguyen, T.K.V. 1999. Socio-economic survey of situation and potential of shrimp culture development at Nai Lagoon – Ninh Thuan province. In: Proceeding of scientific research. Volume IV. University of Fisheries, Nha Trang.

Statistical Office of Ninh Thuan province, 2004. Statistical yearbook - Ninh Thuan province.

Statistical Office of Ninh Hai District, 2004. Statistical yearbook - Ninh Hai district.

Ta, K.T. et al., 2001. Solution for overcoming environmental and aquatic resources degradation in Nai Lagoon, Ninh Thuan province – Project report. University of Fisheries, Nha Trang.

Climate change impacts on fisheries and aquaculture

Sena De Silva, NACA Director General

Climate change is perhaps one of the most important issues confronting the global community and associated debates have intensified over the last decade, most recently with the submission of the final findings of the Inter Governmental Panel on Climate Change (IPCC, 2007). The time has come for development and food production sectors to take note of the above findings, based on a thorough scrutiny and synthesis of the scientific evidence on climate change, and to initiate adaptive and/or mitigating measures.

FAO has initiated many expert consultations on the impacts of climate change on different food production sectors, one of which was held on fisheries and aquaculture. Needless to say that the urgency of the problem has been further exacerbated by the emerging "food crisis" as well as by the potential channeling of food to produce biofuel.

The Expert Consultation on Climate Change Impacts on Fisheries and Aquaculture was held in Rome, 7-9 April, 2008. The consultation was based on three reviews that formed the background for the discussions and the preparation of an all encompassing document to be submitted to the Heads of Government Meetings on Climate change in Rome, July 2008. The three reviews that were provided the background for the consultation were:

- Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture (by Manuel Barange and Ian Perry).

- Climate change and capture fisheries – impacts, adaptation, mitigation, and the way forward (by Tim Daw, Neil Adger, Katrina Brown and Marie-Caroline Badjeck).

- Climate change and aquaculture (by Sena S De Silva and Doris Soto).

These reviews will be published as a FAO Fisheries Technical Paper in due course and are expected to provide a useful documentation regarding the potential impact of climate change on fisheries and aquaculture, and recommendations regarding adaptive measures.

The "policy paper" on climate change on fisheries and aquaculture developed at the consultation is reproduced below. More information from the FAO High Level Conference on Climate Change and Fisheries and Aquaculture is available from the FAO website at: http://www.fao.org/foodclimate/expert/em7.html.

Workshop on Climate Change and Fisheries and Aquaculture: "Options for decision makers"

FAO Headquarters, Rome, 7-9 April 2008

Introduction

From local to global levels, fisheries and aquaculture have very important roles for food supply, food security and income generation. Some 42 million people work directly in the sector, with the great majority in developing countries. Adding those who work in associated processing, marketing, distribution and supply industries, and the sector supports several hundred million livelihoods. Aquatic foods have high nutritional quality, contributing 20 percent or more of average per capita animal protein intake for more than 2.8 billion people, mostly from developing countries. They are also the most widely traded foodstuffs and are essential components of export earnings for many poorer countries. The sector has particular significance for small island states. Climate change is projected to impact broadly across ecosystems, societies and economies, increasing pressure on all livelihoods and food supplies, including those in the fisheries and aquaculture sector. Food quality will have a more pivotal role as food resources come under greater pressure, and the availability and access to fish supplies will become an increasingly critical development issue.

The fisheries sector differs from mainstream agriculture and has distinct interactions and needs with respect to climate change. Capture fisheries have unique features of natural resource harvesting linked with global ecosystem processes. Aquaculture complements and increasingly adds to supply and, though more similar to agriculture in its interactions, has important links with capture fisheries.

The demands of growing populations will require substantial increases in aquatic food supply in the next 20 to 30 years, during which climate change impacts are expected to widen and increase. In the face of these impacts and the existing development and management constraints, the primary challenge for the sector will be to deliver food supply, strengthen economic output and maintain and enhance food security while ensuring ecosystem resilience. This will require concerted, collaborative and determined action across all stakeholders, linking private sector, community and public sector agents.

Developing the knowledge base

The existing pressures of demand, and anticipated challenges, will require better multi-scale understanding of the impacts of climate change and of the interacting contribution of fisheries and aquaculture to food and livelihoods security. Climate change will increase uncertainties in the supply of fish from capture and culture. Such uncertainty will impose new challenges for risk assessment, which is commonly based on knowledge of probabilities from past events. Data for determining effects of past climate change at best cover no more than a few decades, and may no longer be an adequate guide to future expectations.

This means that in the future, planning for uncertainty will need to take into account the greater possibility of unforeseen events, such as the increasing frequency of extreme weather events and “surprises”. However, examples of past management practices in response to existing climate variability and extreme events relating to different regions and resources can provide useful lessons to design robust and responsive adaptation systems, even though they will have to be placed in context of greater uncertainty.

While current knowledge is adequate in many instances to take appropriate action, better communication, application and feedback will be essential in knowledge-building. Action in the following areas will be needed to support mitigation and adaptation policies and programmes in fisheries and aquaculture:

Estimate production levels. Projections of future fisheries production levels at the global and regional scales will be driven by medium- and long-term probabilistic climate change predictions in the context of substantial ecological and management uncertainties.

Forecast impact levels. Detailed impact predictions on specific fisheries and aquaculture systems will be required to determine additional net positive or negative consequences for vulnerable resources and regions. This is particularly important for semi-arid countries with significant coastal or inland fisheries, as they are among the most vulnerable to climate change.

Develop tools for decision-making under uncertainty. Adaptive tools for the fisheries and aquaculture sectors will need to be refined, developed and implemented to guide decision making under uncertainty and address important cross linkages among the relevant sectors. The uncertainties decision-makers will face include i) the responses and adaptations of marine and freshwater production systems to gradual climate change, including critical thresholds and points of no return, ii) the synergistic interactions between climate change and other stressors such as water use, eutrophication, fishing, agriculture, alternative energy, and iii) the ability and resilience of aquatic production systems and related human communities to adapt and cope to multiple stresses.

Expand societal knowledge. Better knowledge will be required of who is or will be vulnerable with respect to climate change and food security impacts, how this arises and how it can addressed. In this regard, gender and equity issues will need to be carefully considered.

Policy, legal and implementation frameworks at national, regional and international levels

Addressing the potential complexities of climate change interactions and their possible scale of impact requires mainstreaming of cross-sectoral responses into governance frameworks. Responses are likely to be more timely, relevant and effective if they are brought into the normal processes of development and engage people and agencies at all levels. This requires not only the recognition of climate-related vectors and processes, and their interaction with others, but also availability of sufficient information for effective decision-making and approaches that engage public and private sectors. All of these elements will be vital in providing the best possible conditions in which the aims of food security – quantity and timing of food supply, access and utilization – can be met.

National

Action plans at the national level can have as their bases the Code of Conduct for Responsible Fisheries and related International Plans of Action (IPOAs), as well as appropriately linked policy and legal frameworks and management plans. Responses will need to employ integrated ecosystem-based approaches to fisheries and aquaculture (EAFs and EAAs) for the national fisheries and aquaculture sector throughout the entire resource extraction, supply and value chain. The future implications of climate change will intensify the justification for finding policy consensus to reform capture fisheries while respecting national sector characteristics.

Requirements include:

- Actions will be needed that focus on key issues such as adjusting fleet and infrastructure capacity and flexibility, identifying management systems that offer negotiated balances between efficiency and access, and creating alternative employment and livelihood opportunities.
- Policy and legal regulatory frameworks will be required for aquaculture to expand along sustainable and equitable development paths.

- Links will need to be improved among fisheries, aquaculture and other sectors that share or compete for resources, production processes or market position, in order to manage conflicts and ensure that food security aims can be maintained.

- Links will be required among national climate change adaptation policies and programmes as well as national cross-sectoral policy frameworks such as those for food security, poverty reduction, emergency preparedness and response, insurance and social safety schemes, agricultural and rural development, and trade policies.

Regional

The potential for spatial displacement of aquatic resources and people as a result of climate change impacts, and the greater variability characteristics of transboundary resources will require existing regional structures and processes to be strengthened or given more specific focus. Policy and legal mechanisms that address these issues will need to be developed or enhanced. Regional market and trading mechanisms are also likely to be more important in linking and buffering supply variability and maintaining sectoral value and investment.

Requirements include:

- Regional fisheries organizations and other regional bodies should be strengthened. They should place climate change awareness and response preparedness clearly on their agendas and link more closely with related regional bodies.

- Fisheries and aquaculture will need to be addressed adequately in cross-sectoral and transboundary resource use planning and in intra-regional markets and trade. In this vein, the potential effects of climate change stressors on regional issues will have to be considered as part of any provisions for action.

- Common platforms are needed for research and data gathering approaches, sharing of best practices in identifying and responding to climate change-related impacts and developing response mechanisms.

International

As sectoral trade and competition issues link with climate change mitigation and adaptation activities, they are likely to become more important, with the potential to define many areas of economic potential and constraint. As a small and often politically weak sector, fisheries and aquaculture may be particularly vulnerable in such competition and conflicts. This increases the importance of having fishery sector representation in policy and legal development processes related to climate change mitigation and adaptation.

Requirements include:

- Fisheries and aquaculture need to be adequately addressed in climate change policies and programmes dealing with global commons, food security and trade.

- Common platforms are needed for international data and research approaches, sharing best practices in identifying and responding to climate change-related impacts and developing response mechanisms.

- Fishery sector responses should be incorporated into processes and decisions related to climate change in the other major sectors (e.g. water) to which fishery issues are linked.

- International fishery agreements and conventions should be more vigorously applied, and strengthened if necessary, to accommodate and support climate change-related activities.

- Cooperation and partnerships should be enhanced for dealing with NGOs, civil society organizations, intergovernmental organizations, including the 1-UN approach, and donor co-ordinated initiatives.

Capacity building: technical and organizational structures

Policy-making and action planning in response to climate change involves not only the technically concerned line agencies such as departments responsible for fisheries, interior affairs, science and education, but also those for national development planning and finance. These institutions, as well as community or political representatives at subnational and national levels, should also be identified to receive targeted information and capacity building. Partnerships would also need to be built and strengthened among public, private, civil society and NGO sectors.

Requirements include:

- Nationally, information gaps and capacity-building requirements need to be identified and addressed through networks of research, training and academic agencies.

- Internationally, networks should be created or developed that encourage and enable regional or global exchanges of information and experiences, linking fishery issues with other those of other sectors such as water management, community development, trade and food security.

- Existing management plans for the fisheries and aquaculture sectors, coastal zones and watersheds need to be reviewed and, if needed, further developed to ensure they cover potential climate change impacts, mitigations and adaptation responses. Connections to wider planning and strategic processes also need to be identified and adjusted.

- Communication and information processes that reach all stakeholders will be essential elements in sectoral response. This will require focused application by communication specialists to ensure that the information is accessible and usable –presenting diverse and complex issues in a form that is targeted and understandable for each audience.

Enabling financial mechanisms: embodying food security concerns in existing and new financial mechanisms

The full potential of existing financial mechanisms will be needed to tackle the issue of climate change. Innovative approaches may also be needed to target financial instruments and create effective incentives and disincentives. The public sector will have an important role in leveraging and integrating private sector investment, interacting through market mechanisms to meet sectoral aims for climate change response and food security. Many of these approaches are new and will need to be tested in the sector.

At the national level:

- Producers, distributors and processors should be able to increase self protection through financial mechanisms. This is particularly relevant for aquaculture (e.g. cluster insurance) but financial services could also be used to promote emergency funds more widely through the sector.
- Investment in the sector, especially in infrastructure, will need to consider climate change which will require developing better information on the costs and benefits of protection.
- Transfer or spread of sector-related risk – from individuals and communities to the state through contingency plans – will be based on specific fiscal provisions but also may be tied to innovations in resource management through which the insured accept responsibilities in exchange for protection.
- Financial instruments that can promote risk reduction and prevention practices include initiatives such as relocation allowances from low lying areas and disincentives for misuse of water in aquaculture.
- Existing and new initiatives for improving equity and economic access, such as microcredit, should be linked to climate change adaptation responses such as livelihood diversification.
- Mitigation options can include fiscal incentives for reducing the sector's carbon footprint, developing more efficient processes and sector agreements, and providing payment for environmental services, particularly offering additional livelihood options to poorer communities.

At the international level:

- Funding agencies can "climate proof" their approaches and, at the same time, take advantage of new opportunities in the fisheries and aquaculture sector by jointly promoting food security, reducing negative impacts of climate variability and change, and improving resource management.
- Donors should be made more aware of the importance of the fisheries and aquaculture sector in terms of food security and its sensitivity to climate change, and of effective ways in which the sector could become part of cross-sectoral investment strategies.
- Private sector investors should be encouraged to incorporate "climate proof" approaches into international sourcing, trade and market development, and into broader corporate responsibility areas, including delivery of local benefits and inclusion of smaller scale producers.

New initiatives in fisheries extension

H.K. De[1], G.S. Saha[1], R. Srichandan[1] and V.P. Vipinkumar[2]

1. Central Institute of Freshwater Aquaculture, Bhubaneswar, Orissa 751 002;
2. Central Marine Fisheries Research Institute, Cochin, Kerala, India.

Improved communication and information access is directly related to social and economic development. However, the rural population still have difficulty in accessing crucial information in forms they can understand in order to make timely decisions. There is a concern that the gap between the information rich and information poor is getting wider. New information and communication technologies are generating possibilities to solve problems of rural poverty, inequality and giving an opportunity to bridge the gap between information-rich and information-poor and to support sustainable development in rural and agricultural communities. However remote rural communities still lack basic communication infrastructure. The challenge is not only to improve the accessibility of communication technology to the rural population but also to improve the relevance of information to local development. The article focuses on innovations in technology dissemination with particular focus on aquaculture.

Public sector initiatives

Single window delivery system

In an information age, the role of appropriate information package and its dissemination is of crucial significance. It is not enough to generate information but it is also essential to ensure that the required information is delivered to the end-users at the earliest and with the least dissemination loss. The establishment of agricultural technology information centers (ATIC) can forge a better interaction between researcher and technology users. This serves as a single window system with an objective to help the farmers and other stakeholders both to provide solution to their location-specific problems and to make available all the technological information along with technology inputs and products for testing and use by them. Such information is useful for:

- Farmers;
- Farmer-entrepreneurs;
- Extension workers and development agencies;
- NGOs; and
- Private sector organisations.

ATICs facilitate direct access to the farmers to the institutional resources that are available in terms of technology, advice and products, thereby reducing technology dissemination losses. Under the National Agricultural Technology Project (NATP) the Indian Council for Agricultural Research (ICAR) has established 44 ATICs in State Agricultural Universities and in ICAR Institutes. Three such ATICs are operating in specialised fisheries research institutes viz., the Central Institute of Freshwater Aquaculture, Bhubaneswar, Orissa ; the Central Marine Fisheries Research Institute, Cochin, Kerala and the Central Institute of Fisheries Technology, Cochin, Kerala.

Kisan call centre

The Department of Agriculture & Cooperation (DAC), Ministry of Agriculture, Govt. of India launched Kisan Call Centers across the country to deliver extension services to the farming community. A Kisan Call Center consists of a complex of telecommunication infrastructure, computer support and human resources organized to respond to queries raised by farmers in their local language. Subject Matter Specialists (SMSs) using telephone and computers, interact with farmers directly to understand the problem and answer the queries at the call centre. Formally launched on 21 Jan 2004 by the Prime Minister of India, the call centres are getting more than 2,000 calls per day. There are call centers for every state which are expected to handle traffic from any part of the country.

Helpline

Leveraging on the IT revolution in India and the increasing penetration of telephones in villages, many State Agricultural Universities and ICAR institutes have started helpline services. The helplines address queries related to farming during fixed days of the week at specified hours. The helpline number is advertised through mass media viz., radio and press. The Central Institute of Freshwater Aquaculture has initiated this service on every Tuesday and Friday during 3.30-5.00 p.m. and the no. is 0674-2111849.

Farm school on the air

Radio has been used extensively as an educational medium in developing countries. Radio has supported educational programmes in a wide range of subject areas in many different countries. The latest technologies are taught to farmers by offering series of lessons broadcast over a period of time (three months usually). Each broadcast ends with few questions to encourage participation and the audience are asked to send in replies within a weeks time. From among the right entries a draw is conducted and the selected ones are awarded. All India Radio, Cuttack recently broadcasted 11 lessons related to aquaculture.

Private sector initiatives

The corner stone of India's blue revolution is availability of quality fish seed and improved management practices for increased productivity, sustainability and stability. This has triggered the search by the farmers for availability of quality fish seed, fish feed and other inputs, easy accessibility to diagnostic services for soil and water, fish health management, availability of appropriate information packages through printed, audio, video and electronic media. It has also prompted multiple players to offer consultancy services in aquaculture.

Private commercial organisations

Shrinking public investment, growing willingness of farmers to pay for services, shifting priorities of aquaculture production towards high value products - prawn, crab, ornamental fishes, value added products etc. have led to the emergence of privatized extension services. Besides partial recovery of cost, privatization renders the extension system more accountable to information seekers. Many private players are engaged in quality seed production, intensive and super intensive culture, processing, value addition, ornamental fish breeding and culture etc. Firms engaged in fisheries namely Hindustan Lever, Lipton, Water base, CPAqua, Avanti, Higashimaru etc have their own well knit network of R&D, extension and marketing. They have a cadre of technicians to offer consultancy to farmers who buy products from them. IFFCO and KRIBHCO have prominently entered the extension arena by passing on full crop production messages through field demonstration and training programmes (Mathur, 2004).

Aqua service centres

Unemployed educated youths have started operating aqua service centres in the line of agri-clinics. These centres are offering services like soil and water testing, feed analysis, seed quality testing (PCR test), disease diagnosis and market intelligence. These centres are in the business of selling inputs such as feed, fertilizer, pesticides, other therapeutics etc. In Andhra Pradesh several such service centres can be found in Kolleru lake area of West Godavari district, although they may be known by different names such as farmer facility centres, aqua service centres etc. Farmers need to pay for availing the services of these centres.

One stop aqua shop

One of the major recommendations of DFID funded project "Investigating improved policy on aquaculture service provision to poor people" was to establish one stop aqua shop (OAS). It is intended that OAS would provide better access to farmers regarding appropriate aquaculture technology as well as information on government schemes and rural banking and micro finance. It was also envisaged that OAS would sell fish seed and other inputs. In Purulia one OAS (Matsya Seva Kendra) started by Kuddus Ansari last year. The shop is a single outlet for all inputs that a fish farmer may require in the cultivation of fish. The inputs include fish seed, fish feed, fertilizer, chemicals etc. (The Telegraph, Kolkata, June 8, 2004). Besides, the OAS is helping farmers in providing information on fish farming through posters and though information brochures supplied by state departments and research institutes. This is becoming quite popular. One OAS has also been established in Ranchi, Jharkhand and four more are coming up at Balangir and Nuapada of Orissa (Tripathi et al 2004).

Initiatives in ICT applications

Information and communication technology (ICT) is defined as capturing, processing, storing, and communicating information electronically within a digital medium. It enables an effective and cost-effective flow of information products, people and capital across national and regional boundaries. The lack of communication facilities in communities therefore, inhibits the social, political and economic empowerment of the majority of the population. The Secretary-General of the United Nations states: "The new information and communications technologies are among the driving forces of globalization. They are bringing people together and bringing decision makers unprecedented new tools for development. At the same time, however, the gap between information 'haves' and

Table 1. Necessary paradigm shifts in extension (Vijayraghavan, 2004).

Components	Traditional extension	Extension for 21st century
1. Goal	Transfer of technology	Enhancing the over all capacity of farmers
2. Need assessment and programme planning	Top-down approach, and rigid	Bottom up approach involving farmers and flexible
3. Source of technology	Mainly government research Institutions	Multiple sources government private and farmers' knowledge system
4. Nature of technology	1. Input intensive, crop based and general recommendations 2. Fixed package of information	1. Knowledge intensive, broad based, farming system perspective and location specific 2. provision for choices
5. Dissemination of technology	i. Individual approach with lack of participation of farmers ii. NGOs not involved	a. Group approach with increased participation of farmers and their organization b. Greater involvement of NGOs
6. Clients	Mostly male farmers	Efforts to reach both male and female farmers, rural youth and farm labourers
7. Farmers' activity	Routine application of technology/inputs	Encouraging farmers experimentation and learning
8. Role of extension agents	Information transfer	Facilitation of learning and building overall capacity of farmers
9. Rewards and incentives for extension personnel	Rewards not linked to performance	Rewards linked to performance
10. Financial sustainability	Very low	High

'have-nots' is widening and there is a real danger that the world's poor will be excluded from the emerging knowledge-based global economy".

Indicated below are some of the ICT initiatives in India:

Aqua choupal

Aqua choupal, the unique web based initiative of ITC Ltd. offers the farmers of the state of Andhra Pradesh all the information, products and services they need to enhance productivity, improve farm gate price realization and cut transaction costs. Farmers can access the latest local and global information on weather, scientific farming practices and market prices at village itself through a web portal all in Telegu. Aqua choupals also facilitate the supply of high quality farm inputs as well as purchase of shrimps at their doorstep.

The M.S. Swaminathan Research Foundation developed 'infovillages' to help ensure food security. The project includes local language content and wireless internet access. The initiative started in 1998 in 10 villages in Pondicherry. It also provides relevant information regarding fish density in the ocean to the fishing communities.

e-choupal

A unique web based initiative of ITCs International Business Division in Central India caters to soya growers regarding all information, products and services required in soya farming. It facilitates supply of high quality farm inputs and purchase of soya at the doorstep of farmers. The project has started 23 telecentres in Hosangabad and has around 600 kiosks in central India.

Rural Knowledge Centre

Rural Knowledge Centre is a part of a nationwide plan and has been set in motion in July 2004 by the Centre in collaboration with the States, NASSCOM, UNDP and a host of NGOs. Its primary aim is to set up multipurpose resource centres at all the six lakh villages of the country by 2007, for which an initial sum of Rs. 100 crores has already been allocated by the Centre. This public - private partnership is expected to help eradicate poverty and improve the lives of poor people through application of information and communication technology (ICT). Each knowledge centre will be run by local self help groups, and will cater to knowledge based livelihoods and create income avenues for rural people, farming communities and disadvantaged people. It is an innovative attempt to explore the in depth interdependence between ICT and human development and demonstrate empirical links between the two using millenium goals as the benchmark. It will lead to rural knowledge revolution and aid in capacity building. Establishment of rural knowledge centres will go a long way in revitalizing traditional knowledge and lessen digital divide.

Cyber extension

Modern communication technologies when applied to conditions in rural areas can help improve communication, increase participation, disseminate information and share knowledge and skills. It is being said that "Cyber Extension" will be the major form of technology dissemination in the near future. The Internet is emerging as a tool with potential to contribute to rural development. Internet access enables rural communities to receive information and assistance from other development organizations; offers opportunities for two-way and horizontal communication and for opening up communication channels for rural communities and development organizations. It can also support bottom-up articulation of development needs and perceptions, and thus help in reducing the isolation of rural communities. It can facilitate dialogue among communities and with government planners, development agencies, researchers, and technical experts; encourage community participation in decision making; coordinating local, regional and national development efforts for increased effectiveness; and help agricultural researchers, technicians, farmers and others in sharing information. Internet can give access to a vast global information resource. One important thing has to be ensured that information availability is demand driven rather than supply driven.

Needed changes

The increasing market orientation of aquaculture in liberalization of trade, the emergence of global markets and competition and increasing concern about food and the environment place the aquaculture sector of developing countries under tremendous pressure. Diversification and intensification are some of the key factors for sustainable aquaculture development and therefore the regular information flow among farming communities, technical and marketing resources and other supplying institutions is a must for steady growth in the farm economy. Small holder farm families who comprise the majority of farming families are facing increased pressure to respond to rapidly changing market demands and to adopt latest of technological innovations.

The agricultural decisions and transactions in the developed world are now manipulated through digital networks. The Internet and mobile telephones in particular, are used by governments to provide services to citizens (e-government) and provide a platform for citizens to interact with fellow citizens as well as experts. Access to information is clearly a key determinant for maintaining a successful farming business (Farrell, 2003).

Public extension systems require a paradigm shift from top-down, blanket dissemination of technological packages, towards providing producers with the knowledge and understanding with which they solve their own location - specific problems.

Conclusion

Fisheries extension has significantly contributed towards enhancement of fisheries production in India. From 50 kg/ha/year in 1950-51 average fish production has increased to 2,200 kg/ha/year in 2002-03. The socio-political environment within which extension system operates has also undergone a lot of changes. The information needs of clients have multiplied. Extension today has to assume multiple roles of providing information about technologies, prices and market, policies; organising farmers for exchange of information, facilitating learning from experiences; provide problem solving consultancy in order to serve the farming community (Sulaiman, 2003). Farmers now need quality information about technological options in farming to produce and participate better in markets. They need to know not only market prices but also trends about market prices to plan cultivation.

In order to address successfully the challenges of WTO, greater attention will have to be paid to information-based technologies. Strengthened means of dissemination will be needed to transmit this information to farmers. To make information transfer more effective, greater use will need to be made of modern information technology and communication among researchers, extensionists and farmers. In the era of information technology, where information play a vital and decisive role in strategic decision making, extension personnel will have to acquire latest knowledge as well as skills in use of various electronic devices including computers, multimedia and the internet. The day is not far off when tele/video conferencing will be common means to interact with larger number of farmers to extend extension messages or sharing market information by extension personnel. In coming years, the area of management and communication skills must be the largest segment for competency building among agricultural extension personnel for supporting farming community.

References

De, H. K. and Saha, G.S. 2005. Aquaculture Extension in India - few emerging issues. In: Development initiatives for farming community (Eds. Baldeo Singh and R. N. Padaria) Indian Society of Extension Education, New Delhi pp 418-423.

Farrell, C.O. 2003. Theme paper presented for seminar on ICT for improving agricultural productivity and competitiveness. 8-12 Sept. Indonesia.

Mathur, P.N. 2004. Extension systems in transition: some policy issues. Asian J. Ext. Edu. 23(1): 73-88.

Rasheed, S.V. 2003. Innovations in agricultural extension in India. SD Dimensions, FAO June 2003.

Tripathi. S.D.; Haylor, G. and Savage, W. 2004. People and policy change in Indian Fisheries. Paper presented in the 7th Asian Fisheries Forum held at Penang, Malaysia during 29 Nov. to 04 Dec.

Vijayraghavan, K. 2004. Reforming Agricultural Extension: needed shift and reforms. Asian J. Ext. Edu. 23(1): 89-103.

Selection potential for feed efficiency in farmed salmonids

Antti Kause[1], Cheryl Quinton[2], Kari Ruohonen[3] and Juha Koskela[4]

1. Principal Research Scientist, MTT Agrifood Research Finland, Biotechnology and Food Research, Biometrical Genetics, 31600 Jokioinen, Finland, email antti.kause@mtt.fi; 2. Research Scientist, MTT Agrifood Research Finland, Biotechnology and Food Research, Biometrical Genetics, 31600 Jokioinen, Finland; 3. Research Professor, Finnish Game and Fisheries Research Institute, Turku Game and Fisheries Research, Itäinen Pitkäkatu; 3. 20520 Turku, Finland; 4. Principal Research Scientist, Finnish Game and Fisheries Research Institute Jyväskylä, Survontie 9, 40500 Jyväskylä, Finland.

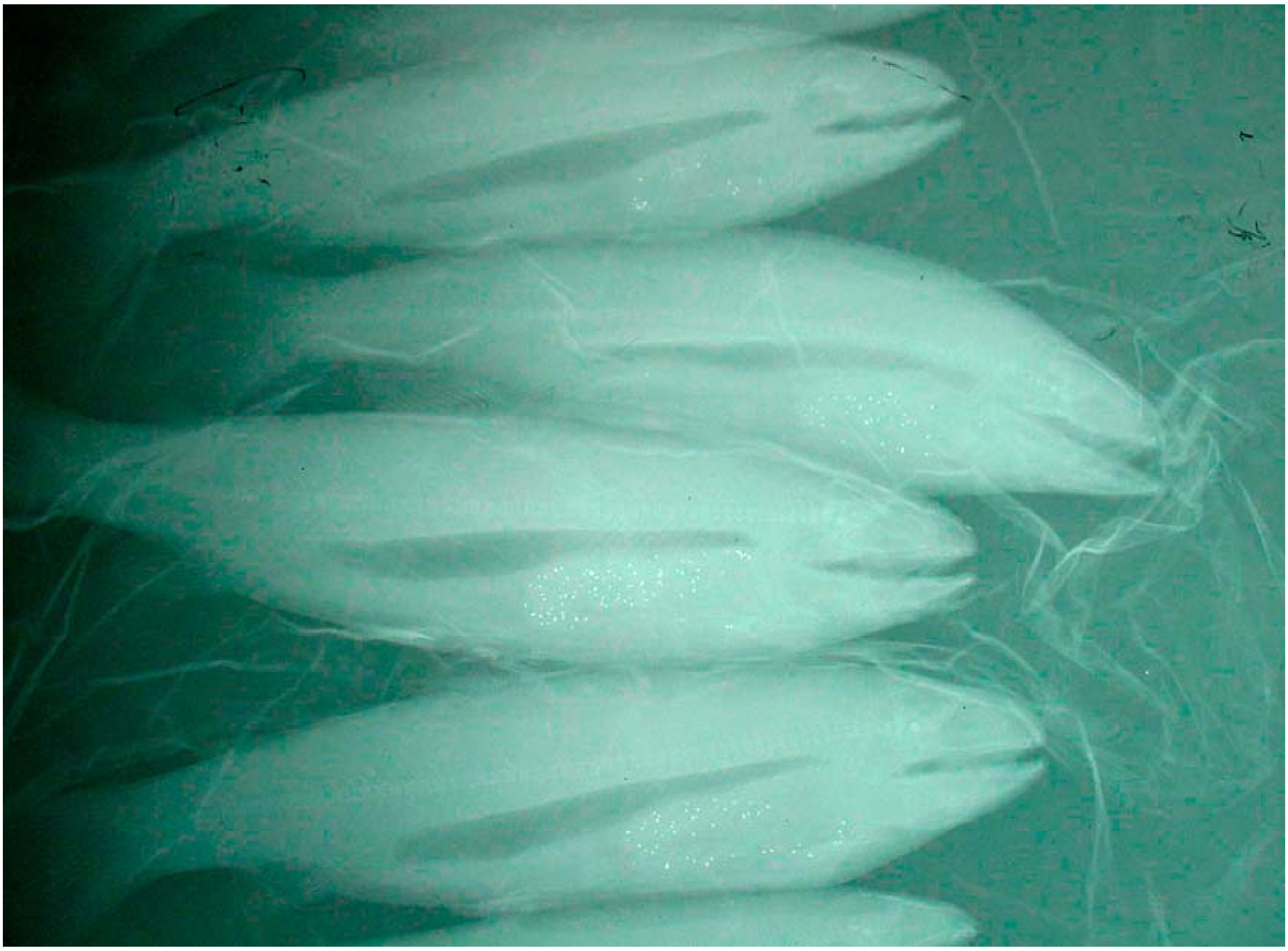
Feed is the major cost in farmed fish production. Improving feed efficiency, a ratio of wet weight gain to feed intake, would have the effect of reducing feed costs and minimising nutrient effluent to the environment. Selective breeding is a potential tool for improving feed efficiency, and improved feed efficiency is one of the major goals in aquaculture breeding programmes. Selective breeding programmes exist for many major aquaculture species, including several salmonid species.

Recording feed intake

To be able to select directly for feed efficiency, feed intake of individual fish should be recorded. Until recently, difficulties in measuring individual feed intake on a large scale have prevented accurate genetic evaluation of feed utilization traits in farmed fish. To solve the recording challenges, we have applied the X-ray method to measure feed intake and feed efficiency of thousands of individuals in pedigreed populations of farmed rainbow trout (*Oncorhynchus mykiss*)[1,2] and European whitefish (*Coregonus lavaretus*)[3,4].

To measure feed intake of individual fish using the X-ray method, all fish held in a tank are first fed with feed containing small radio-opaque glass beads. Thereafter, the fish are X-rayed. The number of glass beads consumed can be counted from the X-ray films. Because the glass bead content of the feed is known, it is possible to calculate the quantity of feed that each fish consumed on a specific meal[1].

Figure 1. Small radio-opaque glass beads added into a feed can be used to record feed intake.



Genetic variation in feed efficiency

The studies on rainbow trout[2] and European whitefish[3] show that direct selection for feed efficiency is possible in farmed fish. Yet, genetic improvement of feed efficiency is expected to be about three (rainbow trout) to eight-fold (European Whitefish) slower compared to the improvement of growth rate. This results because feed efficiency seems to display modest amount of genetic variation for selection. For instance, in European whitefish, only 6 percent of the phenotypic variation in feed efficiency was explained by genetic effects. Simultaneously, feed intake and weight gain, the two component traits of feed efficiency, exhibited moderate genetic variation (23-26% of variation explained by genetics).

Our studies have been conducted during three week to three month long trial periods at an exponential growth phase of the fish. During this time, most feed consumed is directed to growth, and there is only little variation in nutrient diversion to other body functions. It is possible that if feed efficiency could be recorded during longer time periods (e.g. across the whole fish life), more genetic variation for feed efficiency would be revealed.

Indirect selection for feed efficiency

Recording of individual feed intake from thousands of fish is challenging. Thus, it is of interest to assess whether more easily recorded traits that are genetically related to feed efficiency could be used to indirectly select for feed efficiency.

Our study showed that feed efficiency can be indirectly improved by selecting on growth rate[2,3]. Rapid growth is genetically related to improved feed efficiency. This is good news because all fish breeding programmes select for rapid growth anyway.

Moreover, selection against body lipid percentage can be used to indirectly select for lower feed intake, and thus to improve feed efficiency[4]. This is logical because extensive feed intake is related to excess lipid deposition, and lipid deposition is energetically more expensive than deposition of muscle[4]. Fish breeding programmes often control lipid deposition by selection to maintain high product quality. This has an additional benefit of maintaining high feed efficiency.

Figure 2. Rainbow trout.

Implications for selective breeding

Feed efficiency is economically a fundamental trait, and thus even small improvements are economically important. As breeding proceeds, the small genetic changes in feed efficiency accumulate from generation to generation. This leads to moderate feed efficiency changes in a longer term. For instance, during the last four generations of selection in the Finnish national rainbow trout breeding programme, growth rate has increased by ~28%[5]. Feed efficiency is expected to have increased simultaneously by 8% as a correlated genetic response. When majority of fish farmers use the improved fish material, the practical impact of the selection work is extensive. Accordingly, all efforts to increase feed efficiency will be of fundamental importance.

References

1. Kause A, Tobin D, Dobly A, Houlihan DF, Martin SAM, Mäntysaari EA, Ritola O & Ruohonen K 2006. Recording strategies and selection potential of feed intake measured using the X-ray method in rainbow trout. Genetics Selection Evolution 38: 389-410.
2. Kause A, Tobin D, Houlihan DF, Martin SAM, Mäntysaari EA, Ritola O & Ruohonen K. 2006. Feed efficiency of rainbow trout can be improved through selection: Different genetic potential on alternative diets. Journal of Animal Science 84: 807-817.
3. Quinton C, Kause A & Koskela J. 2007. Breeding salmonids for feed efficiency in current fishmeal and future plant-based diet environments. Genetics Selection Evolution 39: 431-446.
4. Quinton C, Kause A, Ruohonen K & Koskela J. 2007. Genetic relationships of body composition and feed utilization traits in European whitefish (*Coregonus lavaretus* L.) and implications for selective breeding in fishmeal- and soybean meal-based diet environments. Journal of Animal Science 85: 3198-3208.
5. Kause A, Ritola O, Paananen T, Wahlroos H & Mäntysaari EA. 2005. Genetic trends in growth, sexual maturity and skeletal deformations, and rate of inbreeding in a breeding programme for rainbow trout. Aquaculture 247: 177-187.

Freshwater prawn hatcheries in Bangladesh: Concern of broodstock

Nesar Ahmed

Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh; E-mail: nesar_2000@yahoo.com

In Bangladesh, freshwater prawn (*Macrobrachium rosenbergii*) farming is currently one of the most important sectors of the national economy, and during the last two decades its development has attracted considerable attention for export potential. Within the overall agro-based economy of the Bangladesh, the contribution of prawn (locally known as golda) production is important to its people for livelihoods, income and food supply. In 2006, Bangladesh exported 49,317 tons of prawn and shrimp valued at US$415 million, of which around 25% was contributed by prawn (DOF, 2007). This figure is expected to rise with the increasing expansion of freshwater prawn cultivation into new areas of Noakhali, Patuakhali, Pabna and Mymensingh districts. Prawn farming is mostly concentrated in southwest Bangladesh, mainly Khulna, Bagerhat and Satkhira districts.

The expansion of M. *rosenbergii* farming depends on availability of prawn fry, the supply of which is currently the main bottleneck for further expansion of prawn culture. The prawn culture sector in Bangladesh still relies on wild postlarvae (PL). Farmers prefer to stock wild PL rather than hatchery produced fry as production of the hatchery PL is limited and farmers consider them to be of lower quality. In addition, the survival of wild PL is much higher than that of hatchery produced PL (Ahmed, 2001). However, there is a growing acceptance of hatchery fry by producers.

Since the late 1980s, there has been concern over the effects of intensive fishing of prawn PL (Ahmed, 2000). Indiscriminate fishing of wild PL with high levels of by-catch (i.e. non-target species caught incidentally) and

Dead broodstock are sold in prawn market.

biodiversity impacts on the coastal ecosystem has provoked imposition of restrictions on wild PL collection (Ahmed 2003). In September 2000, Department of Fisheries imposed a ban on wild PL collection. The rationale for the ban was to protect biodiversity from the harmful effects of intensive PL fishing in the coastal zone (DOF, 2002). However, the lack of alternative livelihoods for poor people engaged in PL fishing is one of the principal constraints on implementing such a ban.

Due to the scarcity of wild PL supply, a prawn hatchery sector has emerged over the last few years. However, the quality of hatchery PL remains a concern for prawn farmers. It is assumed that source of broodstock (i.e. mother prawns or berried females) is an important issue for producing quality fry in hatcheries. Hatcheries are currently unregulated with no quality assurance of broodstock. One of the problems in regulating and managing the supply of brood to prawn hatcheries is the lack of information. At the same time, there is no information on the projected demand of broodstock by hatcheries. The aim of this study was therefore to identify potential sources of broodstock and appropriate harvesting, marketing and transportation systems. Addressing these issues should lead to higher production of quality PL that will help to expand freshwater prawn farming into new areas of Bangladesh through developing and sustaining prawn hatcheries.

Methodology

The study was undertaken in Khulna, Bagerhat and Satkhira districts in southwest Bangladesh, situated in the coastal areas of the Bay of Bengal. Geographically these districts have been identified as the most important and promising areas for freshwater prawn farming, because of the availability of prawn hatcheries and sources of wild PL. These districts were therefore selected for the study. In addition, data were collected from hatcheries in other parts of Bangladesh.

Primary data were gathered by field survey. This survey involved the inspection of the study areas in terms of hatchery operation with broodstock, sources of broodsstock to hatcheries, broodstock collection methods, their marketing and transportation systems. Data were collected for six months from March to August 2007. A total of 24 hatchery operators, 20 broodstock suppliers and 32 wild broodstock collectors participated in questionnaire interviews. Hatcheries were selected through simple random sampling. For this sampling method, a database of prawn hatcheries was collected from Winrock International. The site for wild broodstock collection was selected in the coastal area of Mongla under Bagerhat district. A boat was hired for data collection and observation of wild brood fishing on the Pasur River. Broodstock fishers were interviewed on the river and/or river bank. Visits were also made to Fakirhat and Mollahat areas of

Bagerhat district where broodstock were harvested from prawn farms, locally known as ghers. Broodstock transportation and marketing systems were also observed. Data from questionnaire interviews were coded and entered into a database system using Microsoft Excel software for producing descriptive statistics.

Cross-check interviews were conducted with key informants such as District and Sub-district Fisheries Officers, researchers, policymakers, prawn farmers, NGO workers (i.e., BRAC, PROSHIKA, etc), and staff of Winrock International and WorldFish Centre. Where information was found to be contradictory, further assessment was carried out. A total of 22 key informants were interviewed.

Broodstock ready to use in the hatchery.

Harvested wild broodstock.

Plastic container is commonly used for broodstock transportation.

Harvested broodstock stored in a bamboo basket.

Hatchery development

Although the freshwater prawn culture industry in Bangladesh still depends on wild fry, expanding production and the trend towards intensification require the development of prawn hatcheries. In recent years, increasing shortages of wild fry and their high prices, together with the ban on catching wild PL have stimulated the expansion of the hatchery industry. Prawn hatchery technology in the private sector has been developed rapidly. The growing acceptance of hatchery fry along with government incentives to boost hatchery production has resulted in a sharp increase in the number of prawn hatcheries in Bangladesh. There are 81 freshwater prawn hatcheries in Bangladesh of which 42 (52%) are operational (Winrock International, 2007). A lack of technical knowledge and inadequate skilled manpower are important reasons for the poor results of many hatcheries.

In Bangladesh, an M. *rosenbergii* hatchery first started in Cox's Bazaar in 1986 (Angell, 1994; Winrock International, 2007), after which it spread throughout other parts of Bangladesh. According to the survey, 5% of prawn hatcheries started in or before 1990, 8% between 1991 and 1995, 13% between 1996 and 2000, and 74% after 2000. Almost all hatchery owners stated that the primary reason for starting this business was profitability. However, 12% of owners were attracted to hatchery operation because of own interest. In spite of various constraints, most of the hatchery owners (95%) would like to continue PL production in the future, because of high profit. Those are undecided about continuing to hatchery operation are concerned about inadequate knowledge, lack of experience, high mortality of PL and limited supply of broodstock.

According to the survey, the average annual production capacity of a hatchery was estimated at 2.63 million PL in 2007. From this figure it seems that total annual production of PL is around 110.46 million in Bangladesh

A fisher with char net that is commonly used for broodstock fishing.

(i.e. 2.63 million/hatchery x 42 hatcheries). Hatchery output is insufficient to meet demands in terms of both quality and quantity. Currently hatcheries can only meet 22% of the total annual demand in Bangladesh of around 500 million PL (Dr Abul Hossain, Winrock International, personal communication).

Hatchery operation

Berried females are an essential component for continuous operation in hatcheries. Female prawns generally become reproductively mature within six months of age. Mating can occur only between hard shelled males and soft-shelled females, i.e., females that have just completed a pre-mating or prenuptial molt (D'Abramo et al., 1995). Fecundity can be as high as 80,000 to 100,000 eggs in mature females while first broodstock may be around 5,000 to 20,000 (Brown, 1991). The eggs are carried on the female abdomen attached to the pleopods before hatching. In the nature, female M. *rosenbergii* migrate downstream from their normal habitat in freshwater to brackishwater areas.

According to the hatchery operators, female prawns first mature after reaching a size of 20 to 30 g. Eggs obtained from these females are of good quality and their larvae show high percent survival after hatching. However, females of farmed origin often mature while 30 to 40 g. Use of such precociously mature females results in eggs and larvae of poor quality. Offspring of these females may mature even more precociously.

Although *M. rosenbergii* breeds throughout the year under optimum climatic conditions (28 to 32ºC), the peak breeding activity occurs in Bangladesh during pre-monsoon and monsoon seasons, i.e., from March to August, a production period of around 4 to 5 months, depends on number of production cycles, availability of broodstock and favourable environment. According to the survey, most of the hatcheries (67%) operate two production cycles in a year, while 21% and 12% of hatcheries operate one and three cycles, respectively. Each production cycle normally ranges from 35 to 45 days, an average 40 days. After completion of one cycle, a few days (7 to 10 days) are required for preparing to operate the next cycle. In general, the first cycle produces more PL rather than other cycles due to high demand and the peak stocking season. However, most hatcheries do not operate at full capacity due to low survival of PL, technical constraints, outbreak of disease, and difficulty in securing good quality broodstock.

Broodstock are commonly selected on the basis of readiness to spawn. In general, healthy broodstock are selected for hatchery operation. The average size of broodstock is 75 g and ranges from 40 to 200 g. Broodstock are disinfected with 10% formalin for 30 minutes before use in hatcheries. About two to three broodstock are stocked in a brackishwater tank with 12 PPT salinity and reared until hatching, which is completed within two to three days if advanced berried females are stocked with grey eggs on their pleopods. Once hatching occurs it may continue for 24 to 48 hours. The spent females are removed and released back to the broodstock tank. Brine shrimp nauplii are fed to the prawn larvae. The appearance of first PL is usually observed 20 days after hatching, normally between 22 and 26 days, and 90% of larvae metamorphose within next 10 days. The PL are gradually acclimatised to the freshwater and reared at high densities (2,000 to 5,000/m^2) for 10 to 15 days in the hatchery.

With a few exceptions, the hatchery operators never directly communicate with prawn farmers, market communication normally being made through intermediaries: transporters, fry traders and suppliers. The average price of hatchery PL varies from Tk 1,000 to 1,200 (1 US$ = Tk 67) per 1,000 PL depending on their availability, quality, season, supply and demand. The average price of wild PL is much higher than that of hatchery PL, because of quality. The average price of wild PL varies from Tk 1,800 to 2,400 per 1,000 PL.

Sources of broodstock

Prawn hatcheries require an uninterrupted supply of berried females during the season. For the consistent operation of hatcheries broodstock are collected at regular intervals. The principal sources of broodstock to prawn hatcheries are wild and prawn farm. According to the survey, 33% of hatcheries use natural broodstock, 13% use farm-reared broodstock and the remainder (54%) both sources. In those hatcheries using both sources, it is believed that broodstock are commonly being sourced from prawn farms rather than wild. Among the farm broodstock, almost all are grown from wild PL. A few hatcheries have their own prawn farms for continuous supply of broodstock. The quantity of broodstock used in hatcheries rather obscure because hatchery operators often do not distinguish between wild and farm broodstock. However, it was estimated that only 15% of broodstock were from wild and the rest (85%) were from prawn farms.

Most hatcheries prefer to stock wild broodstock rather than farm-reared broodstock because of quality. However, the supply of wild broodstock is not regular and therefore hatcheries also use farm broodstock. Hatchery operators noted that the demand for wild broodstock has increased due to expansion of hatchery operations and increased number of hatcheries. Inadequate supply of wild broodstock can therefore be a significant constraint for producing quality fry. A few hatcheries were reported to prefer farm broodstock due to low price and availability in markets. However, according to the hatchery operators, the quality of PL, its production rate and survival rate is higher when wild broodstock are used rather than farm broodstock.

The wild broodstock mainly come from Mongla, Joymoni and Sharankhola of Bagerhat district, while farm broodstock mostly come from Fakirhat and Mollahat areas in same district. Suppliers carry these broodstock to the hatcheries in Khulna, Bagerhat and Satkhira districts, and other parts of Bangladesh. According to the survey, a hatchery

Transporting broodstock by van over short distance.

Fishers are drying nets after fishing.

A fisher and his prawn fishing site near the Sunderbans.

uses an average 520 broodstock in a season, ranging from 310 to 2470. From this figure, it seems that a total of 42,120 broodstock are required for operation of all 81 hatcheries in Bangladesh, and is projected to increase to 80,000 broodstock for successful operation in the future.

Broodstock collection

Various methods are used to collect broodstock from different sources (Table 1). In nature, berried females are caught as a bycatch of prawn. A large number of fishers are known to be engaged in fishing of prawns including broodstock. Fishers are involved in broodstock capture on the Pasur River from Mongla through to Joymoni on the coast. The peak season of broodstock fishing is from March to July during the daily high tides and monthly full moons when numbers of broodstock are high. According to the survey, fishing for broodstock first started in 2002 in this area. Since then it spread throughout other parts of coastal areas. Over this time, broodstock fishing has become a profitable business for its participants and has generated new employment. Broodstock collectors are mostly from the rural poor and this activity is a substantial part of their income. It is considered that broodstock collectors contribute substantially to the economy and to a part of the foreign exchange earnings (i.e. most prawns are exported to the international market), although the collectors themselves benefit little.

According to the survey, a fisher caught an average of 32 broodstock (ranging from 19 to 44 pieces) during the season in 2007, while in some years previously the rate was 50 to 60. Broodstock collectors reported that the availability of broodstock has reduced due to over fishing, use of destructive gears, environmental degradation and massive PL collection. A large range of bycatch species are caught and discarded due to the fine mesh nets (i.e. set bag net and pull net) used for PL fishing which may have severe long term impacts on wild prawn production including broodstock. As a result, uncontrolled fishing of PL may pose a threat to the natural population.

Harvesting of prawn including broodstock in a farm.

Broodstock kept in net cages.

Table 1. Fishing of *Macrobrachium* broodstock by using different methods and their percent of catch.

Source	Harvesting technique	% of catch
Wild broodstock	1. Char net	11
	2. Set bag net	1
	3. Pull net	1
	4. Hook and line	2
Farm broodstock	1. Seine net	68
	2. Cast net	17
Source: Survey data (2007).		

Table 2. Average farm-gate prices of broodstock from different sources.

Grade	No. of broods/kg	Average weight of a broodstock (g)	Wild broodstock (Tk/piece)	Farm broodstock (Tk/piece)
5	5 or less	200	300	150
10	6-10	125	230	90
20	11-20	70	180	75
30	21-30	40	120	50
Source: Survey data (2007).				

Marketing of broodstock

In Bangladesh, the market for broodstock is associated with strong demand, driven by continued increases of hatcheries. However, in terms of volume, value and employment, the broodstock market is very small. The broodstock marketing system is less competitive but plays a vital role in connecting the broodstock and hatcheries, thus contributing significantly freshwater prawn farming as well as earning foreign currency. A small number of people, many of whom live below the poverty line, find employment in the broodstock marketing chain as fishers, suppliers, agents, transporters and day labourers, including women and children.

In wild broodstock marketing, fishers are the primary producers. With a few exceptions, fishers never directly communicate with hatchery owners, market communication normally being made through suppliers. A small number of people (around 10 to 15) are engaged in broodstock marketing as suppliers. Their role is to buy broodstock from the fishers in coastal areas and carry them to the hatcheries. Communication between the suppliers and hatchery owners is generally good and takes place by mobile phones. The demand for wild broodstock is high within coastal markets but supply is limited, and a strong network has developed with suppliers and fishers. Around five to six fishers are connected with a supplier and one supplier is linked to two to four hatcheries. A fisher carries typically two to five broodstock per day from remote fishing areas to the supplier in a depot. In general, suppliers rear broodstock for few days in net cages with pelleted feed. Consignments are sent to the hatcheries once sufficient quantities have been obtained, an average 300 broodstock per week per supplier.

Marketing of farm broodstock is almost entirely managed, financed and controlled by a group of powerful intermediaries. Market communication is normally being made through local agents and suppliers. Broodstock marketing is seasonal and suppliers are involved in prawn and fry trading during the rest of the year. In general, farmers sell their broodstock to the suppliers through local agents. A local agent carries typically 25 to 30 broodstock per week from remote villages to the depots of suppliers. Sometimes local agents take small amounts of credit from depot owners to ensure the supply of broodstock from farmers. Local agents also often take temporary credit from the farmers, buying broodstock one day and paying one or two days later. Suppliers also receive cash loan from hatcheries in return for a promise to sell all their broodstock. Hatcheries are linked to suppliers when they act as fry traders. A few hatcheries often take temporary credit from suppliers, buying broodstock one season and paying in exchange of fry during the fry trading season. The hatcheries capital installations and much of their working capital is provided by the banks. Hatcheries typically enjoy a very close working relationship with their banks, for which this sector is big business.

The price of broodstock depends on size and weight, quality, season, and supply and demand. In coastal markets, price is generally higher in early season during March to April and drops in the following months. The average price of wild broodstock from fishers to the suppliers varies from Tk 120 to 300 per piece (Table 2). Comparatively the price of wild broodstock is higher than farm broodstock. The average price of farm broodstock varies from Tk 50 to 150 per piece, depending on grade. Due to higher price of wild brood, suppliers sometimes camouflage farm broodstock as wild in order to get a higher price. Suppliers sell wild broodstock to hatcheries at Tk 350 to 800 per piece, while farm broodstock at Tk 150 to 500 per piece.

Transportation of broodstock

A considerable number of people are involved in the transport of broodstock. Transport of live broodstock to hatcheries takes place in the very early morning hours, to take advantage of cooler temperatures. Pickups, microbuses, taxis, motorcycles, trawlers and vans are used for transportation. In general, taxis, motorcycles, vans are used for small quantities (5 to 20 broods), and others are used for large quantities (50 to 200). Plastic and aluminium containers with 12 PPT brackishwater are commonly used for holding broodstock during transport. Most broodstock are transported with oxygen at a low temperature to reduce their metabolism. Brackishwater is used normally at a ratio of two liters per one broodstock for eight hours transportation. According to the suppliers, the broodstock mortality rate is very low, less than 10%. Mortalities reported by the suppliers are due to the poor transport conditions, water temperature, long duration of transport and poor handling. According to the respondents, 5% of the broodstock are wastage from the time they are caught to the time they are stocked in hatcheries due to poor handling. Because broodstock are caught using different nets and hooks, mortalities are common.

Fishers with hook and line fishing for prawns including broodstock.

A typical prawn hatchery.

Conclusions

Despite strong demand of broodstock by the hatcheries there is no broodstock bank in Bangladesh. Due to the scarcity of wild broodstock supply to the hatcheries, it is urgently needed to establish a broodstock bank in prawn farming areas. To meet a part of immediate demand for quality broodstock, both the public and private sector should come forward to establish their own broodstock banks. Hatcheries could be linked to the public and private broodstock bank to ensure the availability of quality broodstock. It would also necessary to encourage private entrepreneurs to start commercially producing good quality broodstock. Rearing broodstock of good quality requires special techniques and fresh spawns from the nature. Improving the quality of broodstock will result in better quality spawns, reduce mortality rate and increase productivity. However, concerns may arise about the sustainability of broodstock banks in terms of technical, biological, environmental and economic aspects. It is therefore necessary to provide institutional and organisational support and government support for sustainable development of broodstock banks. In addition, broodstock rearing techniques to be developed to maintain genetic quality. Moreover, a certification system should be developed and implemented to maintain the quality. Training of broodstock bank operators in areas of stocking, feeding, rearing and harvesting should be provided. It is also necessary to improve handling and transportation practices to reduce the mortality of broodstock.

Acknowledgments

This study was partially funded by the Winrock International, Bangladesh. The author is grateful to Dr Abul Hossain of Winrock International for his excellent field support. The opinions expressed herein of the author and do not necessarily reflect the views of Winrock International. The author would like to express his gratitude to all people met during field visits those have given a lot of valuable information without which the study could not have been realised.

References

Ahmed, N. 2000. Bangladeshis need prawn hatcheries: farmers seek solution to wild fry dependency. Fish Farming International 27(10):26-27.

Ahmed, N. 2001. Socio-economic Aspects of Freshwater Prawn Culture Development in Bangladesh. PhD Thesis, Institute of Aquaculture, University of Stirling, Scotland, UK.

Ahmed, N. 2003. Environmental impacts of freshwater prawn farming in Bangladesh. Shellfish News 15:25-28.

Angell, C.L. 1994. Promotion of Small-scale Shrimp and Prawn Hatcheries in India and Bangladesh. Bay of Bengal Program (BOBP), Madras, India.

Brown, J.H. 1991. Freshwater prawns. In: Production of Aquatic Animals: Crustaceans, Molluscs, Amphibians and Reptiles, World Animal Science (edited by C.E. Nash), Elsevier Science Publishers, Amsterdam, Netherlands, C4: pp. 31-41.

D'Abramo, L.R., Daniela, W.H., Fondeen, M.W. & Brunson, M.W. 1995. Management practices for culture of freshwater prawn (*Macrobrachium rosenbergii*) in temperate climates. Division of Agriculture, Forestry and Veterinary Medicine, Mississippi State University, Mississippi, USA.

DOF. 2002. Balancing Resource Conservation with Livelihood Protection for Shrimp Fry Collectors: an Integrated Approach to Managing Coastal Resources. Department of Fisheries (DOF), Ministry of Fisheries and Livestock, Dhaka, Bangladesh.

DOF. 2007. Fishery Statistical Yearbook of Bangladesh 2005-2006. Fisheries Resources Survey System, Department of Fisheries (DOF), Ministry of Fisheries and Livestock, Dhaka, Bangladesh.

Winrock International. 2007. List of Freshwater Prawn Hatcheries in Bangladesh. Unpublished Report, Winrock International, Dhaka.

Production of *Cirrhinus molitorella* and *Labeo chrysophekadion* for culture based fisheries development in Lao PDR 2: Nursery culture and grow-out

Oulaytham Lasasimma[1] and Brett A. Ingram[2]

1. Living Aquatic Resources Research Center, National Agriculture and Forestry Research Institute, PO Box 9108, Vientiane, Lao PDR; 2. Marine and Freshwater Fisheries Research Institute (MAFFRI), Private Bag 20, Alexandra, Victoria, 3714, Australia.

Introduction

This article is the second of a two part series that aims to review current, readily available, information on these two indigenous species, *Cirrhinus molitorella* (mud carp, "Pa Keng") and *Labeo* (syn *Morulius*) *chrysophekadion* (black sharkminnow, "Pa Phia"), which are being used to improve and refine artificial propagation and culture techniques to support Culture Based Fisheries (CBF) development in Lao PDR. In particular, the review focuses on information within Lao PDR, as well information from the Mekong Fish Database (MRC 2003). The first part of this review was published in the previous issue of Aquaculture Asia.

Nursery culture

Larviculture

Gorda (2001) described the larviculture of *C. molitorella*. Initially larvae are held in incubation tanks in the hatchery for 4-5 days and fed boiled chicken egg yolk, finely smashed, twice each day, before being placed into fertilised earthen ponds for rearing. Nuanthavong and Vilayphone (2005) reared *C. molitorella* larvae at 19 larvae/L in a 3,000 L tank for 5-7 days. The water was aerated and 1/3 of the volume replaced daily. On the third day after hatching, larvae commenced feeding on boiled egg yolk and green plankton (fed once-twice/day).

Fry rearing

Fry are transferred to nursery facilities shortly after feeding commences. There are many forms of nursery facilities, including earthen ponds, concrete tanks, fiberglass tanks and 'Orlon' cages, that have been used successfully to rear fish fry in Lao PDR (Meenakarn and Funge-Smith 1998). Good pond preparation requires the following steps to be observed (Meenakarn and Funge-Smith 1998):

- Empty the water out of the pond and dry the pond.
- Add lime to the pond at a rate of 1 kg for every 25 m^2 of pond area. Lime assists soil fertility and reduces the amount of fertilizer required to produce an algal bloom in the nursery pond.
- Add organic fertilizer (manure) to the pond at the rate of 1.5 kilos per 10 m^2. Fertilizers that can be used include buffalo, cow, chicken and pig manures. After the manure is applied the pond can be filled to a depth of 5 - 10 cm to allow the breakdown of the manure. After 3 - 5 days, the pond should be filled to a depth of 30 - 50 cm and is then ready for stocking.
- Fry are stocked into the nursery pond at a rate of 125 - 500 individuals/m^2.
- After stocking the fry into the pond (usually done in the early evening) the water level is maintained for one week and then increased to 80 cm.

C. molitorella

Earthen ponds (usually 0.1-0.2 ha and 1.5-2.0 m deep) are used for the nursing of *C. molitorella*. Dry ponds are quick-limed at 900-1,125 kg/ha, and fertilised (animal manures 3,000 kg/ha and/or plant wastes 4,500 kg/ha) to increase the natural biomass of algae and zooplankton, 5-10 days before stocking, according to water temperature (FAO 2007). Fry are stocked at a rate of 450-600 fish/m^2, depending on targeted fish size at harvest. The nursery phase usually takes 4-5 weeks in China. Organic fertilizer is applied at a rate of 1,500-3,000 kg/ha once every 4-5 days to maintain and enhance plankton (FAO 2007). Occasionally other food sources (both direct and indirect to supplement or replace organic fertilizers) are added to the ponds, including soybean milk, soybean cake or other by-products from grain processing, water lettuce and water hyacinth (FAO 2007). After 4-5 weeks fish are about 30 mm (called summer fingerlings in China).

Growth rates are generally high in nursery ponds, but survival rates can vary greatly. Survival rates of *C. molitorella* fry during this period are typically 70-80%, but can exceed 90% under good management (FishBase 2007). In contrast, survival rates of *C. molitorella* fry reared in Lao PDR are considerably lower than this; 30-45% (Gorda 2001, Somboon et al. 2003). One of the principle problems affecting survival of fry stocked into nursery ponds in Lao PDR is predation by carnivorous dragon fly nymphs, tadpoles and fish that enter the ponds (Meenakarn and Funge-Smith 1998).

Stocking density will affect growth and survival in nursery ponds. Somboon et al. (2003) reared *C. molitorella* larvae (0.004 g, 5.0 mm) in fertilised earthen ponds at different stocking densities from 100 fish/m^2 to 1,000 fish/m^2, and after one month final mean lengths and weights varied from 14-36.6 mm and 0.01-0.37 g, respectively. Not surprising growth rates were greatest (14.9%/day) at the lowest stocking density. Somboon et al. (2003) concluded that a stocking density of 500 fish/m^2 was optimal in terms of growth and yield (fish produced). Harvested fish were sold at an average price of 100 Kip/fish (9,000 Lao Kip ≡ US$1).

Gorda (2001) described the rearing of *C. molitorella* larvae in fertilised earthen ponds, which had been dried, limed (200-300 kg/ha), applied with cut grass

Table 1. Polyculture of *C. molitorella* as a primary species with other fish species (Source: FAO 2007).

Type of polyculture	Size of fish (g)	Stocking rate (fish/ha)	Fish production after one year (kg/ha)
C. molitorella[1]	25-50	15,000-25,000	2,000-3,000
Ctenopharyngodon idella (grass carp)[1]	250	1,200-1,800	1,800
Aristichthys nobilis (bighead carp)[1]	500	450-2,250	2,700
Hypophthalmichthys molitrix (silver carp)[2]	250	375-750	700
Tilapia[2]	15-20	3,000-6,000	560
Cyprinus carpio (common carp)[2]	100	375	270
1 = Primary species and 2 = Secondary species.			

Table 2. Published information on the grow-out of *L. chrysophekadion*.

Stocking and culture details	Duration (mths)	Size and yield at harvest	Source
1 fish/m²	9	166 kg/rai (1,038 kg/ha)	Thavonnan and Udomkananat 1979
2 fish/m²	9	290 kg/rai (1,813 kg/ha)	
4 fish/m²	9	249 kg/rai (1,556 kg/ha)	
3 fish/m² in 1,200m² earthen pond (initial size 1.8 g). 192 kg/pond (1,600 kg/ha)	12	60.7 g, 192 kg/pond (1,600 kg/ha)	Thienchareon *et al.* 1990
0.5 fish/m² in polyculture with *Cyprinus carpio* at 1:10 (*L. c* : carp).		71.6 kg/1,600m² (447.5 kg/ha)	Pennapaporn 1970
0.6 fish/m² in polyculture with *Pangasius sutchi* at 1:1 ratio. Fed 5% body weight/day	11	94.63 g (21.9 cm), 590 kg yield	U-domkananat 1983
1.2 fish/m² in polyculture with *Pangasius sutchi* at 1:1 ratio. Fed 5% body weight/day	11	94.63 g (21.9 cm), 714 kg yield	
0.17 fish/m² earthen pond (initial size 1.8 g). Fed 20-30% protein diet	12	428.7 g (32.9 cm)	Unsrisong *et al.* 1990

(780-1,200 kg/ha), chicken manure (5,000 kg/ha), buffalo manure (10,000 kg/ha) and urea (100-150 kg/ha), and then filled. Manure was continually added throughout the culture period. Larvae were stocked at a rate of 400 fish/m², 5-6 days after filling. By the 1st week fish were 11 mm in length and 4th week were 30.2 mm in length, which represented a growth rate of 0.91 mm/day. According to Gorda (2001), in 2000 the Nah Luang Hatchery Station sold 15,000 larvae and 62,060 fry (1 month old) at 5 Kip/fish and 100 Kip/fish, respectively

Nuanthavong and Vilayphone (2005) described the nursing of *C. molitorella* fry at a small private farm in the Luang Prabang Province, undertaken in hapas situated in a 800 m² pond. Initially, fry (5-7 days old) were stocked into hapas made from plankton net (1,800 L; 1.5 x 2.0 x 0.8 m) at a rate of 2.8 larvae/L. After two weeks fry were transferred to larger hapas made from 3 mm mesh (9.4 m³, 3.5 x 3 x 1 m) (stockings density 0.7 fry/L) and reared for a further three weeks. During the culture period fish were fed plankton, rice bran and floating pellets. The survival rate 6 weeks after hatching was 20%.

L. chrysophekadion

The larvae of *L. chrysophekadion* have been reared in fertilised earthen ponds by Thienchareon et al. (1990). The ponds were dried for 5-7 days, limed at a rate of 100 kg/rai (625 kg/ha; 1 rai = 1,600 m²), fertilised with chicken or cattle manure at a rate of 400-600 kg/rai² (2,500-3750 kg/ha), then filled to a depth of 80 cm. After 3-5 days, when the water has turned green due to the increase in phytoplankton, 3 day old fry were stocked at a rate of 200 fish/m². The fish were fed as follows:

- 3-4 day old fry, fed with chicken egg yolk.
- 5-6 day old fry, fed with Artemia or Moina and a mixture of fish meal and rice bran.
- 10-30 days old fry, fed with meal and rice bran.

After one month, fry were to 3-4 cm in length (Thienchareon et al. 1990).

Grow-out

C. molitorella

The most commonly adopted method for on-growing *C. molitorella* is in large earthen ponds in polyculture with other fish species, as both the primary and secondary species, at various densities depending on the species mix (FAO 2007). As the primary species, *C. molitorella* is stocked at 15,000-25,000/ha (25-50 g fish) along with a range of other species including grass carp and bighead carp also as primary

Pond-reared *L. chrysophekadion*.

The fry of *L. chrysophekadion*.

Pond reared *C. molitorella*.

species, and silver carp, common carp, black carp, tilapia and bream as secondary species (FAO 2007) (Table 1). In monoculture, fingerling *C. molitorella* (30-60 mm in size) are on-grown in earthen ponds at a stocking density of 3.5-4.5 million/ha. During the fingerling growing phase, which takes 4-8 months in China, fish are mainly fed commercially manufactured feeds and ponds are fertilised to encourage the proliferation of plankton (FAO 2007).

C. molitorella grows slowly and will not reach a large size, but can be reared at a high density and has a high production rate (FAO 2007). After one year in polyculture as the primary species, *C. molitorella* typically reach 125-200 g, with a production level of 2,000-3,000 kg/ha, accounting for about 24% of total production, which ranges from 7,500 to 10,000 kg/ha (FAO 2007). As a secondary species *C. molitorella* is stocked at 7,500-9,000/ha (25-50 g fish), and after one year production can achieve 1,000-1,500 kg/ha, which may account for 10-15% of total production (FAO 2007).

In Lao PDR grow-out of *C. molitorella* is concentrated in the Luang Prabang Province (Ounidate et al. 1993, Souksavath 2001, Nuanthavong and Vilayphone 2005).

L. chrysophekadion

Several studies have examined the monoculture and polyculture of *L. chrysophekadion* in ponds and although information is limited, yields of 447.5-1,813 kg/ha are reported (Table 2). One study indicated that fish grew from 1.8 g to 60.7 g in 12 months (0.96%/day, 0.16g/day) (Thienchareon et al. 1990), while in another, fish grew from 1.8 g to 428 g (32.9 cm) in 12 months (1.5%/day, 1.17g/day) (Unsrisong et al. 1990). The species may also be suitable for culture in net cages and pens (Warren 2000).

L. chrysophekadion grows well when stocked into reservoirs (Chabjinda et al. 1992a, Leelapatra et al. 2000). In Mae Ngad Somboonchon Reservoir (1,040 ha), Chiang Mai Province, Thailand, L. chrysophekadion grew at a rate of 4.09 g/day, and reached maturity at 2 years of age (62 cm, 2,960 g) (Chabjinda et al. 1992b).

Research and development needs

Based on this review (Parts 1 and 2), a number of key areas of research and development have been identified to improve production of *C. molitorella* and *L. chrysophekadion*, which in turn will facilitate and augment culture based fisheries development in Lao PDR. These needs are:

(a) Captive breeding:

- Develop and refine captive spawning techniques for *C. molitorella* and *L. chrysophekadion* to support culture based fisheries development.

- Establish baseline information on the reproductive performance of *C. molitorella* and *L. chrysophekadion* under various husbandry conditions.

Monitor influence of broodstock holding conditions (ponds and tanks, monoculture and polyculture, stocking density, feeding regime, nutritional profile of diet, etc.) and performance of individually tagged broodstock (e.g. temporal changes in weight, length and condition, fecundity, spawning frequency, gamete quality, etc.).

(b) Incubation and larviculture stage

- Improve the growth and survival of hatchery produced *C. molitorella* and *L. chrysophekadion* eggs and larvae, determine the best food types and feeding regimes, determine the optimal stocking densities for this period of development, and undertake research on weaning larvae to suitable dry feeds.

(c) Fry rearing (nursery) stage

- Improve the growth and survival of hatchery produced *C. molitorella* and *L. chrysophekadion* fry, determine the best fry culture method (pond, hapas, tanks, etc.), determine the best food types and feeding regimes, and determine optimal stocking densities for nursery ponds, hapas and tanks.

Acknowledgements

This review has been undertaken as part of the Australian Centre for International Agricultural Research (ACIAR) Project, Culture-Based Fisheries Development in Lao PDR (Project No. FIS/2005/078). The authors wish to thank the project leader, Prof. Sena S De Silva (Network of Aquaculture centres in Asia-Pacific (NACA), Bangkok, Thailand), as well as Dr. Thuy Nguyen (NACA, Bangkok, Thailand), Mr Lieng Khamsyvilay (Director, Living Aquatic Resources Research Center (LARReC), Vientiane, Lao PDR), Mr Roger Khamphet (Deputy Director, LARReC, Vientiane, Lao PDR) and Mr Bouthong Saphakdy (Department of Livestock and Fisheries, Ministry of Agriculture and Forestry, Lao PDR) for support and advice during the preparation of this review.

References

Chabjinda, K., Tienchareon, P. & Jittakorn, A. (1992a). Black shark, *Morulius chrysophekadion* (Bleeker) in three different reservoirs. Technical Paper No. 11/1992. Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 15 pp.

Chabjinda, K., Tienchareon, P. & Jittakorn, A. (1992b). Monitoring of stocking of black shark, *Morulius chrysophekadion* (Bleeker) in Mae Ngad Somboonchon Reservoir, Chiang Mai Province. Technical Paper No. 10/1992. Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 14 pp.

FAO (2007). *Cirrhinus molitorella* (Valenciennes, 1844) Cultured Aquatic Species Information Programme http://www.fao.org/fi/website/FIRetrieveAction.do?dom=culturespecies&xml=Cirrhinus_molitorella.xml (Acessed November 2007).

FishBase (2007). title. http://www.fishbase.org/search.php (Acessed 10 November 2007).

Gorda, S. (2001). Fish Propagation and Nursing Techniques. LARReC Research Report No 0012, Vientiane. 56 pp.

Leelapatra, W.P., Srisakultiew, P. & Sukumasavin, N. (2000). Biology and Breeding of Indigenous Mekong Fish Species in Thailand. Management of Reservoir Fisheries in the Mekong Basin II, Vientiane.

Meenakarn, S. & Funge-Smith, S. (1998). Small-Scale Fish Hatcheries for Lao PDR. Provincial Aquaculture development Project, Support for technical Services FAO, Bangkok. 35 pp.

MRC (2003). Mekong Fish Database version 2003. CD-ROM. Mekong River Commission, Phnom Penh, Cambodia.

Nuanthavong, T. & Vilayphone, L. (2005). Reproduction and nursing of *Cirrhinus molitorella* in a small fish farm in Luang Prabang Province, Lao PDR. In Proceedings of 7th Technical Symposium on Mekong Fisheries, pp. 197-203 Ubon Ratchathani, Thailand, 15th-17th November 2005.

Continued on page 50.

Mussel farming: alternate water monitoring practice

G. Misra and P. K . Mukhapadhyay

Central Institute of Freshwater Aquaculture Kausalyaganga, Bhubaneswar-751 002, Orissa, India

Mussel ecology

Understanding the function of freshwater mussels within aquatic ecosystems is vital for successful management. The Indian freshwater mussel fauna comprises two genera that are abundantly found in most of the freshwater bodies. The genus Lamellidens is represented by nine species and two sub-species, while the genus *Parreysia* is represented by 35 species and 6 sub-species under two sub-genera (Subba Rao, 1989). These bivalves typically live partly buried in the sand or mud and leave characteristic furrows on the substratum due to the sloughing movements of the wedge-like powerful foot during restricted locomotion. They are encountered in greater abundance in waterways located in alluvial soil areas with soft soil substrate harboring green algae. It may be said that *Lamellidens marginalis* (Fig. 1a) is a typical pond species, while L. corrianus (Fig. 1b) is often encountered in shallow habitats including paddy fields during inundation. The species of the genus *Parreysia* (Fig. 1c) are more frequent in flowing habitats like irrigation canals, streams and rivers. Species of the genus *Lamellidens* are normally distributed in stagnant to slow flowing habitats like ponds, tanks, lakes and reservoirs at a depth of 0.5 m (Fig. 2) and beyond (Misra et. al. 2000; Misra, G. 2005). Neutral to slightly alkaline waters are in general conducive for mussel colonization.

Efficacy of freshwater mussels

Freshwater pearl culture

Mussels had been largely ignored by the aquaculture sector since their practical utility was limited. However, in recent times, role of freshwater bivalves in producing an aquatic gem cannot be ruled out. Cultured pearls are produced both in marine and freshwater environments. Possibly, the genesis of modern freshwater pearl culture can be traced back to the traditional practice from the 12th century in producing pearl-coated Buddha images in the mussel Cristaria plicata in lake Tahu in China. The conventional method of production of cultured pearls in vivo involves huge risk. In India, marine pearl culture had its beginning in the early seventies by the efforts of the Central Marine Fisheries Research Institute and the theory of natural and culture pearl formation in marine oysters is now fairly established. Freshwater pearl culture, on the other hand, remained as an unexplored area despite vast freshwater resources and abundant natural stocks of freshwater mussels in the country. Realizing the scope and importance of inland pearl culture, an indigenous system of culturing pearls from common freshwater mussels, *Lamellidens marginalis*, *L. corrianus* and *Parreysia corrugata* has evolved (Janakiram 1989) producing conventional regular round, mabe (half round and design), small round, oval to irregular pearls of assorted colour and luster. Traditionally in the fisheries sector, freshwater mussel fauna are in great demand because of their requirements in diverse fields viz. shell button industry, lime and handicrafts. Mussel meat, an affluent source of protein, is conventionally used as feed in shrimp and catfish hatcheries and is also eaten in some tribal belts of India, such as West Bengal, Bihar, North Eastern States and Orissa. Their task in maintaining the water body as a natural cleanser is a boon to the aqua-industry.

Water body monitoring process

Water quality monitors often look for benthic macro invertebrates to evaluate water quality. These include aquatic insects, worms, shellfish, crustaceans and other animals that are large enough to see without magnification and live at the bottom of a water body. Increasing effort has been devoted towards the selection of appropriate biomonitors. Quite a few such studies specify that molluscs can endure persistent toxins to a greater extent than other organisms and serve as effective biomonitors or indicators (Fang et al, 2001; Salanki et. al. 2003 and Somoldes et. al. 2003). Bivalves have been used for decades as sentinel organisms to monitor pollution in aquatic environment as they are an important indicator of water quality, including waters used for drinking, irrigation and recreational purposes as their community responds to changes in water or habitat quality. The advantages of molluscs over other organisms for biomonitoring studies are their large size as macro-invertebrates and their restricted mobility. Their abundance in diverse types of aquatic bodies and their trouble-free collection is an added benefit for such studies.

Figure 1. Commonly available mussel species in India.

a. *Lamellidens marginalis*.

b. *Lamellidens corrianus*.

c. *Parreysia corrugate*.

The abiotic and biotic factors of an aquatic ecosystem are interdependent and the fluctuations of abiotic factor frequently affect the biotic factors (flora & fauna) changing their quality and variety. The abundance of this benthic fauna greatly depends on physical and chemical property of the substratum

Figure 2. Collecting freshwater mussels from the peripheral pond area.

and can be employed as a barometer of over all biodiversity in aquatic bionetworks. The widespread reduction in density and diversity of freshwater mussels in aquatic ecosystems suggests that insubstantial changes in water quality characteristics can have pervasive effects. Species of commercially obtained freshwater mussel *Elliptio complanata*, a native of Canada, have been shown to actively filter, concentrate, and retain fecal coliform bacteria from a variety of freshwater stream environments (Beth et. al. 2004).

The advantage of using bioindicators over chemical and physical tests to evaluate water quality is that the presence of living organisms inherently provides information about water quality over time. The lack or poor conditions of bioindicators might provide a clue of adverse consequence. The presence of a mixed population of healthy, mussels along with aquatic insects or fish usually indicates that the water quality has been good for some time. The absence of bioindicators at a site that appears good according to chemical and physical sampling might demand further investigations of water quality. Each species of mussel has different environmental requirements. Some species like *E. complanata*, are more pollution tolerant than species like *Margaretifera margaretifera*, the pearl shell mussel. However, since freshwater mussels are hardy creatures, their presence or absence can provide even more information about the history of water quality at a site.

Bioaccumulation

Mussels are sedentary, benthic and gregarious invertebrates. They filter water continuously and feed on phytoplankton. The water current is taken through the inhalant siphons that passes through the gills, labial palps, mantle of the mussels and is finally ejected through the exhalent siphon. During such processes the suspended soil particles, excess algal blooms and metal ions (Cu, Zn, Ni etc.) are removed from the water. In addition to the gills, the mantle, kidney, foot and hepatopancreas are anticipated to be major sites of metal uptake because of their large surface area, thus clearing the aquatic habitat. They accumulate both essential (Na, Ca, Mg) and non essential (Hg, Cd, Pb) metals in higher concentrations than the ambient water. Through their filter feeding and respiratory mechanisms mussels also take up other pollutants such as hydrophobic organic contaminants, poly aromatic hydrocarbons, metallothionein and organochlorines. The accumulation of contaminants from the water column by bivalves is referred to as 'bioconcentration', a property that makes bivalves potentially useful as 'biomonitors' for water quality monitoring programmes, and also for bioremediation to improve the quality of polluted waters.

Bioaccumulation of toxins is one of the many possible tools that can be employed in bio monitoring. In the United States, hanging culture of Dreissena polymorpha is used to reduce suspended matter loads, toxins and especially organic pollutants. *Mytilus edulis*, the blue mussel have been used traditionally in the marine sector for environmental monitoring due to concern for pollution in coastal and estuarine areas. *Anodonta cygnea* when exposed to toxin strain of cyanobacterium, accumulated huge quantity of the peptide oscillatoria toxin that was present in low concentrations within the cyanobacterial cells. Pollutants or chemicals enter the mussels system as they filter water through their gills for respiration and feeding or in case of inorganic contaminants such as metals, through facilitated diffusion, active transport or endocytosis. Moreover some bivalve species are exposed to pollution through pedal feeding or gill ingestion of sediment. Accumulation occurs in tissues e.g. heavy metals will accumulate primarily in muscles and organ (soft) tissues and organic pollutants accumulate in the lipid. Bivalves

Figure 3. Pearl culture ponds.

have been known to metabolize certain classes of compounds better than others controlling ecotoxicity. Mussels possess only minimal ability to bio-transform poly aromatic hydrocarbon (PAH) and are therefore good sentinels of the accumulation of PAHs. More recently freshwater bivalves have been utilized to assess the quality of lakes, rivers and streams.

Plankton control

For upkeep of water systems in aquaculture practices it is can be useful to include freshwater mussel fauna or follow an integration practice. In freshwater pearl farming mussels can plan a very significant role in water quality management through their control of plankton population as a result of filter feeding. Mussels consume both green and blue-green algal cells (Misra et. al. 1998; Wood et. al. 2006). Freshwater mussels can affect phytoplankton populations in two ways; by direct consumption and indirectly by altering nutrient cycles that may favour undesirable algal species. Pearl farming ponds are provided with floating rafts made up of PVC or bamboo in which the operated mussels are hung in the water column at a depth of 60cm. The stocking density of mussels can be 20,000-30,000 in a 0.4 ha pond. Mussels can also be used for bioremediation or as natural biofilters in prawn farming or simply to control excess algal blooms that may pose a risk of eutrophication. The filtration rate can be accelerated by selecting larger individuals that are likely to be more effective than the smaller ones in accumulating phytoplankton.

Future thrust

In recent times mussels are widely used as indicators of water quality or for remediation purposes, even in water treatment plants. Conserving the mussel fauna will ensure that our river and lakes are clean enough to perform aquaculture and other related activities. Easy dissemination techniques for use mussels is these contexts need to be developed. The reproduction system and gonadal behavior of mussel in particular needs attention. Globally substantial work has been done in relation to conservation of mussel fauna, especially of the endangered species such as *Lampsilis* and *M. margaretifera*. In India as well as in the adjoining countries like Bangladesh, Sri Lanka, and Myanmar the bivalves, Lamellidens marginalis and L. corrianus are known to be distributed in the perennial and artificial freshwater bodies (Subba Rao, 1989). Conservation of these species is of prime importance and thus their culture and maintenance is to be emphasized for uninterrupted accessibility of these species to the concerned sector.

Issues that require further study include the endurance of mussels in eutrophic waterways, the quantity of vigorously feeding mussels required to effectively control algal growth under different ecological conditions, and whether it is possible to rear mussels in adequate numbers for their eventual introduction into water bodies with algal problems. In future a holistic approach is needed to quantify mussel filtration rate along with the propagation experiments to establish their role in water quality management. Establishing water quality criteria that includes freshwater mussel response requires an understanding of conventional assessment approaches and scientific considerations.

Acknowledgements

The authors are thankful to Department of Science and Technology, New Delhi, for financial assistance and Central Institute of Freshwater Aquaculture for Infrastructure.

References

Beth, C., Michael, S., Mac, L., Robin, O. and Jay, L. 2004. Evaluation of potential health risks to Eastern Elliptio (Elliptio complanata) (Mollusca: Bivalvia: Unionida: Unionidae) and implications for sympatric endangered freshwater mussel species. Journal of Aquatic Ecosystems Stress and Recovery 9: 35-42.

Fang, Z. Q., Cheung, R. Y. H. and Wong, M. H. 2001. Heavy metal concentration in edible bivalve and gastropods available in major market of the Pearl River Delta. Journal of Environmental Science 13: 210-217.

Freshwater Pearl Culture. Training Bulletin, Gayatri Misra, Maharathy, C., Mohanty, P., Pattnaik, S., Ghadai, K., Bhanot, K.K. and Janakiram, K. 2000. Central Institute of Freshwater Aquaculture, Bhubaneswar. 37pp.

Misra, G. 2005. Pearl farming – Avenue For Women Entrepreneurship. In Ninawe, A.S and Diwan, A.D. (eds.) Women Empowerment in Fisheries. Narendra Publishing House, Delhi, pp.201–212.

Misra, G. Kumar K. and Janakiram K. 1998. Role of selected feeds in captive culture of Indian pearl mussel *Lamellidens marginalis* (Lamarck). Current and Emerging Trends in Aquaculture. Ed. P. C. Thomas. Daya Publishing House, New Delhi. pp. 241 –243.

Naimo, T. J., A review of the effects of heavy metals on mussels. 1995. Ecotoxicology 4: 341 – 362.

Salanki, J., Farkas, A., Kamardina,T. and Rozsa, K. S. 2001. Molluscs in biological monitoring water quality. Toxicology Letters 11: 403 –410.

Smolden, R., Bervoets, L.,Wepenser, V. and Blust, R. 2003. A conceptual frame work of using mussels as biomonitors in whole effluent toxicity. Human Ecology. 9(3): 741 –760.

Subba Rao, N. V., 1989. Handbook on freshwater molluscs of India. Zoological Survey of India. Calcutta, India, 289 pp.

Janaki Ram, K., 1989. Studies on culture pearl production from freshwater mussels. Current. Science 58 (8): 474-476.

Wood, S. A., Briggs, L. R., Sprosen, J., Ruck, J. G., Wear, R. G., Holland, P. T., Bloxham, M. 2006. Changes in concentration of microcystis in rainbow trout, freshwater mussels and cyanobacteria in lakes Rotoiti and Rotochu. Environmental Toxicity 21: 205 – 222.

Benefit-cost analysis for fingerling production of kutum *Rutilus frisii kutum* (Kamensky, 1901) in 2005 in Iran

Hassan Salehi

Assistant Prof., IFRO, and Head of Economic Group, Iranian Fisheries Research Organization, 279 West Fatemi Ave., Tehran, Iran, email: hsalehi_ir@yahoo.com.

Introduction

Knowledge of production costs and their evolution is essential to the successful management of a hatchery farm, and helps to identify the main items for which cost reduction is worthwhile. Benefit-costs analysis may also assist the manager in decision making and in adjusting to changes.

The primary interest in most fisheries is directed toward establishing viable industries for the purpose of, stock enhancement, domestic consumption, export, employment opportunities, income distribution, or a combination of these objectives (Shang, 1981 and Pillay, 1994). As Shang (1990) noted, elements such as biology, technology, feed and nutrition, engineering, fish pathology, and institutional factors all affect the economics of production. From a micro-economic view point the primary motivation of a fish farm may be profit making, but sometimes these can be other considerations such as stock enhancement (Salehi, 2003).

Research on the economics of kutum (*Rutilus frisii kutum*) culture will play an important role in its future development. It is clear now, to overcome the problem of declining kutum stocks the promotion of hatcheries to produce large quantities of fingerlings for stock enhancement is certainly going to be an important strategy. Stock enhancement is practiced in many countries with different methods and various objectives, not the least of which is the reconstruction of stocks of economically important species. For example, Japan has a long history in using stock enhancement to support and rehabilitate almost 80 species (Matsuda, 2000) with varying results. Iran contributes to these efforts through the reproduction and enhancement of more than thirteen main native species, releasing more than 250 million fingerlings into the Caspian Sea and the Persian Gulf annually (Bartley, 1995, Shehadeh, 1996, Bartley and Rana, 1998, Abdolhay, 1998, Tahori, 1998, Salehi, 2002, 2005 and PDD, 2007).

As Fushimi (Fushimi, 2001) noted, the main issue that should be considered in any stock enhancement plan is the economic aspects. The economic advantages of stock enhancement, and other aspects of population rehabilitation, have been considered in recent years by Bartley (1995) (1999); Sreenivasan (1998); Hansson, et al. (1997); Ahmad et al. (1998); Lorenzen et al. (1998); Gateway (1999), Kitada (1999) and Salehi (1999, 2002, 2005b & 2008). Some researchers emphasized the profitability of stock enhancement and stressed that in some species the rate of return of investment can be very high (Hansson, et al., 1997; Ahmad, et al., 1998; Lorenzen et al., 1998, Lorenzen et al., 2001, Gateway, 1999 and Salehi, 2006). The analysis of the economics of all aspects of stock enhancement for species such as kutum is a very complicated undertaking. It is also very expensive and takes a long time to generate satisfactory returns, although it may have a key role in improving the productivity of stock enhancement.

The natural maturation and reproduction of all bony fishes in the Caspian Sea, including kutum, has faced serious problems. As noted by Razavi Sayyad (1995) the contribution from hatchery production in the Caspian Sea landings has been estimated to be more than 95% for kutum. By considering the background data on stock enhancement of kutum and the results of fishing data, it seems that increase of the contribution of kutum in total fish catch was most probably affected by stock enhancement in Iran.

Study structure and methods

A study of kutum fingerling production was carried out to help clarify fingerling production costs. Specific objectives were:

1. To determine the real costs and production of kutum fingerlings.
2. To find the cost contribution of the input factors.
3. To determine the cost sensitivity of main operating cost factors for hatchery production of kutum fingerlings.

Attention was directed to addressing questions such as: which inputs are significant in explaining outputs from various hatcheries? What constraints inhibit increased productivity and production of existing kutum culture systems? The study, conducted in 2005, covered kutum hatcheries in northern Iran, including Guilan, Mazandaran, and Golestan provinces. For this purpose, a questionnaire was prepared and filled in by an expert team comprised of an economist, statistician and aquaculturist using data available in kutum hatcheries for fingerling production and other related departments in the Iranian Fisheries Organization, with data collection, classification, and analysis covering 2004. Two sources of data were used. Primarily data were obtained through personal interviews with managers and related experts in hatcheries, which were conducted to obtain information on the resources used and the quantity of output. Other relevant documents obtained from the Iranian Fisheries Organization (IFO) were consulted including information from the accounting, budgeting and stock enhancement offices. These data were supplemented with other data maintained by other affiliated departments of IFO, affiliated provincial fisheries offices and the Iranian Fisheries research Organization (IFRO). Data were entered into a Microsoft Excel spreadsheet 2003 and methods for classification, summarizing, averaging, and other functions based on Shang (1981, 1990); Jolly and Clonts (2003) and Salehi (1991, 2004 and 2006) were used for analysis.

Results

Total fingerling production of kutum increased from 2.8 million in 1982 to more than 225 million in 2002, but declined to 179 million by 2004. Fingerling production increased to more than 229 million in 2005 (Table 1) and again declined to 174 million in 2006 (PDD, 2007). From 1991-2006, on average, the contribution of kutum to total landings of bony fish was more than 51% in the Iranian reach of the Caspian Sea, ranging from a high of 67% in 1991 to a low of 40% in 2002. The annual landing of kutum averaged more than 9,209 tonnes over the 1991-2006, ranging from a high of 16,118 tonnes in 2006 to a low of 6,417 tonnes in 2002. Over the period 2000-2006, yearly production of kutum fingerlings averaged more than 186 million (Table 1). The trend line of fingerling releasing of the kutum shows steady growth over the period (Figure 1).

Table 1: Total landings and the number of kutum fingerlings releasing in the Caspian Sea between 1982 and 2006.

Year	Kutum landings (mt)	Number of kutum fingerlings releasing	Total landings of bony fishes (mt)	Contribution of kutum to total landings of bony fishes (%)
1982	563	2,809,000	7,924	7
1986	3,500	51,704,000	6,296	56
1991	10,920	109,843,000	16,335	67
1992	10,085	96,619,000	17,260	58
1993	10,061	100,047,000	17,629	57
1994	11,175	142,733,020	18,638	60
1995	9,525	117,918,845	17,981	53
1996	9,436	142,091,873	17,638	53
1997	8,316	154,367,000	16,698	50
1998	6,878	143,361,000	15,611	44
1999	6,583	147,879,000	12,804	51
2000	8,977	132,900,000	16,863	53
2001	7,199	196,600,000	16,378	44
2002	6,417	225,198,000	16,200	40
2003	8,984	155,000,000	16,573	54
2004	7,036	179,365,000	15,665	45
2005	9,631	229,110,000	21,845	44
2006	16,118	174,300,000	23,802	68
Average	9,209	152,958,296	17,370	46.6

Sources: Developed from Salehi (2005_b) and PDD (2005, 2006, 2007).

From 2000-2005, the contribution of kutum to total landings of bony fishes was almost 47% and annual landings averaged more than 8,040 tonnes. Kutum landings ranged from 7,036 to 9,631 tonnes over the same period. By considering fishing data in light of stock enhancement of kutum, as Table 1 shows, it seems that increases in the contribution of kutum to the total catch in Iran was positively influenced by stock enhancement.

In 2005, of 9,631 tonnes of kutum landings, 56% belongs to the province of Guilan, followed by 39% in the province of Mazandaran, with the balance produced by Golestan province (PDD, 2006). From 2000-2005, annual fishery production of bony fishes averaged more than 20,400 tonnes. Of that landings 47% belongs to the province of Guilan, followed by 35% in the province of Mazandaran, with the balance produced by Golestan province. Mazandaran Province had the highest variation but also showed steady growth in landings, averaging more than 7,000 tonnes over the 2000-2005 period.

As Figure 2 shows, in 2004, total costs per kutum fingerling production averaged IR Rials 130 ($US 0.016) in Iran. This represents a 7% increase in total cost per fingerling relative to 2003. Average cost for labor was IR Rials 54 representing an average of 42% of total costs. The other main costs were feed and fertilizer, maintenance and depreciation averaging 14%, 10% and 9% of total costs respectively. The cost of harvesting and post harvest averaged only 8% of total costs. The steady growth of kutum fingerling enhancement from 1995-2006 in the South Caspian Sea is shown in Figure 1. Fish landing data after the establishment of various kutum hatcheries along the Iranian parts of the Caspian Sea clearly indicate the success of stock enhancement programs over this period (Figure 3).

Cost sensitivity analysis of hatchery production of kutum shows that labor is the most sensitive component. A 50% increase of this item increases the total cost by almost 27%, followed by feed and fertilizer cost (Figure 4).

Discussion

Stock enhancement has many socio-economic and environmental advantages. Many researchers have discussed the positive effects of stock rehabilitation for sturgeon and bony fishes in Iran (see Razavi Sayyad 1995, Abdolhay 1998, 2006, Danesh Khoosh Asl 1998, Tahori 1998, Hosseini 1998, Pourkazemi 2000, 2006, Keyvan 2002, Salehi 2006, 2008 and Moghim et al., 2006). The importance as well as benefit return of hatchery enhancement and its opportunities for resource reconstruction have also been discussed internationally (eg. Bartley 1995, 1999, Hansson et al., 1997, Sreenivasan 1988, Salehi 1999, 2002, 2006, Ahmad et al. 1998, Lorenzen et al. 1998, Garaway 1999, Kitada 1999 and Lorenzen et al. 2001 and Rosenthal et al. 2006). Fsh landing data from 1991-2006 clearly indicate the success of stock enhancement programs initi-ated after the establishment of kutum hatcheries along the Iranian parts of the Caspian Sea over the period (Figure 1).

As shown in this study, the major cost in kutum hatcheries was labor, which averaged IR Rials 54 (almost $US 0.006) for each fingerling, followed by feed and fertilizer, were averaged IR Rials 18. Compared with other aquaculture activities, the share of labor cost in kutum hatcheries was very high compared to carp farming (12%), trout farming (13%), shrimp farming (17%) and shrimp hatcheries due to using foreign experts (26%) (see Salehi, 1999, 2003, 2005a and 2005b). It seems, the main reason for this higher labor cost may be the inactivity of hatcheries during a few months off season, which could be reduced

Table 2: Total landing of bony fishes in the north provinces of Iran over the 2000-2005.

Year / Province	2000	2001	2002	2003	2004	2005	Average yearly	% contribution of province to total landings	SD
Guilan	10,110	8,410	8,320	6,686	5,704	9,211	9,661	47	636
Mazandaran	5,840	4,837	5,280	7,983	6,046	8,316	7,078	35	1,751
Golestan	3,050	3,253	2,600	1,903	3,914	4,318	3,684	18	897
Total	19,000	16,500	16,200	16,572	15,664	21,845	20,423	100	2,012
SD: Standard deviation. Sources: Developed from Salehi, 2005$_b$ and PDD, 2006.									

by adopting extra activities in such hatcheries. The importance of stock rehabilitation in general, and kutum enhancement in particular as a means of biodiversity preservation, and as a source of socio- economics activity has been addressed in this paper. Current production and enhancement of kutum fingerling and the huge investment expended by IFO suggest that this sector might be expected to become increasingly important in coming years. Future fingerling production of kutum is likely to vary widely and will be to a large extent dependent on ability to obtain brood fish from the Caspian Sea as well as continued investment by government. Overall, kutum rehabilitation may benefit from research aimed at developing technically viable production and enhancement systems, improved nutrition, genetic improvement, disease prevention, water quality and industry management. It seems that the co-operation of beach seine net co-operatives and other organizations involved in Iran might be expected to have an important effect on stock enhancement and biodiversity preservation of kutum in the coming years.

Considering an 8.3% fingerling return aged 3.7 years at 815 g average weight (Razavi Sayed, 1995 &1999) it might be expected that more than 19,016,130 kutum fingerlings will be returned by 2008-2009 with total meat production around 15,500 tonnes, assuming a 15% annual growth rate per year for kutum as recorded from 1993-2001 and 2001-2005 (PDD, 2002, 2005, 2006 & 2007). The wholesale price of this production would potentially be around IR Rials 1,100 billion (US$ 116 million). This suggests that a return of US$116 million could potentially be generated from an investment of less than US$ 320,000 used for stock enhancement in the year 2004. There are of course many questions and issues that need to be resolved in order to sustain kutum production such as the state of the environment, reduction of pollution to improve its suitability for kutum produc-

Figure 1: Number of kutum fingerlings releasing from 1991-2005 in the Iranian reach of the Caspian Sea. Sources: Developed from Salehi (2005b) and PDD (2006, 2007).

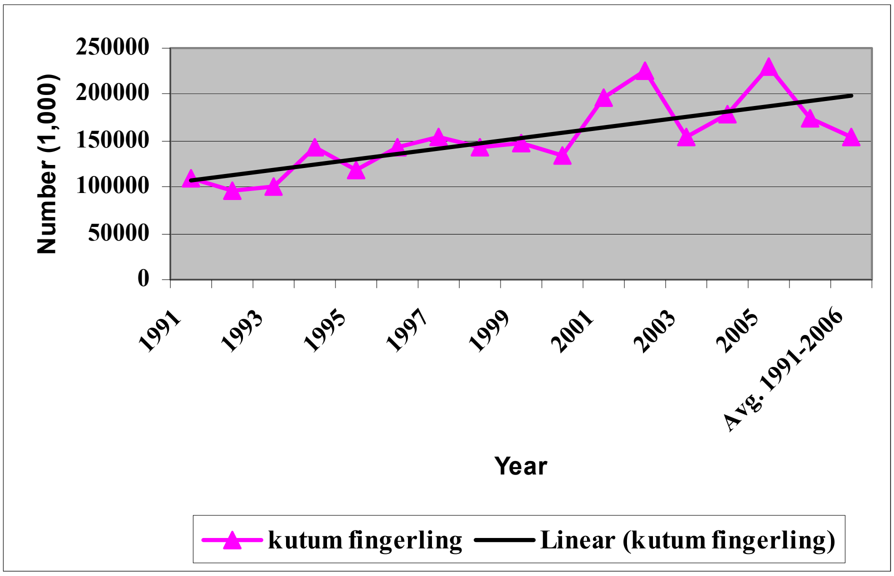


Figure 2: Average cost (Rials per fingerling) of kutum fingerling production in 2004 in Iran (L&S: Labor & Salary, F&F: Feed & Fertilizer, H&Ph: Harvesting & Post harvest, W&E: Water & Energy, Ch&D: Chemical & Drugs, Main: Maintenance, Misc: Miscellaneous and D: Depreciation).

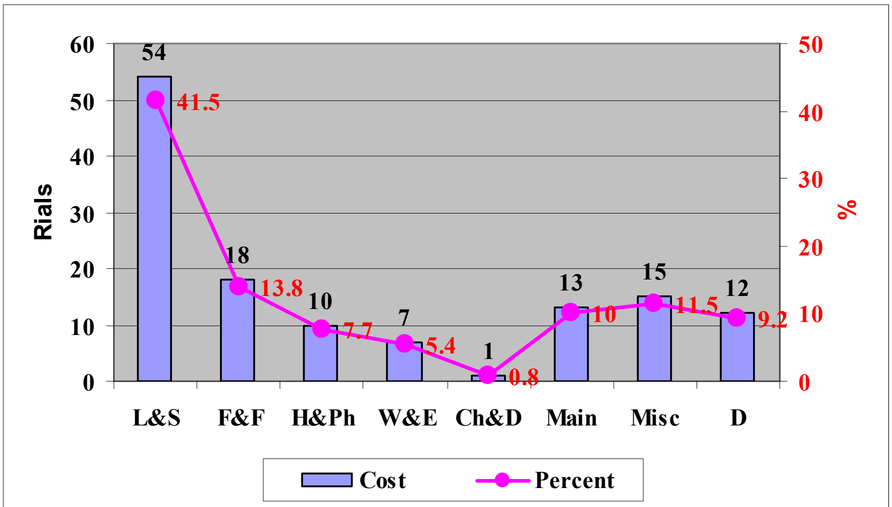


Figure 3: Total landing of kutum over the years 1991-2006 in Iran.

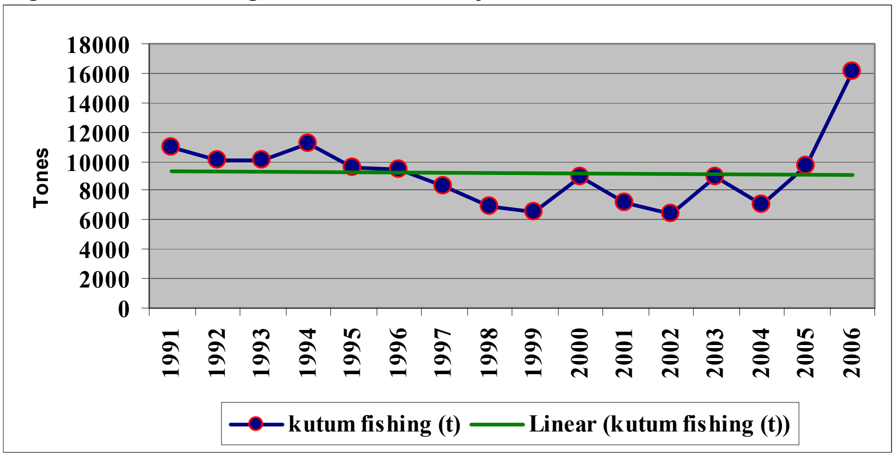
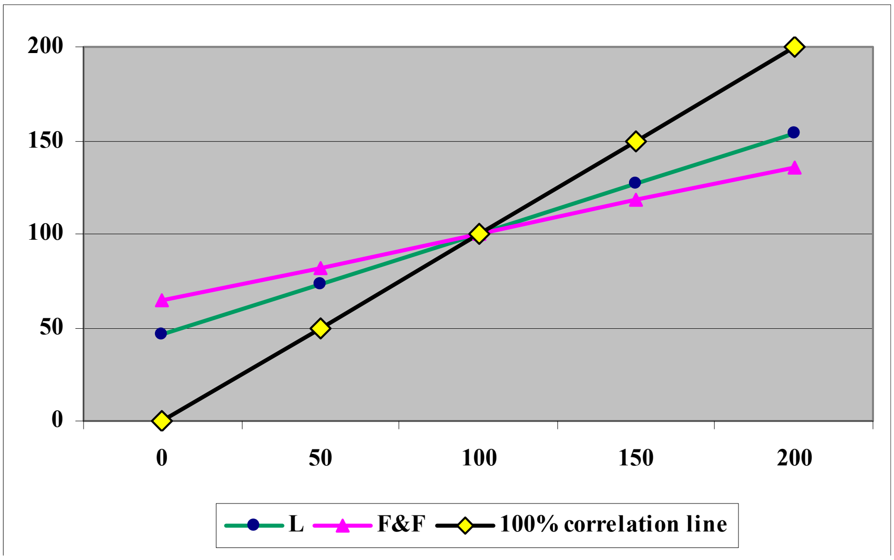


Figure 4. The cost sensitivity of fingerling production of kutum for the year 2004 in Iran.



tion, and the need to address illegal fishing activities. Who will be responsible and answer for these matters? Are 15,500 tonnes kutum attainable?

Overall, from the economic point of view, the results of this study indicate that the hatchery production of kutum is profitable and could present an option for increasing the productivity and breeding procedure of hatchery production in Iranian reach of the Caspian Sea. However, for enhancements to achieve their full potential and provide benefits on a sustainable basis, improvements are required in both policy and research support, particularly, on national and regional basis. Finally, key opportunities for regional cooperation arise from pro-active approaches to regional comparative studies, including identification of key opportunities for learning and designing programmes for collection and analysis regional data.

Acknowledgments

We would like to gratefully acknowledge the assistance of the Fisheries Organisation of Iran, Fisheries Research Institute, and especially Mr Darvish, Mr Abdoulhy, Mr Mogadsi, and Mr Amini.

References

Abdolhay, H. 1998. Artifical hatching for stock rehabilitation. 7th National Fisheries Conference, Responsible Fisheries (in Persian), Shilat, Tehran, Iran, p 187-205.

Abdolhay, H. 2006. Fingerling production and release for stock enhancement in the Southern Caspian Sea: an overview. Journal of Applied Ichthyology 22: 125-131.

Ahmed, I., Bland, S.J.R., Price, C.P. and Kershaw, R. 1998. Open water stocking in Bangladesh, experiences from the Third fisheries Project. FAO Fisheries Technical Paper No. 374: 351-370.

Bartley, M.D. 1995. Marine and coastal area hatchery enhancement programmes: Food security and Conservation of Biological Diversity. Paper prepared for Japanese/FAO Conference on Fisheries and Food security Kyoto, Japan, Dec. 1995, p15.

Bartley, M.D. and K. Rana, 1998. Stocking inland waters of the Islamic Republic of Iran. FAO, 5p.

Bartley, M.D. 1999. Marine ranching : current issues, constraints and opportunities. In Marine ranching; FAO Fish. Circ., No. 943, pp28-43.

Bjorndal, T. 1990. The economics of salmon aquaculture. Blackwell scientific Publications. London. UK. 118p.

Danesh Khoosh Asl, A. 1998. The role of stock enhancement of kutum on quality and quantity of resources in Caspian Sea. 7th National Fisheries Conference. Responsible Fisheries (in Persian), Shilat, Tehran, Iran, p 207-219.

Fushimi, H. 2001. Production of juvenile finfish for stock enhancement in Japan. Aquaculture 200: 33-53.

Garaway, J. 1999. Small water body fisheries and the potential for community-led enhancement: case study from the Lao PDR. PhD Thesis, University of London, 414pp.

Hansson, S. Arrhenius, F. and Nellbring, S. 1997. Benefits from fish stocking: Experiences from stocking young-of-the year pikeperch to a bay in the Baltic Sea. Fish Res. 32: 123-132.

Hosseini, M. 1998. The end of unresponsible sturgeon Fishing. 7th National Fisheries Conference. Responsible Fisheries (in Persian), Shilat, Tehran, Iran, p115-128.

Ivanov, V.P., Vlasenko, A.D., Khodorevskaya, R.P. and Raspopov, V.M. 1999. Contemporary status of caspian sturgeon (Acipenseridae) stock and its conservation. J. Appl. Ichthyol. 15: 103-105.

Jolly, C.M. and Clonts, H. A. 1993. Economics of Aquaculture. Haworth Press. Inc. Binghamton. New York. 319p.

Keyvan, A. 2002. Introduction on biotechnology of cultured sturgeon. Azad University, (in Persian), Lahijan, Iran, 270p.

Kitada, S. 1999. Contribution of hatchery enhancement and comprehensive fishery resource management: from Japanese experience. In: Marine ranching: global perspective with emphasis on the Japanese experience. FAO. Fish. Circ. 943: 98-130.

Khodorevskaya, R.P., Dovgopol, G.F., Zhuravleva, O.L. and Vlasenko, A. D. 1996. Present status of commercial stocks of sturgeon in the Caspian Sea Basin. Proceedings of the International Conference on Sturgeon Biodiversity and Conservation. American Museum of Natural History, New York p28-30.

Lorenzen, K., Juntana, J., and Tourongruang, D. 1998. Assessing culture fisheries practices in small water bodies: a study of village fisheries in Northeast Thailand. Aquaculture Res. 29: 211-224.

Lorenzen, K., Amarasinghe, U.S., Bartley, D.M., Bell, J.D., Bilio, M., De Silva, S.S., Garaway, J.C., Hartmann, W.D., Kapetsky, J.M., Laleye, P., Moreau, J., Sugunan, V.V. and Swar, D.B.

2001. Strategic review of enhancements and culture- based fisheries. Aquaculture in the Third Millennium. Subasinghe, R., Bueno, P., Phillips, M., Hough, C., McGladdery, S. and Arthur, R., NACA/ FAO, Bangkok, Thailand, 2001, p221-237.

Lukyanenko, V.I., Vasilev, A.S., Lukyanenko, V.V. and Khabarov, M.V. 1999. On the increasing threat of extermination of the unique caspian sturgeon population and the urgent measures required to save them. J. Appl. Ichthyol. 15: 99-102.

Matsuda Y. 2000, Recent development on stock enhancement in Japan, cited by Tahori, 1998, Aquaculture Department, Shilat, Tehran, Iran, No. 18. p73-109.

Moghim, M., Kor, D., Tavakolieshkalak, M. and Khoshghalb, M.B. 2006. Stock status of Persian sturgeon along the Iranian coast of the Caspian Sea. Journal of Applied Ichthyology 22: 99-107.

PDD, 2002. Annual report of Shilat, Shiat (in Persian), Tehran, Iran, 42p.

PDD, 2005. Annual report of Shilat, Shiat (in Persian), Tehran, Iran, 40p.

PDD, 2006. Annual report of Shilat, Shiat (in Persian), Tehran, Iran, 63p.

PDD, 2007, Annual report of Shilat, Shiat, (in Persian, unpublished),Tehran, Iran 6p.

Pourkazemi, M. 1999. Management and enhancement of sustainable resource. Aquaculture Department (in Persian), Shilat, Tehran, Iran, 18: 17-30.

Razavi Sayyad, B. 1995. Kutum, IFRO. (in Persian),Tehran, Iran, 165p.

Razavi Sayyad, B. 1999. Introduction to ecology of the Caspian Sea, Kutum, IFRO. (in Persian),Tehran, Iran, 90p.

Rosenthal, H., Pourkaxemi, M., and Bruch, R., 2006. The 5th International Symposium on Sturgeons: a conference with major emphasis on conservation, environmental mitigation and sustainable use of the sturgeon resources. Journal of Applied Ichthyology 22: 1-4.

Salehi, H. 1999. A strategic analysis of carp culture development in Iran. PhD.Thesis, University of Stirling. Stirling, UK, 328p.

Salehi, H. 2002. Economic analysis of kutum (*Rutilus frisii kutum*) fingerling production and release in Iran, (unpublished in Persian), 10p.

Salehi, H. 2004. An economic analysis of carp culture production costs in Iran. Iranian Journal of Fisheries Sciences, IFRO, Tehran, Iran, p1-24.

Salehi, H. 2005a. An economic analysis of trout farming production in Iran. World aquaculture 2005, May 2005, Bali-Indonesia. Unpublished, 35p.

Salehi, H. 2005b.An economic analysis of fingerling production of sturgeon in the south Caspian Sea over the years 2002-03. 5th International Symposium on Sturgeon, Ramsar, 9-13 May, Iran. p.319-324.

Salehi, H. 2006. Comparative economics of kutum (*Rutilus frisii kutum*) fingerling production and releasing over the 2001-2003 in North of Iran (submitted for Pajohesh and Sazandagi magazin), 13p.

Shang, Y. C. 1981. Aquaculture economics: Basic concepts and methods of analysis. Croom Helm Ltd. London. 153p.

Shang, Y. C. 1990. Aquaculture economics analysis: An introduction. Advances in world aquaculture. Volume 2. The world aquaculture society. USA. Louisiana State University. Baten Rouge. 211p.

Shehadeh, Z. H. 1996. Major trends in global aquaculture production and summary overview of the Gulfs (Persian Gulf and Gulf of Oman) area (1984 to 1994). TOFC Committee for Development and Management of the Fishery Resources of the Gulfs, Cairo, Egypt, 1-3 October, 8p.

Sreenivasan A. 1988. Fish stock enhancement in larger Indo- Pacific inland water bodies using carps and tilapias. FAO Fish. Rep. No. 405, p6-33.

Tahori B. H. 1998, Sturgeon hatching in South Caspian Sea. 7th National Fisheries Conferences. Responsible Fisheries (in Persian), Shilat, Tehran, Iran, p221-244.

The effects of feeding frequency on FCR and SGR factors of the fry of rainbow trout, *Oncorhynchus mykiss*

Nasrin Choobkar

Islamic Azad University, Kermanshah Branch, Iran

Economically efficient production of carnivorous fish requires the use of suitable feeds in quantities and frequencies that produce efficient growth, considering both biological performance and return on feed costs invested by the farmer. Standard measures for determing ration performance are specific growth rate (SGR), food conversion ratio (FCR) and also condition factor (CF = weight x 100 / length^3).

Production cost efficiency can be improved by monitoring these performance indicators and assessing the impact of alterations in feed, feeding and other management practices. I conducted a study to investigate the effect of feeding frequency on growth and feed utilization efficiency in rainbow trout. The experiment involved several different treatments with feeding frequencies of 4, 6 and 8 feeds per day. The research was conduced at Ghezelrood Aquaculture center, in Broujerd, Iran.

The aims of my research into the effects of feeding frequency were to:

- Estimate and compare condition factor (CF) between experimental treatments.
- Determine optimum feeding frequencies for growth of fish with consideration of feed expense points.
- Estimate and compare SGR and FCR between experimental treatments.

Differences in feeding rate can result from different temperatures, environmental conditions and life stage of fish. In this experiment, fry of rainbow trout of around 6±1 g in body mass were placed into compartments, with 400 fry stocked in each net and with three replicates of each treatment. The fish were fed with regard to feeding tables based on body mass and temperature. They were grown for a period of 71 days with biometric assessment conducted every two weeks, while anaesthatised with carnation (clove flower) oil at a concen-

Table 1. Average FCR of rainbow trout fry in different feeding frequencies.

Daily feeding frequency	Week 2	Week 4	Week 6	Week 8	Week 10	Total period
4 times	0.61	1.35	4.59	4.71	3.02	1.51
6 times	0.51	0.85	1.90	3.61	3.61	1.52
8 times	0.52	1.34	1.71	3.87	4.42	1.63
The results are mean ± SD(n=20). There was no statistically significant difference between treatments.						

Table 2. Average weight of rainbow trout fry in different feeding frequencies (g).

Daily feeding frequency	Week 2	Week 4	Week 6	Week 8	Week 10
4 times	10.2±1.03	15±2.32	21.5±3.53	27±3.12[b]	34.45±2.99[a]
6 times	10.8±1.10	16.2±1.55	22.3±2.05	28.8±2.23[a]	35.91±2.76[a]
8 times	10.7±1.24	15.6±1.72	21.1±2.39	26.2±2.77[b]	32.2±2.68[b]
The results are mean ± SD(n=20). Statistically significant differences between treatments (p<0.05) are designated by superscript within each column.					

Table 3. Average SGR of rainbow trout fry at different daily feeding frequencies.

Daily feeding frequency	Week 2	Week 4	Week 6	Week 8	Week 10	Total period
4 times	3.78	2.61	2.64	1.67	1.65	2.46[ab]
6 times	4.19	2.89	2.28	1.83	1.47	2.52[a]
8 times	4.12	2.70	2.15	1.55	1.38	2.36[b]
The results are mean ± SD(n=20). Statistically significant results between treatments (p<0.05) are designated by superscript within each column.						

Table 4. Average CF of rainbow trout fry at different daily feeding frequencies.

Daily feeding frequency	Week 2	Week 4	Week 6	Week 8	Week 10
4 times	1.05	1.01	1.31	1.20	1.21
6 times	1.16	1.24	1.39	1.34	1.18
8 times	1.24	1.08	1.33	1.23	1.06

tration of 6 g per 20 litres of water. The data was analysed using an analysis of variance statistical technique.

The results of my study showed that feeding six times per day led to the best results.

The minimum FCR occurred at feeding frequencies of 4 and 6 times per day, with fairly similar (statistically non-significant) overall results across treatments (table 1).

Statistically significant differences in average fish weight between treatments ($p<0.05$) were only detectable in weeks 8 and 10, towards the end of the experiment (table 2). The best results in terms of growth were obtained at a feeding frequency of 6 times per day. Feeding at 8 times per day lead to poor results, possibly because high feeding frequency led to greater energy expenditure in terms of movement, as the accessible food amount at any single feeding time was low, and some fish may have been unable to access food due to high competition.

Statistically significant differences ($p<0.05$) in SGR between treatments were observed over the full experimental period (table 3), but variation in bi-weekly samples during the course of the experiment were not significant. The highest SGR was at a feeding frequency of 6 times per day. No significant difference in CF was detected between any of the treatments (table 4), however, the best growth rates and most efficient FCR were achieved at a feeding frequency of 6 times per day.

A similar study on Channel catfish (Lovel 1989) found that feeding frequency did not have a significant difference on FCR, consistent with the outcomes of this experiment. However, Lovel (1989) also reported that feeding frequency did not significantly affect SGR, which is not consistent with this experiment. This may be due to the different species, different feeding behaviour and experiment conditions.

References

Church, D.C. and W.G. Pond. 1982. Basic animal nutrition and feeding.

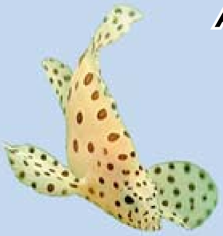
Kayano,Y.D., Jeong, S., Oda, T. and Nekagawa, H. 1990. Optimum feeding frequency on young red spotted grouper, *Epinephelus akaara*. Suisanzoshoku 38: 319-326(in Japanese,with English summary).

Kayano,Y., Yao, S., Yamamoto, S. and Nekagawa, H. 1993. Effects of feeding frequency on the growth and body constituents of young red spotted grouper, *Epinephelus akaara*. Aquaculture 110.

Mcdonald, P., Edwards, R.A. and Greenhalgh, J.F.D. 1973. Animal nutrition.

Mehrabi,Y. 1998. The effects of anaesthetic clove on Oncorhynchus mykiss. Abziparvar, Sixth year, 21.

SAS institute.1996. SAS users guide.SAS Institute Inc. Cary. NC.



Asia-Pacific Marine Finfish Aquaculture Network

Magazine

SKRETTING

The use of poultry by-product meals in pelleted feed for humpback grouper

Rossita Shapawi[1], Saleem Mustafa[1] and Wing-Keong Ng[2]

1. Borneo Marine Research Institute, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia;
2. Fish Nutrition Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Penang 11800, Malaysia.
E-mail: wkng@usm.my.

Introduction

Grouper farming, especially in South-east Asia, is still heavily dependent on feeding with trash fish. The demand for trash fish is increasing steadily despite decreasing prey fish stocks in the world's oceans and competing use for human consumption (Tacon et al., 2006). In order to sustain the rapidly expanding marine fish farming industry in Southeast Asia, more farmers are using commercial formulated feeds in the aquaculture of captive groupers. Currently available commercial feeds for tropical marine carnivorous fish are based on fish meal as the main dietary protein source. Total global fish meal production has remained relatively static over the past quarter century. This limited supply coupled with increasing demand for fish meal has greatly inflated the cost of this commodity. Therefore, finding suitable protein sources as alternatives to fish meal is critical in the commercial culture of carnivorous fish species, especially for fish such as the humpback grouper, *Cromileptes altivelis*, which require high protein (about 50%) in their diets (Williams et al. 2004). Groupers, especially slower growing species such as the humpback grouper, are highly valued fish, priced for their excellent meat quality and taste in the regional live fish trade.

Humpback grouper is a high value carnivorous tropical marine fish with farm gate prices of US$40 to 65 /kg in Malaysia. Retail prices are about US$90 /kg depending on size.

One potential fish meal alternative is poultry by-product meals (PBM) which are rendered by-products from the poultry processing industry. PBM are produced in many parts of the world, including the Southeast Asia region which accounts for approximately one-quarter of the global poultry trade (FAO, 2004). It has high potential to be incorporated in the diet of carnivorous fish species such as groupers due to its high protein content and lower price compared to fish meal. In addition, studies on the apparent digestibility of PBM revealed that this product is well-digested by several fish species (Bureau et al., 1999). Back in 1980s -1990s, PBM was only able to replace fish meal in fish diets at a level not exceeding 50%. Tremendous improvement has been achieved in recent years when PBM was reported to be able to replace fish meal at higher levels of up

Humpback grouper fingerlings are also highly priced in the marine ornamental fish trade due to their polka-dotted body and prominent fan-shaped pectoral fins.

Table 1. Growth performance and feed utilization efficiency of humpback grouper fingerlings fed PBM-based diets.

	FM	FPBM50	FPBM75	FPBM100	PPBM75	PPBM100
Final weight (g)	31.4a	31.3a	31.0a	26.7b	31.7a	30.5a
Weight gain (%)	150.4a	148.9a	154.3a	112.5b	156.7a	148.7a
Specific growth rate (%/d)	1.7a	1.7a	1.7a	1.4b	1.7a	1.7a
Total feed intake (g/fish)	20.7	22.5	22.5	21.5	22.6	20.8
Feed conversion ratio	1.1a	1.2a	1.2a	1.5b	1.2a	1.1a
Protein efficiency ratio	1.8a	1.7ab	1.6b	1.3c	1.7ab	1.7ab
Net protein utilization (%)	29.0bc	27.0c	31.6ab	18.1d	31.8a	31.1ab

Table 2. Nutrient composition of experimental diets (% dry matter).

	Diet					
	FM	FPBM50	FPBM75	FPBM100	PPBM75	PPBM100
Proximate Composition						
Moisture	11.3	11.5	11.4	12.1	11.6	11.6
Ash	14.0	13.4	13.4	13.2	14.4	14.7
Crude lipid	12.6	12.8	12.4	12.1	12.3	12.0
Crude protein	49.9	50.2	51.8	52.4	51.0	50.5
Crude fiber	0.5	0.8	1.5	1.8	0.8	1.3
Nitrogen free extract	23.0	22.9	20.9	20.6	21.5	21.6
Amino Acid composition						
Aspartic acid	4.43	4.13	3.90	3.66	4.00	3.63
Glutamic acid	8.55	7.88	7.48	7.51	8.03	7.49
Serine	2.12	2.52	2.55	3.05	2.04	1.95
Glycine	3.99	5.05	5.21	5.40	5.54	6.15
Histidine	1.11	1.22	1.11	1.16	1.26	1.32
Arginine	3.17	3.39	3.79	3.94	3.92	4.08
Threonine	2.26	2.25	2.17	2.25	2.07	1.99
Alanine	3.29	3.24	3.30	3.29	3.48	3.38
Proline	2.07	2.90	3.55	3.99	3.37	3.63
Tyrosine	1.01	1.27	1.22	1.38	1.23	1.16
Valine	2.70	2.73	2.92	3.02	2.59	2.39
Methionine	1.47	1.13	1.01	0.87	1.22	1.13
Cystine	0.37	0.71	0.79	1.08	0.55	0.56
Isoleucine	2.38	2.26	2.27	2.27	2.18	2.01
Leucine	4.03	3.92	4.01	4.05	3.83	3.61
Phenylalanine	2.16	2.33	2.18	2.39	2.06	2.10
Tryptophan	0.45	0.44	0.43	0.44	0.45	0.45
Lysine	3.96	3.25	2.99	2.72	3.45	2.99

to 100% (Nengas et al., 1999; Takagi et al., 2000; Gaylord and Rawles, 2005). The improved performance of PBM was mainly due to the improved quality of the product through the use of more advanced processing technology. We recently conducted a feeding trial using PBM of two origins (local vs. imported) and grades (feed vs. pet food) in the diets of humpback grouper at graded levels and compared with a fish meal-based diet (control diet) for the effects on growth, feed efficiency, body composition and nutrient digestibility.

Materials and methods

Six experimental diets were formulated to replace fish meal with PBM. Diet 1 (FM) was the control diet with Danish fish meal as the only protein source. Diets 2-4 were formulated to replace fish meal with a locally sourced feed-grade PBM (Dindings Soya & Multifeeds Ltd., Malaysia) at 50% (FPBM50), 75% (FPBM750) or 100% (FPBM100), respectively. In Diets 5 and 6, 75% (PPBM75) and 100% (PPBM100) of fish meal, respectively, were replaced by an imported pet food grade PBM [National Renderers Association (NRA), USA]. Chromic oxide (1%) was added to determine the apparent digestibility coefficient (ADC) of the diets. Humpback grouper fingerlings of mean initial body weight 12.41 ± 0.24 g were randomly distributed into groups of 15 fish in cylindrical cages (61 cm depth and 43 cm diameter; total of 18 cages), and placed in a 150-ton seawater polyethylene tank, supplied with aeration. The experimental diets were fed close to apparent satiation twice a day to triplicate groups of fish. The feeding trial was conducted for eight weeks.

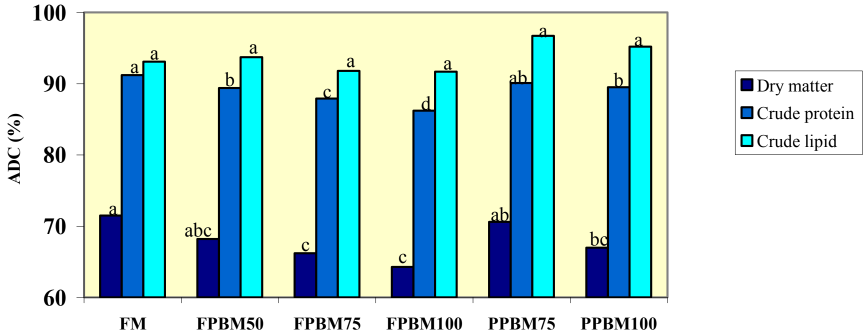
Upon completion of the feeding trial, remaining fish from the same treatments were pooled, divided into duplicate sets and transferred into 12 fiberglass tanks (300L) with a flow-through system. After one week acclimatization in the new culture system, feces were collected by carefully siphoning the tank bottom for diet digestibility determination.

Results and discussion

Good growth and survival rates of humpback grouper fingerlings were observed. Except for diet FPBM100 (replacement with 100% local PBM), all PBM-based diets performed as well as the control diet (Table 1). Feed conversion ratio (FCR) ranged from 1.1 to 1.5. No significant difference was detected in the total feed intake of fish fed the various experimental diets (P>0.05). The results demonstrated that a significant amount of fish meal can be replaced with PBM in the diet of humpback grouper without adverse effects on growth performance and feed utilization. In view of the high protein requirement of humpback groupers, the use of PBM will contribute significantly to cost-savings. In addition, humpback groupers are slow-growing species, which takes a longer time to reach marketable size compared with other grouper species. This longer culture period implies a higher requirement for feed input and cost of maintenance. Therefore, feed costs can be substantially reduced with the inclusion of greater quantities of PBM in the diets of humpback grouper and possibly in the diets of other tropical marine carnivorous cultured fish species.

The feeding trial was conducted at the Borneo Marine Research Institute in Sabah, Malaysia.

Figure 1. Nutrient apparent digestibility coefficient (ADC) of experimental diets



The amino acid composition of the PBM used was within the published values for this ingredient, and it influenced the overall amino acid composition of the experimental diets (Table 2). It was interesting to note that the cystine concentration in FPBM was about double that found in PPBM but the sparing value of cystine for methionine in grouper is currently not known. Both methionine and lysine appeared to be the limiting amino acids in the experimental diets with 100% PBM. The methionine concentration was 0.87 % in FPBM100 diet and ranged from 1.01 – 1.47 % in the other experimental diets. This might have contributed in part to the poor growth of fish fed diet FPBM100. Longer-termed feeding trials will be required to determine if a dietary methionine level of below 1% can support the normal growth of humpback grouper fingerlings. The quantitative lysine requirement for humpback grouper is currently not known. Compared to the control diet, the FPBM100 diet had markedly lower lysine content which was the lowest concentration among all the PBM-based diets.

The dry matter and protein ADC for the FPBM100 diet were the lowest among the various diets (Figure 1). This was probably the major contributing factor to the poor growth performance of humpback grouper fingerling fed this diet. High lipid ADC values were observed in all dietary treatments (91.7 – 96.7 %), and these values were not significantly different among dietary treatments. The better nutrient digestibility of the PPBM compared to FPBM allowed higher dietary levels of this ingredient to be included without noticeable growth depression. In conclusion, terrestrial PBM can successfully replace more than half of the protein from marine fish meal in the formulated diets for the humpback grouper, a marine carnivorous tropical fish. However, the use of PBM as the sole protein source in the diets of humpback grouper might be constrained by lowered nutrient digestibility and limiting essential amino acids, especially methionine and lysine. Further research with longer-term feeding trials is currently being carried out to evaluate the nutritive value of PBM for marine fish species.

The full results of this project were published in:

Shapawi, R., Ng, W.K., & Mustafa, S., 2007. Replacement of fish meal with poultry by-product meal in diets formulated for the humpback grouper, Cromileptes altivelis. Aquaculture 273, 118-126.

References

Bureau, D.P., Harris, A.M., Cho, C.Y., 1999. Apparent digestibility of rendered animal protein ingredients for rainbow trout. Aquaculture 180: 345-358.

FAO, 2004. EMPRES Transboundary Animal Diseases Bulletin No 25, January-June 2004.

Gaylord, T.G. and Rawles, S.D., 2005. The modification of poultry by-product meal for use in hybrid striped bass *Morone chrysops* x *M. saxatilis* diets. J. World Aquacult. Soc. 36: 365-376.

Nengas, I., Alexis, M.N., Davis, S.J. 1999. High Inclusion levels of poultry meals and related by products in diets for gilthead seabream, *Sparus aurata* L. Aquaculture 179: 12-23.

Tacon, A.G.J., Hassan, M.R., Subasinghe, R.P., 2006. Use of fishery resources as feed inputs to aquaculture development: trends and policy implications. FAO Fisheries Circular No. 1018. FAO. Italy, Rome, 99 pp.

Takagi, S.T., Hosokawa, H., Shimeno, S., Ukawa, M., 2000. Utilization of poultry by-product meal in a diet for red sea bream *Pagrus major*. Nippon Suisan Gakkaishi 66: 428-438.

Williams, K.C., Irvin S., Barclay, M., 2004. Polka dot grouper *Cromileptes altivelis* juvenile require high protein and moderate lipid diets for optimal growth and nutrient retention. Aquacult. Nutr. 10: 125-134.

Production update – marine finfish aquaculture in the Asia-Pacific region

Mike Rimmer, James Cook University

Correspondence: c/- Balai Budidaya Air Payau Ujung Batee, Banda Aceh, Nanggroe Aceh Darussalam, Indonesia.

Introduction

The Food and Agriculture Organisation of the United Nations (FAO) updates its statistics on global aquaculture production and value annually (www.fao.org). This article summarises recent changes in production trends for marine finfish aquaculture in the Asia-Pacific region based on these FAO data, which now cover the period up to 2006. Although the FAO data sets go back to 1950 (production) and 1984 (value), only the last 10 years' data are presented here.

Note: the data compiled by FAO are provided by the producer countries. In many cases the classification of aquaculture production is not reliable, particularly at species level (see the FAO web site for comment on the accuracy of the data sets). To reduce potential inaccuracies I have confined this analysis to fairly broad search criteria, or to well-known species. However, there are undoubtedly inaccuracies in the data sets; for example, Australian production of barramundi is classified as 'brackishwater' although most barramundi produced in Australia are farmed in freshwater ponds. Unless otherwise noted, data were sorted for: Countries: Continent = Asia & Oceania; Environments: Brackishwater and Mariculture.

Marine finfish

Production of marine finfish in the Asia-Pacific region increased 4.7% between 2005 and 2006, from 1,148,892 to 1,203,165 tonnes (Table 1). Overall value increased by 3.1%, from USD 4.09 billion to 4.22 billion from 2005 to 2006 (Table 2). The largest producer remains China, with 715,000 tonnes of production in 2006 valued at USD 734 million. Based on these data, China produces nearly 60% of total regional production, but this represents only 17% of total value, suggesting that much of Chinese production is of low-value species.

Figure 1. Value in USD millions (line) and production by country (columns) of milkfish (*Chanos chanos*) in the Asia-Pacific region, 1997 – 2006.

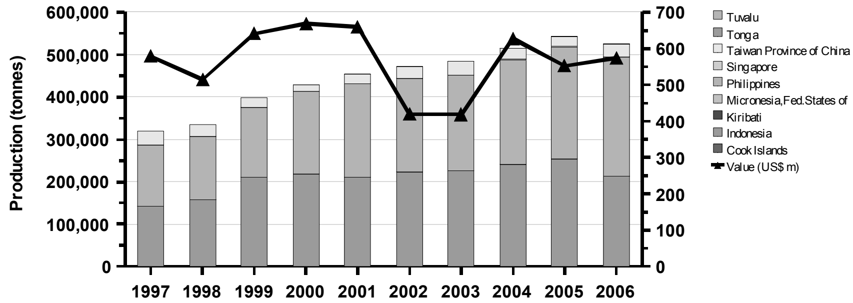


Figure 2. Value in USD millions (line) and production by country (columns) of barramundi (*Lates calcarifer*) in the Asia-Pacific region, 1997 – 2006.

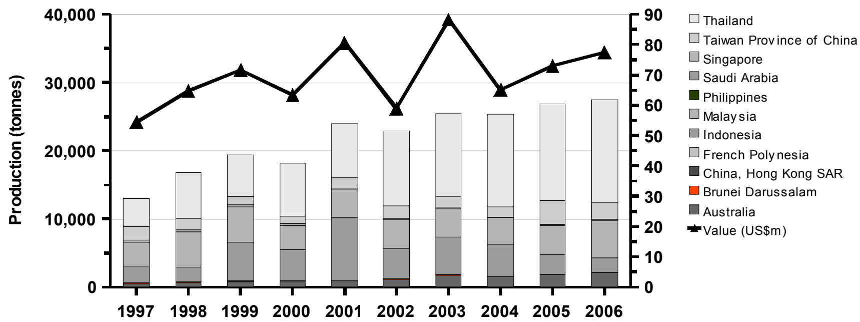
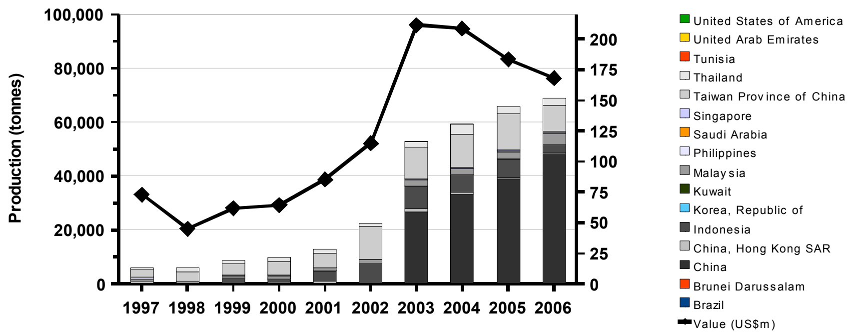


Figure 3. Global production value in USD millions (line) and production by country (columns) of groupers (Family Serranidae), 1997 – 2006.



Japan has the highest value of marine finfish production, with 246,000 tonnes of production valued at USD 1.97 billion. Japan's focus on producing high-value marine finfish is demonstrated by the fact that Japan produces around 20% of regional production, but the value of Japanese production forms 47% of the regional total. The bulk of Japanese production of marine finfish (~155,000 tonnes) remains the Japanese amberjack (*Seriola quinqueradiata*).

Production trends in some selected species

Milkfish

Milkfish (*Chanos chanos*) remains a popular commodity in Asia and the Pacific. Although production of milkfish decreased slightly from 542,842 tonnes in 2005 to 524,010 tonnes in 2006, value of production increased from USD 552 million to USD 574 million over the same period (Figure 1). Indonesia and the Philippines are consistently the largest producers of milkfish, with 94% of production in 2006. Milkfish is also cultured in the Pacific Islands (Cook Islands, Federated States of Micronesia, Kiribati, Tonga, Tuvalu) but total production from the Pacific is only about 13 tonnes.

Barramundi

Barramundi (*Lates calcarifer*) production stayed relatively steady at 27,522 tonnes, up slightly from 26,915 tonnes in 2005 (Figure 2) (note that these figures exclude production listed as from freshwater, which is a relatively minor component of total production). Thailand remains the largest producer of farmed barramundi with 55% of production. Total value of production increased slightly from USD 73.1 million to USD 77.5 million (Figure 2).

Grouper

Global production of groupers (Family Serranidae) increased from 65,714 to 69,074 tonnes from 2005 to 2006, an

Figure 4. Value in USD millions (line) and production by country (columns) of Japanese amberjack (*Seriola quinqueradiata*) in the Asia-Pacific region, 1997 – 2006.

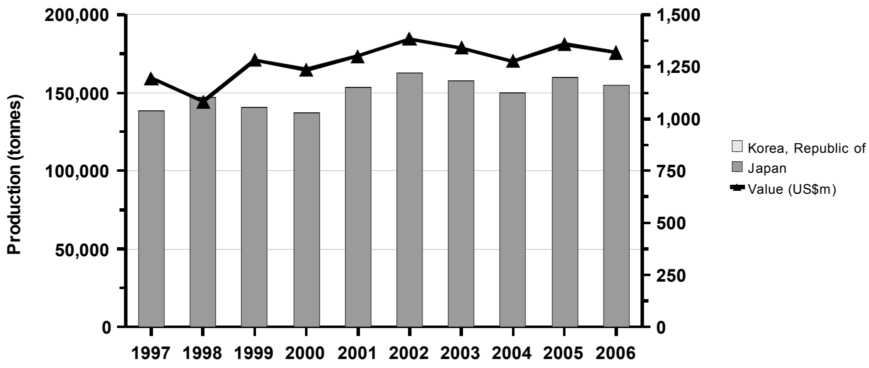


Figure 5. Value in USD millions (line) and production by country (columns) of cobia (*Rachycentron canadum*) in the Asia-Pacific region, 1997 – 2006.

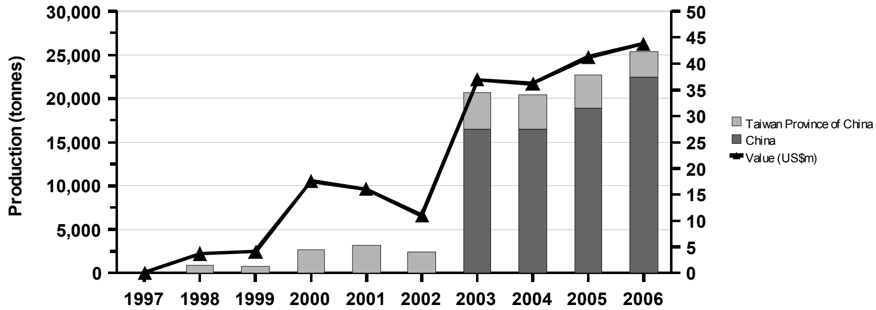


Table 1. Aquaculture production of marine finfish (tonnes) in the Asia-Pacific 1997 – 2006. FAO data by ISSCAAP Division: Marine Finfish; Countries: Continents = Asia & Oceania; Environments: Brackishwater & Mariculture.

Country (tonnes)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Australia	2,184	1,699	1,602	2,731	4,075	4,009	2,414	4,558	2,240	3,638
Bahrain	<0.5	1	3	12	<0.5	3	4	8	3	2
Brunei Darussalam	<0.5	<0.5	36	53	30	16	18	42	42	30
China	254,979	306,697	338,805	426,957	494,725	560,404	519,158	582,566	658,928	715,275
China, Hong Kong SAR	2,960	1,200	1,250	1,769	2,468	1,211	1,486	1,541	1,539	1,488
Cyprus	842	1,053	1,313	1,735	1,725	1,705	1,654	2,069	2,452	2,560
Fiji Islands	-	-	-	-	-	-	-	-	-	-
French Polynesia	.	2	<0.5	1	4	1	2	3	9	9
Guam	5	5	7	7	7	7	.	.	.	.
India	1,429	1,740	.	.	.	.	2,644	8,000	17,000	18,510
Indonesia	12,264	8,386	14,879	12,623	15,020	23,007	22,810	19,884	18,783	15,558
Israel	1,430	1,817	2,359	2,874	3,404	3,202	3,349	3,850	3,864	3,378
Japan	245,847	255,297	253,289	245,566	252,173	260,382	264,710	252,674	256,192	246,336
Korea, Republic of	39,121	37,323	34,382	27,052	29,297	48,073	72,393	64,195	80,861	88,604
Kuwait	154	150	176	346	179	179	164	100	142	11
Malaysia	2,706	2,266	3,092	5,645	5,165	5,570	7,369	7,704	8,451	12,081
Oman	-	13	-	-	-	-	352	503	168	89
Philippines	726	144	188	266	376	305	732	591	724	951
Qatar	2	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5
Saudi Arabia	<0.5	31	30	42	62	45	49	41	97	165
Singapore	205	210	295	421	259	181	226	396	579	689
Taiwan Province of China	13,511	15,373	14,558	15,518	17,450	26,715	29,553	26,925	25,192	20,964
Thailand	1,243	1,682	1,175	1,358	1,463	1,179	2,349	3,597	2,602	3,056
Turkey	13,800	18,810	23,000	33,337	28,485	26,020	37,717	47,442	68,454	69,201
United Arab Emirates	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2,300	570	570	570
Total	**593,408**	**653,899**	**690,439**	**778,313**	**856,368**	**962,214**	**971,453**	**1,027,259**	**1,148,892**	**1,203,165**

Table 2. Value of marine finfish production (USD millions) in the Asia-Pacific region 1997 – 2006. FAO data sorted for ISSCAAP Division: Marine Finfish; Countries: Asia, Oceania; Environments: Brackishwater, Mariculture.

Country (USD millions)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Australia	30	18	24	87	107	103	53	85	32	48
Bahrain	0	0	0	0	0	0	0	0	0	0
Brunei Darussalam	0	0	0	0	0	0	0	0	0	0
China	178	184	203	256	322	560	474	536	662	734
Hong Kong SAR	35	11	9	15	23	9	13	13	11	11
Cyprus	7	8	8	9	8	9	10	14	20	18
Fiji Islands	0	0	0	0	0	0	0	0	0	0
French Polynesia	0	0	0	0	0	0	0	0	0	0
Guam	0	0	0	0	0	0	0	0	0	0
India	1	1	0	0	0	0	3	7	18	20
Indonesia	21	14	28	26	34	58	99	61	23	15
Israel	20	21	28	21	22	17	18	21	21	28
Japan	2,141	1,878	2,082	2,020	2,058	2,102	2,103	2,001	2,044	1,968
Korea, Republic of	435	267	326	276	227	298	537	531	702	824
Kuwait	1	1	1	2	1	1	1	1	1	0
Malaysia	23	11	12	22	19	20	39	35	44	67
Oman	0	0	0	0	0	0	2	2	1	1
Philippines	7	1	1	1	2	1	2	3	3	5
Qatar	0	0	0	0	0	0	0	0	0	0
Saudi Arabia	0	0	0	0	0	0	0	0	0	1
Singapore	2	2	2	3	2	1	2	3	4	4
Taiwan Province of China	73	79	84	91	97	107	144	142	137	107
Thailand	9	9	8	9	9	6	12	22	14	17
Turkey	114	153	169	131	85	78	176	245	349	348
United Arab Emirates	0	0	0	0	0	0	7	4	4	4
TOTAL	**3,097**	**2,658**	**2,988**	**2,969**	**3,016**	**3,373**	**3,696**	**3,727**	**4,091**	**4,219**

increase of 5% (Figure 3). (Note that this analysis includes countries outside the Asia-Pacific region, however the bulk of production is from Asia-Pacific countries). China remains the largest producer of farmed grouper, contributing 70% of total production. The next largest producer is Taiwan Province of China, with 14% of production. Despite this increase in reported production, total value of production decreased by 9%, from USD 184 million to USD 168 million over the same period (Figure 3). Value for farmed grouper has been trending downward since 2003, possibly due to increasing supply of lower-valued cultured species.

Japanese amberjack

Although there is some production of Japanese amberjack from the Republic of Korea, the bulk of production is from Japan (Figure 4). Production has been relatively steady over the past 10 years, and decreased slightly from 159,741 tonnes in 2005 to 155,004 tonnes in 2006. Value also decreased slightly from USD 1.36 billion to USD 1.32 billion in 2005 – 2006 (Figure 4). The price of Japanese amberjack has remained steady at USD 8.50 per kilogram since 2001.

Cobia

Cobia (*Rachycentron canadum*) is an emerging species of considerable interest to farmers in the Asia-Pacific region. Presently, China and Taiwan Province of China are the only two countries in the Asia-Pacific region to report production of cobia. The apparent dramatic increase in cobia production in 2003 (Figure 5) is likely due to China beginning to report disaggregated production which had previously been reported as ‘marine finfish’ production. In 2005 – 2006, cobia production increased from 22,745 to 25,367 tonnes (Figure 5). Outside of the Asia-Pacific region, only Mayotte and Réunion reported production of cobia with a provisional figure of about 26 tonnes. Total value of production increased from USD 41.2 million to USD 43.8 million (Figure 5).

Conclusion

While marine finfish aquaculture continues to expand in the Asia-Pacific region, these data suggest that the rate of growth is beginning to slow. The growth in production (4.7%) was substantially below the 10-year average of 9.6% p.a. In contrast, the growth in value (3.1%) was closer to the 10-year average of 4.2% p.a. These data suggest that, overall, markets for marine finfish remain relatively buoyant despite increasing production.

Crustacean parasites and their management in brackishwater finfish culture

K.P. Jithendran*, M. Natarajan and I.S. Azad
*Central Institute of Brackishwater Aquaculture, 75 Santhome High Road, Chennai - 600 028, India.**
Email: kpjithendran@yahoo.com, Fax: +91-44-24610311.

Introduction

There are three main groups of parasitic crustaceans affecting commercially important aquaculture species, most of which are external parasites: the Branchiura, Copepoda and Isopoda. Members of the Branchiura and Isopoda are relatively large and both sexes are parasitic, while copepods, the most common crustacean parasites, are generally small to microscopic with both free living and parasitic stages in their life cycle. Male parasitic copepods die after copulation in the pre-adult stages, so those that are seen attached to fish are generally mature females with distinctive paired egg sacs at the posterior end. The crustacean parasites dealt here are primarily those that are likely to cause problems when commonly cultured fish species are grown in inland low saline or freshwater, though such studies are scarce in India. Under culture conditions, modified specificity is also exhibited by many crustacean parasites in that they will invade ‘unnatural’ hosts that are not normally present in their natural habitats.

Parasitic crustaceans are numerous and have worldwide distribution in fresh, brackish and salt waters (Figure 1). Usually they cause only minor harm to their hosts when present in small numbers. However, in case of heavy infections severe damage to skin, muscles, and gill tissue accompanied with secondary infections can occur. Parasitic crustaceans a great diversity of forms with marked structural modifications to suit their parasitic mode of life. These range from the typical features of normal copepods such as unfused abdominal segments and nearly full complements of appendages, to genera such as *Lernaea* (‘anchor worm’) in which the body segments are fused together and many of the appendages are missing or modified at least in parasitic stages. Generally, sensory organs and the reproductive systems are well developed. Sexes are usually separate with clear sexual dimorphism with predominant dwarfism among males. In branchiura the body is dorso-ventrally flattened with two pairs of antennae and pre-oral proboscis. The second maxillae are modified to form prehensile suckers (eg. Argulus).

Parasites

The common crustacean parasite species encountered in brackish water or low saline systems are given in Table 1.

Life cycle and transmission

Parasitic copepods have a complex life cycle with different larval stages; between each of which is a moult. Eggs hatch to release free-swimming nauplius larvae. After a succession of naupliar stages they moult to form copepodid stages. In primitive groups of parasitic copepods such as ergasilids, the copepodids are free swimming. Copulation occurs during the free-swimming stages, after which the male die. The female is left to seek, attach and mature on a marine or freshwater fish host with the help of the prominent claw like second antennae. In more evolved copepods such as the caligids some or all of the copepodid stages may be parasitic including adult males. Caligid copepods generally have direct life cycle, consisting of a free-living planktonic nauplius stage, free swimming infective copepodid stages, attached chalimus, pre-adults and adult stages. In case of *Lernaea* sp. the eggs released by the female hatch in 1-3 days with subsequent nauplii larvae. The nauplius metamorphoses into first or second copepodid stage in 4-16

Figure 1. Important crustacean parasites in brackishwater fish: *Lernanthropus* sp. and *Caligus* sp.

Table 1. Common crustacean parasitic infection in brackish water finfish in coastal and estuarine zones.

Subclass / family	Genus	Characteristics
Branchiura		
Argulidae	*Argulus* sp.	Body broad and flat covered anteriorly with dorsal shield with a pair of compound eyes, hooks and barbs, which it uses to attach to the fins, gills and skin of its host, second maxillae usually form prehensile suckers.
Copepoda		
Caligidae	*Caligus* sp. *Lepeophtheirus* sp. *Anuretes* sp.	Transparent, cephalothorax covered dorsally by a sub circular shield, with a pair of suckers on the frontal edge of the body and four pair of legs, vestigial abdomen in some species, found in large numbers on gills and body surface with different stages of life cycle in the same host.
Ergasilidae	*Ergasilus* sp.	Cephalothorax constituting half or more of body length, the second antennae are modified for clinging to the host, moderate to large numbers on gills with rigorous feeding action and movements.
Lernanthropidae	*Lernanthropus* sp.	Few in number but large in size, feed on gill tissues and blood, seriously damage the tissues.
Lernaeidae	*Lernaea* sp.	Body unsegmented, with its anterior part deeply embedded in host tissue with the help of a hold fast organ, infect nostril, skin, fin, gills, buccal cavity.
Isopoda		
Cymothoidae	*Cymothoa* sp.	Entire dorsal surface of body divided into many narrow segments, eyes are sessile, parasite immovably attached to surface, buccal or branchial cavity of fish.

days. No further development occurs unless it attaches to a host. Larvae pass through five successive copepodid stages before attachment. Copulation occurs during the fourth copepodid stage and the male dies similar to the *Ergasilus* sp. Although *Argulus* sp. cannot survive without a host for long period, they may swim freely looking for new host. Unlike other crustaceans, there is no sexual dimorphism; eggs are not carried by the females in egg sacs, but the parasite leaves its host to deposit its eggs on submerged objects. Larvae do not hatch as nauplii but as copepodid stage with thoracic appendages to follow a series of subsequent larval stages by progressive development of the dorsal shield and abdomen, the maxillary suckers and reproductive organs. Thus, transmission of parasites within the system is by physical contact with infected animals or by the free living infective stages after reproduction. Many species simply glide from one fish to other. Many parasites are transferred to culture system by way of water, live feed, wild fish, contaminated farm implements etc. Hence control methods may vary greatly depending upon the farm conditions, the type of parasites and its life cycle stages.

Parasites, clinical signs and effects

Branchiurans

Members of the family Argulidae represented by genus Argulus commonly called as ‘fish lice’ has a broad, flat oval body with hooks and barbs, which it uses to attach to the fins, gills and skin of its host. They are one of the most widespread and dangerous ectoparasites of freshwater and marine fish. They damage the fish directly by extracting blood and vital tissue fluids from the host with their modified mouthparts. The mode of feeding of Argulus involves secretion and injection of relatively large quantities of digestive fluids, which are toxic to the fish. The sting of one fish lice can kill a small fish. Feeding sites become hemorrhagic and ulcerated and provide access to secondary infections by other pathogens. Mucous is secreted when skin, fin and gills become infected.

Branchiuran parasites on fishes are usually found in the walls of the branchial cavity and not permanently attached to their hosts, but can crawl on their surfaces and can slowly swim leaving one fish to another. Sexual dimorphism is not marked. The only way to prevent *Argulus* infection is to deny parasites access to cultivable fish. Since both adults and larval stages are active swimmers, it is difficult to prevent them from entering the pond. Appropriate filter designs might prove more efficacious to check the degree of infestation.

Copepods

Caligus sp.

Caligus sp. or ‘sea lice’ are common copepod parasites in the family Caligidae, infesting a wide range of fish species in the coastal and estuarine zones although other lesser known fish species viz., *Lepeophtheirus* sp. and Anuretes sp. are have also been reported to be afflicted in the Indian subcontinent. Three species of *Caligus*, *C. epidemicus*, *C. orientalis* and *C. punctatus* are the potential major pathogens in the development of cage culture. *Caligus orientalis* seriously affects wild populations as well. When they first infect a farmed fish population they cause extensive irritation and nervous activity. Feeding on the fish skin, mucous and blood, these lice can cause small hemorrhages and sore, erode the skin and expose the underlying tissue to secondary infection. Caligid copepods have direct life cycle, consisting of a free-living planktonic nauplius stage, free swimming infective

Table 2 Common treatment against copepods in brackish water finfish.

Drugs / chemicals	Dose	Type of treatment, duration
Formalin	100-200 ppm	Short bath; 30-60 min
H_2O_2	1000 ppm	Short bath; 30-60 min
Dichlorvos	0.75 - 1 ppm	Short bath; 60 min
Caprylic acid	I mM	Short bath; 5-10 min

copepodid stages, attached chalimus, pre-adults and adult stages. In most cases, it is the attached chalimus stages that cause significant pathological lesions leading to mortality when present in large numbers. The pre-adult and adult stages are not very invasive and cause minor tissue damage. In disease situations, death is caused by the development of secondary infections exacerbated by stress, osmoregulatory failure and in the case of the gills, respiratory impairment.

The intensity of copepod infestation generally increases after rainfall and late spring and decline in winter and summer due to the lack of recruitment and parasite death. This is a major problem in cage cultured brackish water fishes but the economic impact of this disease is not known.

Ergasilus sp.

Ergasilid copepods are found on the body surface, gills and branchial and nasal cavities of many fish species including seabass, grouper, mullet, pearl spot, tilapia etc, where it feeds on the blood and epithelium. Heavy infestations can result in mechanical damage, patechial hemorrhage, impaired respiration, epithelial hyperplasia, and anemia with growth retardation. Severe gill damage is caused by the feeding activity of the copepod and this often leads to fish death. Proliferation of this parasite is observed in summer.

Lernanthropus sp.

This species is relatively large, reddish in colour, firmly attached to the gills, inflicts serous damage to the gills by way of erosion, desquamation and necrosis of the secondary lamellae near the site of attachment. The grasping action of the mandibles and the maxillae results in the exposure of blood vessels and hemorrhages. This serious pathogen is frequently encountered in many species of wild fish and cage cultured sea bass.

Lernaea sp.

Better known as the 'anchor worm', this species affects a large number of warm water fishes. Adults are visible to the naked eye. Although *Lernaea* is typically a freshwater copepod, it has been reported from brackishwater fish also. The parasite seems to have an affinity for the heart region of small fish and kills them by piercing the heart or other vital organs. The female lernaeidid copepod has long filamentous body with trailing attached eggs sacs. Morphological modifications include the head, which is a rounded knob inserted into the musculature of its fish host; one or two pairs of anchors to hold it in position. Damage to the fish host includes hemmorhagic and ulcerated lesions with potential for secondary infections, anemia, retarded growth, loss of weight and loss of equilibrium.

The destructive activity of *Lernaea* sp. is due to its relatively large size and its mode of attachment and feeding. As the maximum damage to the fish is caused by the adult parasite which remain attached to the host tissue with an anterior holdfast organ and also by the developmental stages that remain attached to the host, any reliable and effective prophylactic measures should aim at killing the free living stages of the parasites at nauplii and copepodid stages before it gets attached to the fish host. *Lernaea* is extremely difficult to control because only the free-living larvae are susceptible to treatment. The adult female produces three sets of eggs; these eggs produce larvae over a four week period. Since the larvae remain free living for about one week, it is necessary to treat once a week for four weeks to eliminate this parasite.

Isopods

Cymothoa sp.

This cause serious problem in fishes kept in captivity or cages. Isopods are large parasites of wild tropical marine fish and rarely found in other culture of crustacean organisms (*Macrobrachium* sp., *Peneaus monodon*) in coastal freshwater or on brackishwater fishes inhabiting freshwater. They have a short free-living planktonic phase; juveniles and adults are exclusively parasitic living on the skin, buccal cavity and gill chamber of the fish (eg. *Cymothoa*). The damage caused by them resembles that of other copepods but the most serious effect of isopod infection is destruction of host tissue resulting from the pressure of the parasites body. No specific control or therapeutic measures against isopods have been in practice except the manual removal of the parasite and by implementing optimum management practices during culture as infection by the planktonic phase is the common feature.

Diagnosis and management

Diagnosis is usually done by gross and microscopic examination of scrapings from skin, gills, fins etc. from affected fishes and by observing general clinical symptoms. Pre-disposing factors for transmission of crustacean parasites are poor water exchange and thus sufficient water exchange can prevent their proliferation. Modification of husbandry practices can be a very effective method to reduce the magnitude of infection. Application of husbandry practices to control the abundance of parasitic copepods requires a good knowledge of their biology (eg. growth rates, duration of survival of infectious stages off-host etc.) and host range. Routine disease management measures such as reducing stocking density and water quality management are likely to reduce the impact of parasitic copepods. It is well recognized that a few unhealthy / stressed animals are more susceptible to infection and harbour the majority of the parasites. In pond culture, overcrowding and poor water quality has been cited as factors responsible for the development of parasitic copepod diseases. The important management techniques to be followed are, rearing different batches in separate tanks, pond drying, removal of all probable hosts from the stocking sites prior to stocking so that all infectious stages die due to lack of hosts, quarantine prior to stocking and introduction to the rearing system and frequent cleaning of holding tank/nets. The parasites can be controlled by fresh water bath for 10-15 min or by chemical treatment using 1000 ppm hydrogen peroxide or 100-200 ppm formalin for 30-60 min. Some of the treatments commonly applied in brackishwater fishes are shown in Table 2. Strong aeration must be provided during treatment. Drying of unused tanks also helps to destroy the developing stages. Treated fish should be transferred to clean parasite free facility.

It is well recognized that parasites act as mechanical vectors of the pathogens though they are not an obligatory host. It is likely that any fluid or tissue feeding parasites could potentially act as a vector for bacteria, fungus, virus etc. It has been speculated that parasitic copepods may serve as vectors of viral and bacterial diseases of fish due to their feeding activities on host mucous, tissues and blood.

Parasitic copepods with relatively narrow host ranges such as Ergasilus are easier to control especially, where there are few wild hosts present. Species with broad host ranges and / or abundant wild hosts (eg. *Caligus* sp.) in the vicinity of aquaculture sites are generally difficult to control because of recurrent infestations from carrier hosts. *Lernaea* sp. is very difficult to control due to different stages of life cycle showing different susceptibility to chemicals. Further the concentration of these chemicals required to kill the developmental stages are toxic to fish. Temperature dependant development of larval stages and the lethal effects of even low salinity on larval stages etc. can be utilized for the control of fresh infections in the system. Eradication of copepods using freshwater bath is also suggested.

Conclusions

Crustacean parasites are numerous and have a worldwide distribution in marine and brackishwater aquaculture systems. Copepods comprise the largest group of crustacean parasites on fish causing economical loss. Disease outbreaks and subsequent mortalities are rare under effective broodstock management systems due to effective treatment methods. However, increasing incidence of copepod parasitism is becoming a regular phenomenon in culture conditions. The only sure way to prevent parasitic infection is to deny the parasite access to the protected habitat. Although it is well established that parasitic crustaceans have a major impact on brackish water aquaculture there are relatively few published reports of disease and / or disease treatments and economic losses associated with these infections in India. We need to study the ecology of the parasite, including seasonality, maturation and the population dynamics and transmission mechanisms vis-à-vis physicochemical parameters of the rearing water in order to prevent and control the outbreak of the species in brackish water aquaculture.

References

Heckmann, R. (2003). Other ectoparasites infesting fish; copepods, branchiurans, isopods, mites and bivalves. Aquaculture Magazine, Nov/Dec. 2003. pp. 20-31.

Ho, J. S. (2000). The major problems of cage aquaculture in Asia relating to sea lice. In I.C. Liao, C.K. Lin, eds. Cage aquaculture in Asia: Proceedings of the First International Symposium on cage Aquaculture in Asia. Manila: Asian Fisheries Society, and Bangkok: World Aquaculture Society. Southeast Asian Chapter, pp 13-19.

Johnson S.C., Treasurer J.W., Bravo, S., Nagasawa, K. and Kabata, Z. (2004). A review of the impact of parasitic copepods on marine aquaculture, Zoological Studies, 43: 229-243.

Kabata, Z. (1985). Parasites and diseases of fish cultured in the tropics. Taylor and Francis Ltd., 4 John St. London. p 316.

Nagasawa, K. (2004). Sealice, *Lepeophtheirus salmonis* and *Caligus orientalis* (Copepoda: Caligidae) of wild and farmed fish in sea and brackishwaters of Japan and adjacent regions: A review. Zoological Studies, 43: 173-178.

Nagasawa, K. and E.R. Cruz-Lacierda (eds.) (2004). Diseases of cultured groupers. Southeast Asian Fisheries Development Center, Aquaculture Department, Iloilo, Philippines.81.p.

Pillai, N.K. (1985). Fauna of India. Parasitic copepods of marine fishes. Technical and General Press, Calcutta, 900 pp.

Prabha, C. and Pillai, N.K. (1986). Additions to the copepods parasitic on the marine fishes of India 4. On twenty six species of caligids. Rec. Zool. Surv. India, Occas. Pap. 79: 1-139.

Rajkumar, M. Perumal, P. and Trilles, J.P. (2005). *Cymothoa indica* (Crustacea, Isopoda, Cymothoidae) parasitizes the cultured larvae of the Asian seabass *Lates calcarifer* under laboratory conditions, Disease of Aquatic Organisms, 66: 87-90.

Roberts, R.J. (2001). Fish Pathology. Third edition, W.B. Saunders London. P. 472. SEAFDEC (2001). Health management in Aquaculture, (eds. Gilda Lio Po, Celia R. Lavilla and Erlinda R Cruz-Lacierda), SEAFDEC, Philippines. pp. 55-73.

Thirunavukkarasu, A.R., Mathew Abraham and Kailasam, M. (2004). Hand book of seed production and culture of Asian seabass, *Lates calcarifer* (Bloch). Bulletin No. 18. p.58.

Lao PDR...from page 31.

Ounidate, Khometun & Parsirth (1993). Technical report on the aquacultue of *C.molitorella* in Luang Prabang. Living Aquatic Resource Research Center, Vientiane, Lao PDR.

Pennapaporn, P. (1970). The culture of pla-ka, *Morulius chrysophekadion* (Bleeker) with common carp, *Cyprinus carpio* Linn. in ponds. Annual Report 1970. Pond and Experiment Culture section. Aquaculture Unit, Inland Fisheries Division. Department of Fisheries. 133-141 pp.

Somboon, Souksavath, O., Amphone, Soulignamath, P., Khamsivilay, L. & Saphakdy, B. (2003). Nursing *Cirrhinus molitorella* in the earthen ponds with four different stocking densities. In Proceedings of the Fifth Technical Symposium on Mekong Fisheries, 11-12 December 2002 (Poulsen, A. ed., pp. 155-158. Mekong River Commission Phnom Penh.

Souksavath, O. (2001). Report on nursing of *Cirrhinus molitorella* in ponds and cages, Luang Prabang, Lao PDR. Internal report. LARReC, Vientiane, Lao PDR.

Thavonnan, W. & Udomkananat, K. (1979). Culture of black shark in earth ponds for growth rate Annual report 1979. Kanchanaburi Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 51-57.

Thienchareon, P., Ounsrisong, G., Jittakorn, A. & Sriwatanawarunyu, S. (1990). A study on production of *Morulius chrysophekadion* grown in earthy ponds. Annual Report 1990. Chiangmai Inland Fisheries development Center. Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 100-113 pp.

U-domkananat, K. (1983). A study on production and stocking rate of Pla Ka Dum (*Morulius chrysophekadion*) and Pla Svay (*Pangasius sutchi*). Annual Report 1983 Kanchanaburi Inland Fisheries Station, Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 23-26 pp.

Unsrisong, K., Jittakorn, A., Sriwatanawarunyu, S. & Thienchareon, P. (1990). A culture of *Morulius chrysophekadion* (Bleeker) spawners in earthy ponds. Annual Report 1990. Chiangmai Inland Fisheries Research Center. Inland Fisheries Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. 86-99 pp.

Warren, T.J. (2000). Indigenous Mekong Fish Species with Potential for Aquaculture, Stocking or Translocation. Management of Reservoir Fisheries in the Mekong Basin II, Vientiane. 92 pp.

NACA Newsletter

ISSN 0115-8503

Published by the Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand

Volume XXIII, No. 3
July-September 2008

Participants in the Beijing workshop on development of aquaculture certification guidelines.

Aquaculture certification guidelines development process continues in Beijing, Washington D.C.

The final two workshops on the development of international guidelines for aquaculture certification have been held in Beijing, China, 6-8 May and Silver Springs, USA, 30 May 2008. The workshops, hosted by the Government of China and the Government of the United States respectively, are the final meetings in a series of six international expert consultations intended to build consensus and gather technical input for the development of the guidelines. Previous consultations have been held in Thailand, Brazil, India and the UK.

The Beijing workshop was conducted as a joint initiative of FAO, NACA, the Chinese Academy of Fishery Sciences and Department for Certification and Accreditation Administration of China. It brought together 65 participants, including several experts and stakeholders in aquaculture from China, and regional/international experts from FAO, NACA and SEAFDEC, from government agencies, private business, and experts involved in certification schemes and food safety. This workshop had a strong emphasis on aquaculture products from China, and looked at opportunities and challenges for implementing the certification guidelines in China towards improving aquatic production and trade of aquaculture products nationally, regionally, and globally. Many useful observations were made on the status and implementation of certification schemes for aquaculture products in China, and the outcomes provide important inputs to the process of development of the international guidelines and strategies for implementation of aquaculture certification.

The Silver Springs workshop similarly provided the opportunity for input and open discussion among interested stakeholders. This workshop focused mainly on the North America region (USA and Canada) as a major global seafood market with many diverse stakeholders in certification in aquaculture. This workshop provided the opportunity for dialogue between the secretariat, producing country representatives, and stakeholders in the North American seafood supply chain. The workshop assessed the status, opportunities and mechanisms for enhanced partnerships within supply chains to support change, and as may be necessary, to assist aquaculture certification in producing countries. The workshop also reviewed the most recent version of the draft aquaculture certification guidelines.

The draft guidelines

The draft guidelines that have emerged cover the range of potential issues which may be considered relevant for the certification in aquaculture production including: animal health and welfare, food safety and quality, environmental integrity and social responsibility associated with aquaculture. The draft guidelines address the development of standards, accreditation and associated certification procedures.

Next steps

The next step in the consultation process will be to draft aquaculture certification guidelines will be presented by FAO to its member governments for discussion and consideration at the upcoming Fourth Session of the COFI Sub-Committee on Aquaculture, to be held in Puerto Varas, Chile in 6-10 October 2008.

More information

For more information about the workshops and the development of the guidelines please refer to the links below or contact koji@enaca.org.

The draft international guidelines on aquaculture certification (version 4.2):

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=166&lid=945.

Summary of the consultation process for development of the guidelines:

- http://www.enaca.org/modules/tinyd10/index.php?id=1.

The report and presentations from the Beijing workshop:

- http://www.enaca.org/modules/tinyd11/index.php?id=20.

Key documents and presentations from the Silver Springs workshop can be downloaded from:

- http://www.enaca.org/modules/tinyd11/index.php?id=21.

Development of BMPs for catfish farming in Vietnam – survey of management practices

A comprehensive survey of management practices in the catfish farming sector is planned in support of the project *Development of Better Management Practices for Catfish Aquaculture in the Mekong Delta, Vietnam.* The project team has just spent a week in the delta developing and testing a set of questionnaires, including survey forms for hatchery, nursery and grow-out farms.

During the visit our project team conducted field trials to test the draft questionnaires painstakingly developed during a previous field visit from 11 to 16 May 2008. We found that the questionnaires still needed some modification in light of field conditions, but happily the cooperation of the farmers was excellent; they were eager to share information and spent hours discussing with us the highs and lows of catfish farming and their perceptions on the way forward.

We also had opportunity to meet and hold discussions with provincial aquaculture authorities with regard to future collaboration in promoting the adoption of better management practices. Overall, many parts of the industry seemed very knowledgeable about the concerns of the overseas markets in terms of BMP related issues such as traceability, pollution, use of chemicals and related disease treatments. This high level of awareness/understanding would seem to bode well for the understanding of BMPs and their uptake in Vietnam. We also learnt that government at various levels (district, province and national) must be an integral part of the process of BMP development and implementation in order to reach an acceptable co-management arrangement.

At a relatively large farm in Vinh Long province we were fortunate to observe Tesco Lotus representatives negotiating directly with the farmer. Larger processors seem to be aiming for a more vertically integrated approach as many are now starting grow-out operations to complement the processing operations. Some are even intending to also include hatchery and nursery operations. A variety of market/value chain links seem to be forming and a market chain analysis will be an important supporting component of the BMP project.

The team hopes to complete the survey of existing management practices by early August 2008, and the analysis by the end of September. Data will be presented at a national workshop for development of BMP interventions, which will be then field tested through selected demonstration farms in early 2009.

A video of the feeding of catfish is available at:

- http://www.enaca.org/modules/news/article.php?storyid=1752

Please see the project web page for an overview of the project's activities and regular updates on progress:

- http://www.enaca.org/modules/inlandprojects/index.php?content_id=1

Report by Thuy Nguyen on behalf of the project team which includes personnel of Fisheries Victoria (Department of Primary Industries, Victoria, Australia), NACA, the Research Institute for Aquaculture No. 2 and Can Tho University.

NACA extends cooperation with ADB for tsunami rehabilitation in Indonesia

NACA has extended its cooperation with the Asian Development Bank for assistance to rehabilitation of the fisheries sector in the Special Province of Nanggroe Aceh Darussalam through the ADB Earthquake and Tsunami Emergency Support Project (ETESP) Fisheries Component. The Director General of NACA signed a new contract with the Asian Development Bank on 11th March that will extend the services of NACA until January 2009. The new package will assist the Rehabilitation and Reconstruction Agency for Aceh and Nias (BRR) to complete ongoing fisheries sector rehabilitation work, and extends the scope of the services with additional assistance with aquaculture and fisheries training, policy formulation and development of livelihood centres.

To date, the NACA assistance in Aceh and Nias has reached over 20,000 coastal farmers and fishers, men and women, and their families. The new package will enable this support to be continued, but with more emphasis on capacity building and development of services to lay a foundation for longer-term recovery and growth of the fisheries sector in Aceh and Nias.

International hands-on training programme on molecular biology techniques

Fish Genetics and Biotechnology division of CIFA is contemplating to organize a hands-on training on molecular biological techniques, which would cover all the basic and essential techniques Researchers interested in molecular biology need to experience the many ways in which research is conducted in this field, and the hands-on nature of the molecular biology techniques course is an effective way to introduce them to these methods. Thus the present training is expected to serve effectively the researchers working in the area of fish genetics and biotechnology. The hands-on training programme would be conducted at CIFA, Kausalyaganga, Bhubaneswar, Orissa state, India during 13th – 27th October 2008 (tentative). A maximum of ten participants will be trained on a first-come basis. This training is suitable for researchers, scientists, government officials, teachers and students working in the field of Aquaculture/Life Sciences/genetics/biotechnology. For a brief overview of the course contents, visit the link below or contact Dr Kuldeep Kumar, Senior Scientist in charge of Anabas, Murrel and Pearl units, CIFA, Phone: 91-674-2465446, Ext-320, 2465421, fax: 91-674-2465407 or email kuldeepkumar_kk@yahoo.co.in.

Cage aquaculture carrying capacity tool now available

A Cage Aquaculture Decision Support Tool (CADS_TOOL) is now available from the Australian Institute of Marine Science website. CADS_TOOL is a decision support system for cage aquaculture managers, developed by Dr. Halmar Halide. CADS_TOOL is coded in Java and designed to run on any computer platform. The objective of this software is to:

- Classify a site.
- Select the best site from several site alternatives.
- Calculate the sustainable holding density of a chosen site.
- Perform a basic economic appraisal of a site.

CADS_TOOL was first demonstrated at the workshop Modeling carrying capacity for tropical finfish cage culture: towards a consensus view, held in Lampung, Indonesia, in November 2007. This workshop was funded by the Australian Centre for International Agricultural Research (ACIAR), and convened by the Network of Aquaculture Centres in Asia-Pacific (NACA) and the Directorate General of Aquaculture of Indonesia.

This workshop aimed to demonstrate and compare models developed for the estimation of the sustainable development of finfish cage culture in the Asia Pacific Region, and to develop a consensus view of how to best implement such models and make recommendations for best management practice. The workshop identified a number of models currently used to calculate carrying capacity. Two of these are of particular relevance to the Asia Pacific region:

- TROPOMOD, a tropical extension of the temperate models DEPOMOD and MERAMOD, developed under PHILMINAQ.
- CADS_TOOL (Cage Aquaculture Decision Support Tool), developed under ACIAR project FIS/2003/027.

Workshop participants identified that there is a regional need for development of carrying capacity models, and suggested that ongoing work should be broadened to include study sites in two or three countries.

CADS_TOOL was developed as part of the Australian Centre for International Agricultural Research (ACIAR) project FIS/2003/027 Planning tools for environmentally sustainable tropical finfish cage culture in Indonesia and northern Australia. This project is a collaboration between the Australian Institute of Marine Science, (Dr. David McKinnon) and the Research Institute for Coastal Aquaculture, Maros, South Sulawesi, Indonesia (Dr. Rachmansyah). Dr Halmar Halide was employed by this project at the Australian Institute of Marine Science, and has now returned to Hasanuddin University, Makassar.

The CADS Tool can be downloaded from: http://data.aims.gov.au/cads/

Participants in the 6th grouper hatchery training course.

6th Regional Grouper Hatchery Production Training Course completed

A total of 19 participants from 10 countries attended the 6th Regional Grouper Hatchery Production Training Course from 5-25 May 2008 in BADC Situbondo, Indonesia. These participants came from Australia, Hong Kong SAR (China), Indonesia, India, Iran, Malaysia, Oman, Thailand, Trinidad and Tobago and Vietnam. The training course was officially opened by Dr Made L Nurdjana, Director General for Aquaculture, Directorate General for Aquaculture. The opening ceremony also attended by the Head of the Situbondo District Fisheries, and the Head of the East Java Provincial Fisheries.

The training course was a success, participants were able to conduct hands-on activities from egg harvest to larviculture. Field trips to hatchery, nursery and grow-out of grouper and marine finfish were organized to enable participants to have a broader understanding of the overall marine finfish operation in Indonesia.

InterVet provided support to the training course by sending Dr Cedric Komar, Technical Manager, to provide lectures on health management in marine aquaculture to participants.

In additional to providing the scholarships for the training course, Skretting sent its Technical Manager from the Marine Hatchery Feeds Division, Mr Nick King, to provide presentations and demonstrations of rotifer culture, rotifer and Artemia enrichments for the training course.

2008 Forum on Fisheries Science and Technology, 25-27 September 2008, Shanghai, China

The Chinese Academy of Fishery Sciences will convene the Forum on Fishery Science and Technology in Shanghai, China in September. The purpose of the forum is to provide a high-level platform for scientists in China as well as around the world to exchange their newest research fruits, to share their experiences and achievements in the development of fisheries and aquaculture with other countries. The forum has been supported by many fisheries and aquaculture scientists all over the world since 2003 and played an important role in promoting the development of fishery science and technology.

The theme of the 2008 forum is Sustainable Development and Ecological Safety of Fisheries, and will focus on the following areas:

- Aquaculture carrying capacity and ecological balance
- Ecological environment adjustment and restoration
- Eco-friendly fishing gear
- Rational exploitation and management for fisheries resources
- Seed source and germplasm improvement for aquaculture
- Food safety and fishery ecology

For more information about the forum, including registration details, download the from: http://library.enaca.org/announcements/cafs-forum-2008.pdf.

Aquaculture success stories 'write shop'

Following the recommendations of the Workshop on Research Needs to Sustaining Aquaculture to 2025 and Beyond, June 2007, held in Rayong, Thailand (sponsored by IDRC Canada), NACA, the International Institute for Sustainable Development (IISD) and the World Fisheries Trust (WFT) will document "Aquaculture Success Stories" covering a wide range of topics that were established through consensus at the Rayong Workshop.

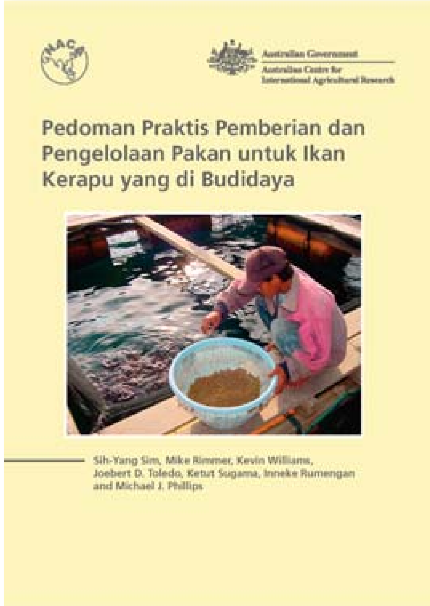
As aquaculture seeks to move to a more sustainable future and meet the challenges of globalization, it is important to consider how the lessons of the past may guide future development. The documentation and comparative analysis of success stories is the first step in this process. This activity is intended to capture the trends and lessons learned that have driven the rapid evolution of aquaculture (augmented with comparable cases on small scale fisheries). The success stories will form part of the strategy for guiding further actions intended to influence policy development and set a new course for the sustainable development of aquaculture.

Our plans include the development of a series of 'influencing strategies' to share the lessons learned from the documentation and analysis of the success stories. This will include the production of a variety of materials tailored to reach out to the identified target audiences and decision makers and active, targeted dissemination.

The success stories will be prepared at a "write shop" to be conducted from 22-27 September in Thailand. Arrangements are being made to liaise with selected experts in the region to cooperate in this activity, and it is expected the initial phase of the activity to be completed in the course of 2008.

For more information about the write shop, contact sena.desilva@enaca.org. The report of the June 2007 Rayong workshop, which serves as background material, is available for download at: http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=189&lid=902.

Bookshelf: New publications for free download



Marine finfish aquaculture publications translated into Bahasa

Two of NACA's most popular marine finfish publications are now also available in Bahasa Indonesia:

A Guide to Small-scale Marine Finfish Hatchery Technology (Panduan Teknologi Hatcheri Ikan Laut Skala Kecil)

This guide provides an outline of the requirements to establish a small-scale marine finfish hatchery, particularly the economic aspects. It is intended to provide sufficient information for potential investors to decide whether investment in such ventures is appropriate for them. The guide provides some basic technical information in order to give an indication of the level of technical expertise necessary to operate a small-scale marine finfish hatchery. However, it is not intended as a detailed technical guide to the operation of small-scale hatcheries. Additional resources, such as training courses in marine finfish hatchery production, are available and these are listed in this document. This guide has been written by a team of experts in marine finfish aquaculture who have been involved in a multinational collaborative research project since 1999. Development of small-scale hatcheries may be more appropriate where there are existing marine hatchery operations, e.g. for shrimp or milkfish. By definition, small-scale hatcheries do not have broodstock facilities, so a supply of fertilised eggs (usually from a larger hatchery) is essential. Access to fertilised eggs and experienced hatchery staff will limit the application of small-scale hatchery technology. Despite this, there is considerable potential for this technology to be widely adopted. Download from:

http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=75&lid=582.

A Practical Guide to Feeds and Feed Management for Cultured Grouper (Pedoman Praktis Pemberian dan Pengelolaan Pakan untuk Ikan Kerapu yang di Budidaya)

Groupers are carnivorous and consequently prefer feeds high in fish protein. Most farms in Asia still rely on what is commonly termed 'trash fish'. Despite the apparent abundance and availability of 'trash' fish in many areas, there are some issues and problems related to its use in fish farming. To provide farmers with a viable alternative to feeding trash fish to grouper, the Australian Centre for International Agricultural Research (ACIAR) supported project FIS/97/73 Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region from 1999 to 2002, with one component to develop formulated feed for grouper aquaculture. The experiences of the project have been synthesized into this Practical Guide to Feeds and Feed Management for Cultured Groupers to promote the use of formulated feeds; promote reduction in the use of 'trash' fish in grouper aquaculture; and to assist farmers in making more efficient use of feeds and feed resources. This guide explores new and better farming practices making use of formulated feeds, as well as technical aspects of feed storage and quality control, management of feeding including weaning of groupers onto formulated feeds and economic considerations. Download from:

http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=77&lid=583.

Vietnamese translation of culture-based fisheries book

ACIAR and NACA are pleased to make available a Vietnamese translation of the book "Better Practice Approaches for the Development of Culture-based Fisheries in Asia". The book is also available for download in English and Lao (see the link below).

The primary objective of this manual is to provide guidelines for attaining better-practices in culture-based fisheries, an emerging practice in rural areas in the Asian region. It deals will the principles of culture-based fishery practices, primarily based on relatively long-term experiences in Sri Lanka and Vietnam. It is not only targeted at researchers per se, but also at stakeholders at the grass root levels, as well as planners and policy developers, particularly those of Asian nations embarking on culture-based fisheries as a strategy to enhance fish food production in rural areas. As such, the manual does not deal with the dynamics and interactions of stocked populations. It deals with the gross factors that are applicable to improving fish yields and therefore revenue; and sustaining culturebased fisheries as a development activity in the long-term. The manual addresses the constraints to culture-based fisheries development in the region, and provides guidelines on ways and means of overcoming such constraints. Download from:

http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=193&lid=944.

New free publications from FAO

FAO has released several great new publications for free download this quarter. Download them from the links below:

Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper No. 505, edited by Mohammad R. Hasan, 205p. Download from:

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=941.

Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper No. 501, edited by Melba G. Bondad-Reantaso, 2007, 628p. Download from:

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=930.

Comparative assessment of the environmental costs of aquaculture and other food production sectors. FAO Fisheries Proceedings No. 10, Edited by Devin Barley, Cecile Brugere, Doris Soto, Pierre Gerber and Brian Harvey, 2007, 241p. Download from:

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=200&lid=927.

Study and Analysis of Feeds and Fertilizers for Sustainable Aquaculture Development. FAO Fisheries Technical Paper 497, Edited By Mohammad R. Hasan, Thomas Hecht, Sena S. De Silva, Albert G.J. Tacon, 2007, 507 pp. Download from:

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=925.

Assessment and communication of environmental risks in coastal aquaculture. GESAMP (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Environmental Protection) 2008, Rome, FAO. Reports and Studies GESAMP No. 76: 198 pp. Download from:

- http://www.enaca.org/modules/wfdownloads/singlefile.php?cid=73&lid=943.

Network of Aquaculture Centres in Asia-Pacific

Mailing address:
P.O. Box 1040,
Kasetsart University
Post Office,
Ladyao, Jatujak,
Bangkok 10903,
Thailand

Phone +66 (2) 561 1728
Fax +66 (2) 561 1727
Email: info@enaca.org
Website: www.enaca.org

NACA is a network composed of 17 member governments in the Asia-Pacific Region.