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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.

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Mariculture: The new hot topic

When we first started analysing our website logfiles about four years ago it was apparent from the statistics on what pages visitors read the most that shrimp farming was the flavour of the decade in the aquaculture world. However, over the last two to three years we have seen interest in shrimp farming tail off after many countries switched into cultivation of *Penaeus vannamei* and as increasing production levels impacted market price, making it a less attractive investment.

The new hot topic is mariculture, particularly of finfish. While interest does not (currently) appear as frenzied as that formerly surrounding the shrimp farming industry, it is nevertheless very strong and apparently increasing as improvements in hatchery technology and husbandry make commercial seed production an increasingly viable proposition. Many people have suggested that the growing competition for land is also a factor driving the aquaculture industry to look more closely at its 'offshore' farming options.

But are we ready for a sudden expansion of mariculture? Looking back at the development of shrimp farming there are a few lessons that should be learned (or at least, not forgotten). It is clear that the early, explosive growth of the shrimp farming industry took caught policy makers off guard with regulation lagging far behind the development of the industry throughout much of its history. The lack of checks on development was undoubtedly a major factor in many of the environmental and aquatic animal health issues that subsequently arose. To be fair, that kind of development had not been seen in the aquaculture industry before and it was something of a learning experience for all concerned.

This time, however, both governments and industry should be better prepared. We know that unchecked aquaculture development can lead to environmental problems, resource management issues and adversely affect the productivity of the industry itself. Many of the issues that are likely to emerge with the up scaling of the industry are already known from localised development hotspots, as are many tools and mechanisms that can be used to prevent or mitigate against them. The need to engage farmers directly in environmental management, given the predominance of small-scale producers in the region, and to help them find ways to profit from it (such as the Better Management Practices developed by the Consortium on Shrimp Farming and the Environment – discussed in this issue's Notes From the Publisher column), are better appreciated.

Given the speed with which development tends to take place in the region, there is a need to plan ahead in order to facilitate orderly expansion of established and emerging mariculture industries. As Andre Norton once wrote, "I merely note that if you want to catch something, running after isn't always the best way".

Simon Wilkinson

AQUACULTURE ASIA

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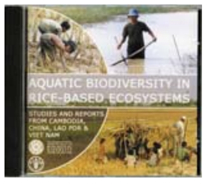

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Notes from the Publisher

Investments into NACA: The bottom line for farmers and governments

We continue with the theme "investment" in this issue. In the previous issue, we looked at NACA itself as an investment. NACA is founded on cooperation and collaboration with the intention of sharing regional resources among members and associates - governments, institutions and individuals - for the ultimate benefit of primary producers. Investment made in fostering specific collaborations with well defined practical long term objectives can be very rewarding. This begins a series on selected projects and initiatives that NACA governments have invested in.

First, on health management. Two examples under the regional health programme illustrate the benefits of such investments and hold promise for further strengthening of regional cooperation to benefit farmers, who are the focus of the current NACA five year (2006-2010) work programme.

PCR Lab Inter-Calibration. The first example concerns the running of a voluntary PCR ring testing exercise in India. PCR screening of broodstock or seed, or both, for white spot syndrome virus (WSSV) can be effective in reducing the risk of disease outbreaks. But in many cases diseases on farms continue to impact very significantly on production, even when PCR-screened seed is used prior to stocking. Of several reasons cited for the continued occurrence of disease on farms, the lack of harmonization and inter-calibration of PCR testing capabilities of various PCR labs is one of the most important. Responding to this, NACA, with ACIAR collaboration through ACIAR's regional shrimp health project, facilitated the project partners from India, Australia and Thailand to set up and run the first voluntary PCR ring testing exercise in India, which was participated by 49 service labs. Each of the labs were provided with 10 samples which were prepared, re-tested and validated very meticulously by scientists from CSIRO, Australia and CIBA, India. This exercise provided several useful lessons, noteworthy amongst them are: (1) voluntary participation by the private sector; (2) a sense of confidence the industry has on such regional processes; (3) ownership and commitment of the national government through its institutions like MPEDA and CIBA; (4) technical support by project partners under the NACA umbrella; and (5) the efficiency and cost-effectiveness of the whole process. Investments such as this can have long lasting impacts and it is expected that MPEDA will use the ring testing experience to setup a laboratory accreditation programme in the near future.

BMP Shrimp. The second example is work with small-scale shrimp farmers in India. The shrimp consortium partners-NACA, FAO, WWF, WB, UNEP-through wide ranging stakeholders consultations have built a consensus on international principles for responsible shrimp farming. Developing better management practices and assisting shrimp farmers to implement them so that improved compliance to international principles can be accomplished is not an easy task. The investment on this, through the MPEDA/NACA/ACIAR/ICAR project in India, is another good example of long term benefits of meaningful and practical regional collaboration. The project, now on its fifth year, has been highly successful in bringing together shrimp farmers (organized into aquaclubs and the aquaclubs into clusters) to collectively implement better management practices to reduce disease-related losses, improve yields and produce quality and traceable antibiotic-free shrimp. The crop results in 2005 from 930 demonstration ponds spread over 484 hectares of area in 15 aquaclubs of Andhra Pradesh showed a two-fold increase in production, 34% increase in size of shrimp, 15% increase in crop duration, 68% improvement in survival and 65% less disease prevalence when compared to surrounding non-demonstration ponds. As a result, for every 1000 rupees ($22) invested, demonstration farmers made a profit of 128 rupees ($2.9), compared to the 38 rupees or $0.86 made by non-demonstration farmers.

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For NACA, the biggest success is the visible positive change in the attitude of shrimp farmers that the project has sparked. Economic rewards, while important, could be short lived, but attitudinal changes in farmers are a long-term benefit from a modest investment. Responsible farmers and a sustainable process to keep the lessons learned perpetuating within the farming community are the biggest long-term rewards any project can ask for.

Genetics and Biodiversity. Global awareness of the importance of biodiversity and genetic conservation rose with the publication of the Brundtland Report, "Our Common Future' in 1987, and the establishment of the Convention on Biological diversity (CBD). Earth has very meagre useable freshwater resources, some 0.06% of all the water on the planet, but this resource is home for approximately 25% of global, inland vertebrate biodiversity; a fact that imposes an increased responsibility on inland aquatic resources management and development.

The Genetics and Biodiversity program was established about two years ago, to assist member governments in managing and conserving their natural aquatic genetic resources. This goal can be achieved through capacity building and research. Basic knowledge and available tools and techniques that are applied for genetic characterisation, which in turn, are used as fundamental basics to develop sound management plans, will continue to be disseminated through training workshops. The first training workshop on the use of molecular genetic techniques in aquaculture and inland fishery management organised in December last year, brought over 20 participants from 11 member countries. The workshops, in cooperation with Kasetsart Unviersity's Princess Walailak Centre, FAO, MRC and World Fish Centre, covered both theoretical and practical application of population genetics. Participants from this workshop acquired competence to provide technical services for relevant future projects. The training manual is being published for wider use.

Potential negative impacts of genetics related management issues such as inbreeding, genetic drifts, introgressive hybridisation and unconscious selection will be addressed through development of broodstock management strategies. NACA has been actively involved in such activities, for example conservation of the Mekong giant catfish project. The bottom line for farmers of the Genetics and Biodiversity program is to provide farmers with genetically improved strains with fast growth rate and better able to tolerate disease. The bottom line for the environment is to minimize negative impacts on biodiversity from aquaculture and inland fishery management practices.

This issue's Note's From the Publisher was written with Dr. Nguyen T.T. Thuy and Dr. C.V. Mohan.

Selection of high-health postlarvae: A prerequisite for sustainability of the Indian shrimp industry

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Shrimp culture as an industry has been contributing significantly to the export earning, employment generation, poverty alleviation and to the economic development of India in recent years. India's vast coastal belt and conducive environment has led to the rapid expansion of shrimp farming activities. Culture practices are gradually being intensified but also vary with the investment capabilities of the entrepreneur. Since shrimp larval quality plays a key factor in influencing the successful shrimp culture, farmers and PL producers need a rapid and simple technique to evaluate postlarvae health quality with respect to future growth and survival. Characterizing good PL quality can benefit shrimp farmers by increasing crop profits and help hatchery managers to identify and assess the effects of factors affecting PL quality.

In recent years, shrimp health management has become the main focus of improving production and minimizing infectious diseases in shrimp ponds for smooth development of aquaculture industry. To accomplish this goal, one should be concerned with the quality of postlarvae especially the selection of high-health postlarvae shrimp (Table 1 & 2), before stocking in the pond.

Criteria for selection of high-health postlarvae (PL)

The success of any farming operation is dependent upon the quality of the postlarvae stocked in the pond. Strong, healthy postlarvae placed into a healthy environment have the best chance of growing well and giving good survival, harvests and profits. Weak or diseased postlarvae will not perform well and potentially can place every shrimp in a pond at risk. Clearly, the choice of hatcheries from whom you buy your postlarvae is a critical decision. Some of the useful criteria are given below to help farmers identify high-health postlarvae:

Appearance

Tail

A PL tail should be noticeably open. The presence of pigment cells in the uropods, which gives the tail an open appearance, is a useful indication of the stage of development. If the uropods are not pigmented which make the tail appear closed, then the postlarvae are not sufficiently developed for stocking. The preferred age of PL at stocking for *Litopenaeus vannamei* or *L stylirostris* is 7-10 days old and 18 days for *Penaeus monodon*.

Colour

This criterion has often been used as a measure of PL quality. However, there is very little information available regarding the effect of molt stage and color. Good quality PL have transparent bodies with star-like brown or dark brown pigmentation. However, a pink or red colouration can indicate stress related to rearing or handling.

Swimming activity and behaviour

PL should be visibly strong and active, swimming from side to side and respond rapidly to external stimuli. This activity of PL can be easily observed if water in a basin containing PL is agitated or whirled. The healthy ones move to the sides against the current whereas the weak ones remain in the

Table 1. Indicators of high-health postlarvae.

- Active swimming with straight bodies and respond rapidly to external stimuli.
- Transparent body and tail muscle with few pigmentation spots.
- Clean shell which indicates that the animal is generally growing fast and molting frequently.
- Appearance of a clear, thick and smooth muscle.
- High index of gut fullness.
- Dark colour and relatively large hepatopancreas with a large number of lipid vacuoles.
- State of branched gill lamellae in postlarvae.

center. Unhealthy PL appear lethargic and unresponsive to external stimuli.

Size

Larger animals are generally more aggressive in searching for food and have a better chance of survival over smaller ones. It is preferably to stock PL of uniform size and any significant variation is indicative of different age levels. Generally speaking, age variations are acceptable as long as size differences are minimal. Uniformly sized postlarvae coming from a single complete spawning and large clutch of eggs appear to perform well in ponds. Postlarval stages between PL 15-20 are preferred for stocking. Selection for postlarvae length and depth does not directly indicate that the PL are sound but only indicates the state of nutrition of larvae. The number of rostral spines indicates the age of the postlarvae (4 to 6 spines- PL 15-20).

PL should also be examined for signs of infestations (debris adhering to the body, swimmerets etc.) and deformities (broken rostrum, crooked body, enlarged head, undeveloped gills etc.). High-health PL should appear clean and have no physical abnormalities.

Feeding

Gut fullness can be determined with the help of a dissecting microscope. A healthy PL will have a full digestive tract, except after a long time in shipment. The presence of empty guts may be the first sign of disease or can be the result of underfeeding or stress. In either case, it should be investigated immediately.

Clean shell

A clean shell represents frequent molts, indicating fast, consistent growth. Slow growth is indicated by the presence of protozoans such as *Zoothamnium*, *Vorticella*, *Epistylis* or *Acineta*, filamentous bacteria, dirt, organic matter and necrosis (black spots or brown lesions) on the shell. Lack of luster or shine on the shell can be an early sign of disease.

Pathognomonic lesions

In assessing the general well being of the PL, consider the following typical external lesions as an indicator of poor larval quality:

- Epibiont fouling: The presence of these organisms indicates poor water quality and larvae that have an irregular molt cycle. It is important to check both moribund and active PL for their degree of fouling.
- Cuticle black spot.
- Postlarvae with larval mycosis
- Appendage or body deformities.
- Opaqueness of trunk muscle.
- Reddish discolouration.
- Whitish line along the dorsal part of the trunk exoskeleton.
- Monodon Baculovirus occlusion bodies (MBV).
- Presence of luminescence.

Stress tests

Acute stress tests have often been used to distinguish between healthy and weak PL and are often used by commercial hatcheries to evaluate PL hardiness. If PL hardiness is indicative of future growth and survival performance, stress tests may become important parameters of PL quality. In most procedures PL are subjected to sudden changes in salinity or to selected chemical solutions. There are several types of stress tests that can be used, including temperature, salinity and pH stress tests. At least two tests should be used for each batch of PL. since salinity and formalin stress tests are the most effective and the easiest to perform; these are used by most of the commercial hatcheries to evaluate the health status of the PL. Some of the stress tests commonly used by entrepreneurs are given below:

Formalin test

Before stocking in grow-out ponds postlarvae are selected by exposing the animals to 150 ppm formalin for 30 minutes. This is used to cull weak PL for white spot syndrome virus (WSSV). This technique has been successful in reducing the number of infected PL stocked into ponds.

Salinity Shock

This is commonly applied stress test to determine postlarvae hardiness. In this test, PL are rapidly immersed in freshwater for 15 minutes followed by normal seawater for another 15 minutes. PL in good health show high survival after being returned into normal seawater.

Temperature test

Subject 50-100 PL to a temperature of 22-24°C for 5-10 min. High-health PL don't die and recover quickly when put back in water of 28-32°C.

Stress hormone test

Some researchers have tried using stress hormone such as corticosteroids to assess the response of PL to induced stress using chemical. The test is still in experimental stage and needs further documentation to verify its usefulness.

Starvation

50PL are kept starved for 24 h in a flat-water bowl without aeration. High-health PL show good survival when returned to normal condition.

These stress tests are simple, rapid, and inexpensive and do not require specialized equipment or extensive scientific skill. They be used either at a hatchery or in the field to evaluate health status of PL.

Prestocking/acclimation examination of PL

Routine assessment of PL during acclimation consists of

1. Microscopic examination of randomly selected PL at the moment of arrival or before being stocked into acclimation tests; and
2. Routine assessment of PL throughout acclimation.

1. Microscopic assessment

Microscopic assessment helps further to evaluate the quality of PL before packing at the hatchery for shipment to the farm. It should be done upon arrival of PL at the farm site to assess the effects of transportation on PL.

- Immediately upon arrival, collect twenty PL from one of the transport containers or bags while the acclimation supervisor examines the parameters of the water in the transport containers and bags.
- This evaluation should be done immediately to determine any stress resulting from transportation and not from being held in the acclimation container.
- Examine each PL sampled and record the condition based on the clinical index mentioned earlier.
- Record all results on a PL State of Health Examination form.
- Collect 1 litre of water from the acclimation tank (sampling from the bottom upwards) and carefully examine PL, with the aid of a dissecting microscope for more precise observation, for the following characteristics:

Index of gut fullness

Since water temperature should be maintained at around 22°C during long transport, it is unlikely that the index of gut fullness will be more. However, a percentage estimate of gut fullness upon arrival can serve as a guideline for the farmers to evaluate the intensity of feeding behavior during acclimation. Larvae collected from estuaries will probably contain higher gut fullness because the trip is shorter and the temperature is probably higher.

Mucus and debris on setae

Accumulation of mucus and debris on the setae, antennae and appendages is a strong indicator of stress. With the help of microscope take a three-dimensional image of the PL and examine the spaces between the setae and antenna hairs for any build-up of debris.

Opaqueness of swimmerets and tail muscle

An obvious sign of stress is change in opaqueness of the tail muscle. Normally, the tail muscle will be transparent with a few pigmentation spots. However, when stressed, the tail muscle and swimmerets may become or in extreme cases, completely white. This problem can be quite serious and potentially fatal if left untreated.

Physical deformities

Although deformities are not directly related to stress, a large number of deformed PL within a population can be indicative of chronic diseases. Deformities can also be used as an indicator for future survival estimates in the grow-out pond. Morphological examination should be focused on the following:

- Complete, well-developed, unbent rostrum.
- No curvature or cramped tail.
- Well-formed eyes and eye stalks.
- Well-formed complete swimmerets.
- Overall physical appearance.

Muscle to gut ratio

A microscopic examination of the relative thickness of the ventral abdominal muscle and the gut in the 6th abdominal segment of the tail of the PL should be conducted to determine the muscle to gut ratio. This gives a useful indication of the nutritional status of the postlarvae. The muscle should be completely fill the shell from the gut down. A high muscle to gut ratio is generally preferable. When the PL are stressed, the muscle has a grainy appearance much like the grain in the wood. The muscle will appear grayish or brown in colour. Healthy PL have a clear, thick, smooth muscle.

Condition of the hepatopancreas

The hepatopancreas of the PL should be examined for its general condition that is primarily indicated by the number of lipid vacuoles and its overall size. The presence of a relatively large hepatopancreas with a large number of lipid vacuoles is considered a sign of good health. PL with a small hepatopancreas containing few lipid vacuoles is a sign of under feeding and improved feeding prior to harvest may be required in order to enhance their quality standard.

Colour of the hepatopancreas

The hepatopancreas should not be transparent and should have a good colouration. Typically, it should be dark yellow in colour. A dark colour hepatopancreas generally indicates better health of postlarvae.

Gill development

The state of gill development should be examined as it gives a better idea of when PL are able to tolerate salinity changes, which often occur when the shrimp are transferred to the on-growing facilities. When the gill lamellae have become branched like Christmas trees, approximately around PL 9-10, they are generally able to tolerate fairly rapid changes in salinity and can be easily be acclimated to on-growing conditions. Where gill lamellae remain unbranched, the shrimp should not be subjected to major or rapid salinity changes and should not be considered ready for transfer from the postlarval tanks.

Intestinal peristalsis

A high power microscopic examination of the intestinal tract of the PL should be conducted in order to ascertain the peristaltic activity of the intestinal muscles. Strong gut peristalsis in combination with a full gut is an indication of good health and high nutritional status of PL.

Melanization

PL should be examined for melanization, which often occurs where limbs have been cannibalized or where bacterial infections have occurred. Excessive melanization is a cause for concern and

Table 2. Scorecard for high-health postlarvae.

Criteria	Observations	Qualitative assessment	Score
Swimming activity	Activity level of postlarvae swimming behaviour	Very active Moderate Low	+++ ++ +
Size variation	Calculation of coefficient of variation (CV) of PL size	< 15% 15-25% >25%	+++ ++ +
Deformities	Deformities in limbs and head	< 5% 5-10% > 10%	+++ ++ +
Gut fullness	Degrees of fullness of digestive tract	Full gut with faecal strands Moderately full Empty gut	+++ ++ +
Fouling organisms	Degree of fouling by epibionts	< 5% 5-10% > 10%	+++ ++ +
Muscle opaqueness	Opaque muscle in tail of PL	< 5% 5-10% > 10%	+++ ++ +
Muscle to gut ratio	Comparison of ratio between muscle and gut thickness	> 3:1 1-3:1 < 1:1	+++ ++ +
Condition of the hepatopancreas	Relative quantity of lipid vacuoles	Abundant vacuoles Very small vacuoles No lipid vacuoles	+++ ++ +
Colour of the hepatopancreas	Relative colouration of hepatopancreas	Dark Pale Transparent	+++ ++ +
Gill development	Degree of branching of gill lamellae	Complete Intermediate Slight	+++ ++ +
Intestinal peristalsis	Movement of gut muscle	High Moderate Low	+++ ++ +
Melanization	Melanization of body or limbs	No necrosis Very minor necrosis Appendages and parts of body affected	+++ ++ +
Direct observation of luminescence	Night time observation of the tank	< 5% 5-10% > 10%	+++ ++ +
Molting	Molts in the water	< 5% 5-10% > 10%	+++ ++ +
PCR	Virus	Negative Positive	+++ +
Survival rate	Estimation of survival rate in each tank	> 80% 50-80% < 50%	+++ ++ +
Score rating: +++ = Excellent; ++ = Fair; + = Poor			

requires treatment through water quality and feeding regime enhancement and sometimes reductions in stocking density to prevent cannibalism and reduce bacterial loads.

2. Routine (acclimation) assessment

In addition to the stress test and microscopic examination, a routine assessment of PL should be done every hour during the acclimation period. Constant observations provide subjective assessments of the PL general condition during fluctuations of water quality inherent in acclimation. If indications of stress are observed, steps can be taken to slow down the acclimation process and reduce the stress. This routine assessment can be conducted by sampling 1 litre of water and carefully examining the PL swimming in the container and the acclimation tank for the following:

Level of swimming activity

If PL accumulate on the surface, agitating aggressively and if there DO level is low, inject pure oxygen into the water. If PL are lethargic and swimming activity is diminished, reduce the rate of water exchange, allowing PL more time to adjust physiologically.

Erratic swimming behaviour

A periodic rhythm of cramping up and relaxing signifies an attempt to molt. A large percentage of the acclimation tank's populating molting is an indication of stress. If this occurs, reduce the rate of water exchange, increase feed and reduce the temperature to less than 23°C to suppress cannibalistic activity by nonmolting PL.

Opaqueness of tail muscle

This sign is an indicator of physiological stress. If observed at a high frequency, slow down the acclimation schedule to allow for physiological adjustments.

Presence of molts

Floating exoskeletons indicate molting. Take proper steps just to discourage cannibalism. A slow acclimation water exchange is recommended to prevent molting. Do not mistake exoskeletons for dying or dead PL. If a major molt occurs, check gill movement and heart activity. If no organs appear to be active, mass mortality may be occurring.

Index of gut fullness

Active feeding and high index of fullness are positive signs, indicating that there is little stress. Generally, PL will not feed if they are under stress. A low index of gut fullness and excessive feed present may indicate stress. If this occurs, suspend feeding and reduce water exchange.

Presence of mortalities

Under normal conditions, a mortality rate greater than 3% should put the acclimation supervisor on alert. Check water quality, reduce rate of water exchange and if guts are full, reduce the temperature to slow the PL metabolic rate. These procedures may provide sufficient time for a thorough investigation into the cause of the mortalities.

Frequency of cannibalism

Generally, cannibalistic behaviour indicates that there are insufficient quantities of feed or a high level of mortality. An increase in feed quantity and frequency should minimize cannibalism.

Survival rate

Survival cages and a holding tank with sub-sampled PL may be used to determine the survival rate and to monitor mortalities as follows:

- Before stocking, collect 200 PL from several different tanks and place into different cages to determine survival.
- Place the cages near the edge of a pond at a minimum depth of 50 cm. The cages should be firmly anchored to the mud, with a minimum of 15 cm water depth in the cage.
- Do not feed PL in the cages and leave them undisturbed for 48 hours.
- After 48 hours, remove all PL from the cages and count them individually. Live PL should be counted separately from dead ones.
- Divide the number of live PL by the number of PL originally placed in the cages to calculate survival rate. Multiply that number by 100 to obtain the percentage of PL that survived.
- After counting the PL, examine seams and corners for trapped or squeezed PL and holes where they may have escaped.
- The survival count is a useful indicator of the acclimation process. A survival rate of 80-100% suggests high quality PL, 60-79% survival is considered acceptable and survival below 60% considered not adequate for pond stocking.

Detection of pathogens

Various molecular biology techniques such as DNA probes and polymerase chain reaction (PCR) provide accurate, sensitive and rapid diagnostic tools for detecting and identifying shrimp pathogens especially viral diseases. Recently, various sets of primer sequences have been successfully designed from WSSV. These primers have been used in the PCR methods for WSSV, both in postlarval shrimp and shrimp broodstock. PCR exploits the capability of amplifying a small amount of genetic material from an organisms, this facilitate the detection of virus especially carriers which normally contain small amount of virus particles. The establishment of PCR laboratories, both from the government and private sector for successful screening of WSSV postlarval shrimp in India not only helps in improving the high-health shrimp postlarval production but also minimize the spread of WSSV in grow-out ponds as well.

Good management

Producing high-health postlarvae is not only dependent on reducing the impact of shrimp pathogens but also relies heavily on good hatchery management. Many factors affect the quality of PL viz. feed quality and quantity, molting, water quality (temperature, salinity, ammonia, suspended solids, faeces), phytoplankton density and other environmental conditions. Factors such as the seawater supply system, regular disinfection and dry-out of hatchery facilities and adequate aeration in larval tanks, can also have an impact on the quality of postlarvae produced by a hatchery. Moreover, the use of some chemicals and antibiotics such as chloramphenicol and oxolinic acid in the hatchery may reduce larval growth and inhibit defence mechanisms of larvae itself since these type of drugs reduce the activity of acid or alkaline phosphatase which are considered to play a key role in the protein metobolism in shrimp.

These factors can be regulated through the use of good hatchery management practices and this will have a major impact on the quality of PL produced. The larval production plan should be aimed at producing the highest quality seed, because subsequent on-growing performance is directly related to post larval quality. It is thus in the on-growing phase where status of PL quality is of immense importance.

Conclusion

Success of any farming activity is dependent on the availability of high-health seed in required quantity at the right time. As the demand for shrimp seed has increased with the development of commercial shrimp farming, a growing number of commercial shrimp hatcheries have also been established. Most of these hatcheries have the necessary infrastructure capabilities but need to be geared up for production of healthy and disease free postlarvae.

The quality of shrimp seed is at present a prime factor affecting production and economic efficiency of the culture practices. Poor survival and lack of predictability of PL in the grow-out phase are major obstacles in developing a stable shrimp farming industry. It is important to establish an effective farming system for producing and distributing high quality shrimp seed. Scientific research needs to be carried out on the genetic improvement of cultured shrimp species. Shrimp breeding techniques should also be improved to maintain the genetic quality of species at production level. Also, to maintain the quality of seed in production, a certified system should be developed and implemented for shrimp hatcheries. A health certificate system and inspection mechanism should be established by the government for the trans-boundary movement of shrimp broodstock and seed within and beyond the country.

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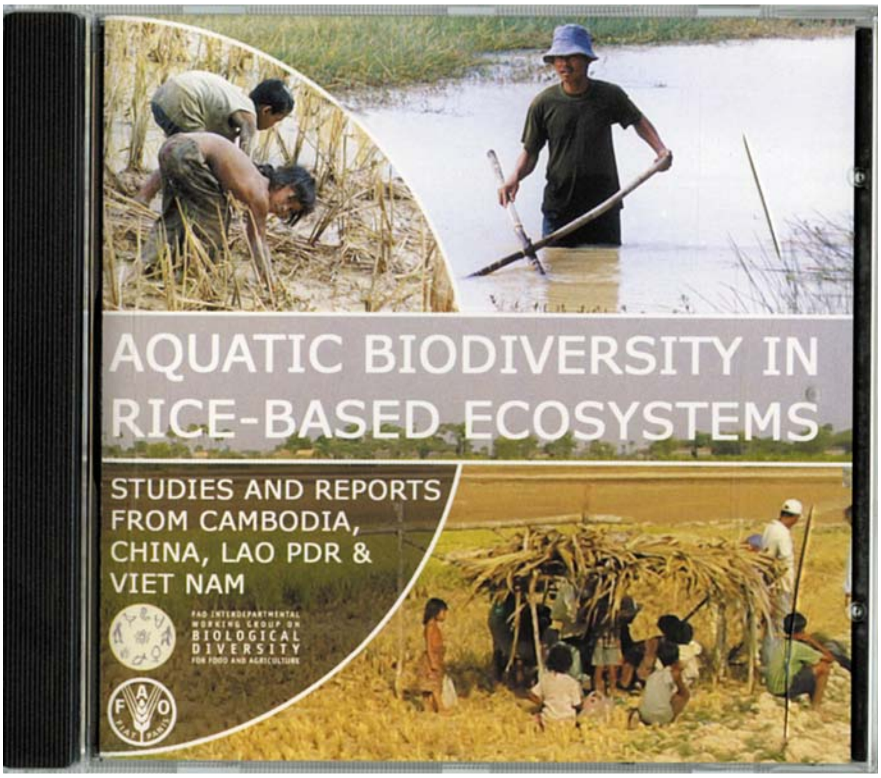

New from FAO, this CD-ROM illustrates the vital role that aquatic biodiversity from rice-based ecosystems plays for the livelihoods of rural people in southeast Asia. It contains the findings of five case studies on the availability and use of aquatic biodiversity as well as local management arrangements from Cambodia, China, the Lao People's Democratic Republic and Viet Nam. The rich variety of utilized aquatic species (fishes, reptiles, amphibians, crustaceans, molluscs, insects and plants) collected by farmers in their rice fields is presented together with information on traditional practices and local knowledge regarding collection tools and methods, species availability, consumption and preparation methods.

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Nucleotides - novel immunostimulants in aquaculture feed

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The outbreak of disease is a major problem in the aquaculture industry. To prevent disease, antibiotics are widely used in culture systems. However, the prolonged use of antibiotics can result in the development of resistant strains of pathogens. This has lead to research on alternatives including immunostimulants such as glucan, chitin, levamisole and lipopolysaccharides to enhance the immune system of fish and shrimps. In recent years, one of the immunostimulants that has received greatest attention are nucleotides, the building blocks of RNA and DNA. They are also an important constituent of enzymes and cofactors such as ATP, NAD and FAD.

Generally in mammals, dietary nucleotides are thought to be semi-essential in early infancy because some of the epithelial cells of the intestine or blood cells cannot synthesize de novo nucleotides to meet their requirements and must derive nucleotides from other organs or from other dietary sources. In mammals the inclusion of dietary nucleotides can enhance cell mediated immunity, lymphocyte proliferation, interlukin-2 production and improve host resistance to bacterial infections. Likewise in fish and crustaceans several reports have shown the beneficial influences of oral administration of nucleotides on immune functions and disease resistance. It has been demonstrated in fish such as Atlantic salmon (*Salmo salar*), coho salmon (*Onchorynchus kisutch*), rainbow trout (*O. mykiss*), common carp (*C. carpio*), European sea bass and hybrid striped bass, but has not yet been reported in shrimps.

Sources of nucleotides

Commercial nucleotides are derived from brewer's yeast and yeast extracts. Single cell protein, fish solubles, animal protein solubles, complete fishmeal and unicellular organisms are also main sources of nucleotides. Oils, oilseeds such as soya and grains such as wheat or corn contain very low levels of nucleotides.

Importance of nucleotides

Fish and crustaceans possess specific receptors for nucleotides and they may act as attractants. Nucleotides play a role in the immune system, physiological functions including encoding genetic information, mediating energy metabolism and signal transudation. Dietary nucleotides also have a nitrogen sparing effect as the absorbed nucleotides can spare the use of amino acids as precursors in nucleic acid synthesis. In early development of larvae, nucleotides are essential for their rapid growth or cell replication. Their requirements are greater during states of disease or stress for increased blood cell production. Reproduction and egg development create additional demand for RNA and DNA, which can be met by a nucleotide-enriched diet. Nucleotides can carry chemical energy in their early hydrolized acid-anhydrate bonds and combine with other groups to form enzymes. When nucleotides are given to fish as dietary sources, their immune system responds well to pathogen challenge.

Mechanisms of nucleotides

Nucleotide formation in fish or shrimp is very time and energy consuming so supply of nucleotides through feed will save energy. Nucleotides can be partially absorbed in the gut, principally as nucleosides, which are recombined with phosphoric acids to nucleotides and nucleic acids and enter the blood for transport to different organs for the formation of new cells. When disease occurs in fish or shrimp, it need not have to synthesize nucleotides used to produce DNA when cells divide.

Nucleotides in aquaculture feeds

Sakai et al. (2001) reported that oral administration of nucleotides resulted in enhanced phagocytic and NBT responses in kidney phagocytic cells of common carp for more than 10 days post treatment at 15mg/100g. Furthermore, the number of *Aeromonas hydrophila* also decreased in the blood, kidney and liver after intraperitoneal injection. Burrels et al. (2001) reported beneficial effects of dietary nucleotides when challenging salmonids with infectious salmon anaemia virus and *Vibrio anguillarum*. In another study with Atlantic salmon (*S. salar*) indicated that fish fed with 0.03% nucleotides increased antibody titres following vaccination against *Aeromonas salmonicida*, the causative agent of furunculosis and had reduced mortality. Peng Li et al. (2994) reported increased production in hybrid striped bass and also resistance to *Streptococcus iniae* infection. Ramadan and Atef (1991) showed that dietary nucleotides significantly enhanced the weight gain of tilapia. Rumsey et al. (1992) reported the incorporation of 0.6-4.1% yeast RNA extract in purified diets significantly increased feed intake and weight gain in rainbow trout.

In nature shrimps are supplied with nucleotides because they feed on detritus rich in microorganisms. These microorganisms are rich in RNA or DNA (Giesecke and Tiemeyel 1982) so the benefit of supplemental nucleotides to shrimp is not clear. However, recent work showed that shrimp fed with yeast extract showed higher total haemocyte counts, greater numbers of granulocytes and a faster clearance rate of bacteria following challenge, a positive result. To date no information is available on specific dietary requirements for nucleotides in shrimp but it has been suggested that research could be done between 2 and 5% of hydrolized additives based on single cell protein or yeast in shrimps.

Conclusion

From these experiments it is concluded that dietary nucleotides positively influence the immune system of fish or shrimp, although the evidence for shrimp is not so clear. Further research is required to investigate the impact of nucleotides on shrimp disease resistance or growth, and to commercialise useful nucleotides that are identified.

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Brood stock and all female scampi grow out ponds in South India

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Freshwater prawn *Macrobrachium rosenbergii* enjoys a cosmopolitan distribution having being introduced onto every continent as an eco-friendly candidate species for aquaculture; emerging as an alternative to penaeid prawn culture (Kutty, 2003). Freshwater prawn production exclusively confined to scampi has registered a 10-fold (1000%) increase since the nineties (Moraes-Riodades and Valenti, 2001). To date *M. rosenbergii* culture has been conducted either for commercial purposes or research activities in a total of 77 countries (New, 1995). With the boom in the aquaculture of scampi has come a corresponding growth in the demand for viable seed, which has topped 6 billion throughout India (Sakthivel, 2003). In this context the practice of collecting seed from the wild continues, contributing a significant proportion of the total seed supply for aquaculture (FAO, 2000). Most wild stocks are over exploited, for instance the scampi landings in Vembanad Lake have dwindled to a mere 39 tons from 300 tons during 1960s (Kurup and Harikrishnan, 2000).

However, more *Macrobrachium* hatcheries also being established since the technology for mass production of seed is well developed. Although *Macrobrachium* grows, matures, and spawns readily under captive conditions, most hatcheries rely on wild broodstock, which has contributed to the over exploitation of wild populations and led to shortages (Hien et al., 1998). Hence the hatcheries in South India, particularly Tamilnadu and Andhra Pradesh, have resorted to a novel way to circumvent this problem. Here five out of the nine major hatcheries and the prawn farms are closely positioned and hence the hatcheries have requested the farm owners to establish an exclusive brood stock pond. The all male pond is harvested for export while the brooders are collected by the hatcheries on the spot. This recycling of animals between hatchery and grow out ponds has led to inbreeding depression (New, 2000).

Brood stock ponds

The PL12 are reared in nursery ponds for a period of two months and grow into juveniles (6.5±1.5g) at which stage they are harvested and stocked into grow out ponds. Prior to stocking the juveniles are sorted indigenously into males and females with 96±2% accuracy (Super segregators, Wintech aquatics, Nellore, Andhra Pradesh). The males are reared in a separate grow out pond while the females are stocked separately in a brood stock pond. The sex ratio in these ponds is maintained at four females to one male. The stocking density ranges between 6-12m^2. The brood stock ponds are maintained for a minimum period of six months adopting the same rearing methods practiced for male ponds. No separate diet is fed to the brooders. After six months, the brood stock ponds are harvested in toto or in a phased manner in two subsequent harvests within 15±5 days at the convenience of hatchery owners. The survival rate of brooders is about 85% and the prawns are sold at the rate of US $ 0.5/brooder.

Female pond

Due to the high commercial value of blue claw males (80-100 g/individual) farmers have conducted all-male culture since 1999. In the process they have attained considerable success in sexing the seeds manually. However this practice has led to the surplus availability of females, which are not

Harvest of females for the local market.

as lucrative as males. Hence the need of farms to have a supply of brooders is a boon since it compensates the seed cost to some extent (US $ 950/100,000 juveniles with an average sex ratio of 47 females: 53% males).

However when there is no opportunity to raise brood stock to supply a hatchery, the farmer is left with the 47% female juvenile population which he can not afford to throw away since he has paid for them. Under such circumstances the farmer often tries to partially redeem the cost by rearing the juveniles in a separate female pond. After a rearing period of two months the females attain an average size of 15-20 g/prawn which is harvested in one lot and sold in the local markets at around US$ 2/kg. Even a small scale farm with two ponds thus assigns one for female or brood stock pond. Economically the return from the brooder pond is better as mentioned above but neither of them are as lucrative as males because of the difference in growth rate. After attaining sexual maturity (about 20 g in female pond) the females have to channel more energy for reproduction along with the obligatory processes of somatic growth and molting. Hence the farmers prefer to grow all males rather than mixed culture since in monoculture of males the operational costs are invested exclusively for males while in mixed culture it is spent on the slower growing females also.

The all male segregation technique employed in *Macrobrachium rosenbergii* culture needs scientific validation (Personal communication, Amir Sagi, International symposium on Fresh water prawns, 2003 held at Cochin, India). This practice of growing males, females and brooders separately is paradoxical since there is an increasing dearth of wild brooders and an urgent need for quality seeds. The disposal of females on reaching a marketable size of 20 grams and the supply of brooders from the brooder ponds to the hatcheries will aggravate the inbreeding depression in the years to come. There is an urgent need to protect, conserve and maintain the wild population by according sanctuary status to the native stock in Vembanad lake which is the home ground of scampi (Kurup and Harikrishnan, 2000) as a resource for augmenting heterosis of captive cultured populations and to study the current level of inbreeding depression in the industry. Maintenance of broodstock and selective breeding by hatcheries would go a long was towards sustaining the quality of broodstock and larvae. Effective management of brood stock ponds is essential since they are the source of larvae for the next generation. The development of an exclusive brood stock diet is also the need of the hour since it directly influences the quality and quantity of the broodstock and larvae.

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Genetically modified fish and its potential applications

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Genetic engineering has brought with it revolutions in the life sciences over the past decade. The beneficial trait of a particular gene from one organism can now be transferred to another in a less amount of time and with more precision. This technology has already achieved a tremendous success in agriculture and made it easier for farmers to grow certain crops and reduced the use of certain pesticides. In recent years, genetic engineering has also been applied to produce specific animal strains generally referred to as genetically modified organisms (GMOs) that also have the potential to improve livestock crops. However, its commercial application needs careful to address potential environmental, social and regulatory. The only genetically modified animals that are likely to come to market in the near future are fish. In this context, this article provides an overview of recent developments in genetically modification of fishes and potential applications of this technology.

Transgenic fish

GMOs are defined by international agreements and much national legislation in a very narrow sense as being essentially transgenic organisms, i.e. organisms that have had foreign genes inserted into their genome. Transgenic fish are produced by introducing foreign DNA segment/sequences (homologous or heterologous transgenes) into newly fertilized or unfertilized eggs resulting in genomic integration of DNA in a stable and heritable manner.

Transgenes

A transgene, containing a strong expression promoter/enhancer element and a structural gene, is usually constructed in a bacterial plasmid. Since the gene sequences are interrupted by non-coding sequences i.e. introns, when a gene is developed as part of a construct, it is not usually taken directly from the donor's DNA. These introns are spliced out during the production of mRNA. mRNA is extracted from cells or tissues where the gene is expressed and is used to synthesize complementary DNA (cDNA) by the enzyme reverse transcriptase. This cDNA is then inserted into a plasmid vector and cloned into *E. coli* to produce a cDNA library. This cDNA library is then screened using a probe to identify the matching cDNA. The desired cDNA is then snipped out and spliced to the promoter sequence.

It also appears that certain introns are required for the full expression of the gene, which implies that some introns may have a regulatory function even though the sequence is not translated.

Depending on the purpose of the gene transfer studies, transgenes can be grouped into three general categories:

1. Gain-of-function: Adds new function to the transgenic individuals. e.g. growth hormone (GH) enhances growth.
2. Reporter function: Identifies the success of gene transfer effort and measures the strength of a promoter/enhancer element.
3. Loss-of-function: Interferes with the expression of host genes (this has potential application to produce disease-resistant transgenic brood stock).

Since 1985, a wide range of transgenic fish species have been produced including gold fish, medaka, zebra, salmon, channel catfish, common carp, Japanese loach, northern pike, rainbow trout, tilapia, and walleye by various gene transfer methods including microinjection, electroporation, retroviral infection, lipofection, sperm-mediated gene transfer, embryonic stem cells, particle gun bombardment and calcium precipitation.

Current and potential applications

Gene transfer technology has been applied for the expression of desirable traits to improve the aquaculture production (by increasing growth or adapting fish to adverse environmental conditions). Traits that have been experimented with include growth enhancement, salinity tolerance, cold tolerance and disease resistance.

Several useful genes that can be transferred into different aquatic species have been identified (Table 1).

Growth enhancement

The primary aim of fish farming is to obtain faster tissue growth more economically. The most important hormone controlling growth and development is growth hormone (a peptide hormone) - also known as somatotrophin, which is secreted by the anterior pituitary gland. The secretion of growth hormone (GH) is controlled by the combined effects of two other hormones, growth hormone releasing hormone (GHRH), also known as somatocrinin, and growth hormone inhibitory hormone (GHIH), also known as somatostatin produced by the hypothalamus. Growth hormone could be used as a growth-enhancing agent through feed in fish culture; however, two major factors, viz. difficulty of obtaining sufficient quantities and digestion by protease enzymes, if given orally, discourage its direct use.

Attempts have been made to increase growth rates and thus reduce time-to-market size. In 1985, Zhu et al. produced transgenic gold fish with human growth hormone gene driven by mouse metallothionein promoter. Thereafter, many attempts have been made with different growth hormones (eg. Rat growth hormone, fish growth hormone) and with different promoters (e.g. LTR sequence of the avian Rous

Sarcoma Virus (RSV), carp b-actin). The success of the growth enhancement work with transgenic fish is impressive and underscores potential usefulness in aquaculture, eg. increased growth in salmon, channel catfish, rainbow trout, carp, tilapia and northern pike. When the transgenic fish exhibit faster grown it appears that it also optimizes many of their metabolic and physiological process (improvement in food conversion ratio, good palatability and consumption of food). There are reports that transgenically growth-enhanced fish show some promise of improvement on both counts (Entis 1998; Rahman and Maclean 1999).

Cold tolerance

Initial research attempts have been made to produce fish capable of living at abnormally low temperatures. Antifreeze protein (AFP) gene derived from polar region fish (winter flounder or ocean pout) was used in a gene construct with the aim of producing Atlantic salmon surviving in very low temperatures on the east coast of Canada (Fletcher et al. 1988). To date four major types of antifreeze proteins have been found in fish: Glycoprotein from Antarctic cod, type I from winter flounder, type II from sea raven, and type III from ocean pout. However, initial thrusts at improving cold tolerance gene transfer have been minimally successful. Success may be achieved in the future by modifying the existing constructs (Fletcher 1988, Davies, 1989, Shears, 1991).

Salinity tolerance

Salinity tolerance is another trait that is being investigated to increase the environmental tolerance/potential culture area. Two adenohypophysial hormones of the pituitary, corticotrophin and prolactin are essentially concerned with osmoregulation in fishes. Prolactin hormones play role in hatching, osmoregulation, behaviour and general metabolism. Once the euryhaline trait is expressed, freshwater fish can be cultured in brackishwater or seawater (or vice versa) depending upon the level of gene expression. However, work on producing transgenic hyper prolacteinameic fish is still at the inchoate stage.

Until such fish have been produced and evaluated the risks and benefits of utilizing them commercially cannot readily be determined other than in the most general terms (MacClean and Laight, 2000).

Disease resistance

The most important potential area of trangenesis is to enhance disease resistance. Many bacterial and viral diseases have been serious threats to the survival of the aquaculture industry. The use of antibiotics in controlling diseases has been banned by many countries due to the presence of residues in end consumer products with fears of health concerns. This has lead to increased interest in producing fish with inbuilt immunity from serious diseases. One approach is aimed at increasing general resistance against bacterial infections and another approach is to increase resistance against a specific viral pathogen. Enhancement of antibacterial enzyme (eg. Rainbow trout lysozyme coding sequence and ocean pout AFP promoter into Atlantic salmon, an all fish construct, by Hew et al. 1995), and antibacterial peptide (eg. cecropins/pluerocidin amide) have been attempted to express the disease resistance traits. Fish can be produced with built-in immunity to a particular virus or any other pathogen, by inserting the gene that determines the antigenicity of that specific pathogen, into the germ line. Infectious Hematopoietic Necrosis Virus (IHNV) G and N protein coding sequences have been inserted in expression vector and transferred to rainbow trout by Anderson et al. (1996). It is reported that N protein sequence alone failed to confer the immunity, but the G protein coding sequence either alone or in conjugation with the N sequence conferred immunity from the lethal effects of the virus.

Even though disease resistance can be improved by hybridization, or through selective breeding, the advantage of this method is that the desired variety can be produced in a very short period of time.

Transgenic production of pharmaceuticals

Transgenic organisms can be used as biofactories for the production of highly valuable pharmaceutical proteins. Like transgenic goats, cows, and other livestock, fish can also be used to produce valuable biomedical products. Comparatively low cost, and absence of risks of accidental transfer of retroviruses or prions to mammals are some of the advantages that make fish one of the best biofactories for production of pharmaceuticals.

Biosensors

The field of environmental toxicology has begun very recently to obtain benefit from the transgenic technology. In a generalized conceptual approach, the transgenic fish would be placed in water containing a chemical to be tested. Following uptake, distribution and accumulation of the substance in fish tissues, the genomically integrated response elements would be activated and the reporter gene would be upregulated. The fish would be removed from the water and assayed for reporter gene activity that would be proportional to the concentration of the chemical to which the fish has been exposed (Winn, R. N., 2001).

Scientists from the National University of Singapore are developing a breed of zebra fish danio (*Brachydanio rerio*) that can detect water pollutants by changing its body colour. Fluorescent genes extracted from jellyfish are used to give a fluorescent glow to the body of the zebra fish. Such fluorescent-coloured transgenic fish will be able to respond to the presence of chemicals, heavy metals and toxins through the stress-responsive promoter. By using such transgenic fish, pollutants can be detected with one quick look. This transgenic fish, sold under the trademarked name GloFish, is to be first genetically modified pet. The Texas-based Yorktown Technologies has licensed to sell as glofish the zebra fish, originally developed to detect environmental toxins. The team is also working towards producing fish that give off a different coloured glow depending on water temperatures. This

Table 1: Some aquatic GMO's being tested for use in aquaculture.

Species	Foreign gene	Desired effect and comments	Country
Atlantic salmon (Davies et al. 1989b, Fletcher et al., 1988, 1992 & 2004, Hew et al., 1992 & 1995, Du et al., 1992)	AFP AFP salmon GH	Cold tolerance Increased growth and feed efficiency	United States, Canada United States, Canada
Coho salmon (Delvin et al., 1995)	Chinook salmon GH + AFP	After 1 year, 10- to 30-fold growth increase	Canada
Chinook salmon (Sin et al., 1993)	AFP salmon GH	Increased growth and feed efficiency	New Zealand
Rainbow trout (Chourrout et al., 1986, Nilsson et al., 1992, Agellon et al., 1988, Disney 1988)	AFP salmon GH	Increased growth and feed efficiency	United States, Canada
Cutthroat trout (Delvin et al., 1995)	Chinook salmon GH + AFP	Increased growth	Canada
Tilapia (Brem et al., 1988, Maclean et al., 1995 & 2002, Martinez et al., 1996, Rahman et al., 1998 & 2000)	AFP salmon GH	Increased growth and feed efficiency; stable inheritance	Canada, United Kingdom
	Tilapia GH	Increased growth and stable inheritance	Cuba
Tilapia	Modified tilapia insulin-producing gene	P roduction of human insulin for diabetics	Canada
Salmon (Hew et al., 1995)	Rainbow trout lysosome gene and flounder pleurocidin gene	Disease resistance, still in development	United States, Canada
Striped bass	Insect genes	Disease resistance, still in early stages of research	United States
Mud loach (Zhu et al., 1986, Tsai et al., 195)	Mud loach GH + mud loach and mouse promoter genes	Increased growth and feed efficiency; 2- to 30-fold increase in growth; inheritable transgene	China, Korea, Rep.
Channel catfish (Dunham et al., 1992)	GH	33% growth improvement in culture conditions	United States
Common carp (Zhu et al., 1989, Zhang et al., 1990, Chen et al., 1993, Chatakondi et al., 1995)	Salmon and human GH	150% growth improvement in culture conditions; improved disease resistance; tolerance of low oxygen level	China, United States
Indian major carps (Venugopal et al., 2002a)	Human GH	Increased growth	India
Goldfish (Zhu et al., 1985)	GH AFP	Increased growth	China
Northern Pike (Gross et al., 1992)	GH	Increased growth	United States
Abalone	Coho salmon GH + various promoters	Increased growth	United States
Oysters	Coho salmon GH + various promoters	Increased growth	United States
Fish to other life forms			
Rabbit	Salmon calcitonin-producing gene	Calcitonin production to control calcium loss from bones	United Kingdom
Strawberry and potatoes	AFP	Increased cold tolerance	United Kingdom, Canada
AFP = anti-freeze protein gene (Arctic flatfish). GH = growth hormone gene.			
Source: FAO website.			

may lead to the use of fluorescent fish as temperature indicators.

Pleiotropic effects

When a desired gene is inserted with the aim of expressing a particular trait, that gene may also affect more that one trait. One gene affecting more than one trait is known as pleiotropy. Pleiotropic effects may be positive or negative. For example, the increased growth rate of transgenic individuals could also be a result of increased food consumption, feed conversion efficiency or both. So it becomes important to evaluate several commercially important traits in transgenic fish to see the additional effects.

All-fish construct

It is now possible to produce constructs that contain only fish-derived sequences, employing coding sequences of fish origin spliced to promoters such as those from fish (eg. Carp b-actin, ocean pout antifreeze protein (AFP) or sock eye salmon metllothionein). Depending on the purpose, all-fish constructs may be autotransgenic (introduction of gene-construct made from the same species) or allotransgenic (introduction of gene-construct made from different species). The autotransgenic approach promises comparatively less ethical problems and is supposed to increase market demand of transgenic fish.

Transgenic fish in India

Research on animal transgenesis was initiated by National Institute of Immunology (NII) in India. Thereafter, investigations have been made on rohu (*Labeo rohita*), zebra (*Brachydanio rerio*), and catfish. Transgenic-fish research has started in different institutes including the Madurai Kamaraj University (MKU), Tamil Nadu, Centre for Cellular and Molecular Biology (CCMB), Hyderabad and the National Matha College, Kollam with constructs borrowed from foreign scientists. The first Indian transgenic fish was produced at MKU in 1991 using borrowed constructs. Transgenic rohu produced from indigenous construct at Madurai Kamaraj University has shown eight times higher growth rate than its control siblings. Indian Council of Agricultural Research (ICAR) Scientists have recently initiated research on transgenic fish with an approach to increase growth rate and produce biosensors.

Containment of transgenic fish

It is important to keep the transgenic fish isolated from the wild fish population while a thorough evaluation is conducted about their possible impacts and obtaining proper legal acceptance. The following methods can be adopted to isolate transgenic fish populations:

- Sterility: Genetic introgression of transgenes into the wild gene pool can be controlled by inducing sterility with transgenic or non-transgenic methods. Triploidy is the most common non-transgenic method to induce sterility. Molecules that antagonize a genetic function necessary for fertility are expressed transgenetically (eg. use of antisense genes). Containment by geographical isolation (isolated site for transgenic aquaculture).

Thermal containment - warm water species can be kept in geothermally isolated area, for example, surrounded by cold water where they are unable to survive if they escape.

- Biological containment - genetically isolation.
- Physical containment, including screening, avoiding transport of transgenic fish/egg/larvae by birds, applying toxin if fish is escaped into natural water body by flood or any other means.

Conclusions

Transgenic techniques can be used as an effective tool to express desired traits in target fish to make them more compatible for culture thereby ultimately increasing aquaculture production. This approach is advantageous as compared to traditional methods viz. selective breeding, cross breeding, etc. which take more time and offer less precision. A shorter generation time, external fertilization and high fecundity are some of the advantages of using fish for such studies. Certain fish species (e.g. zebra and medaka) have advantages over mammalian experimental model. Effective use of transgenic fish research offers the opportunity to improve the growth of fish production, pharmaceuticals and to support other functions such as surveillance of environmental pollution. Thus, we feel that research in transgenic fish is soon going to make a positive revolution in India in the near future.

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Rainbow trout farming in hill terrace of Nuwakot, Nepal

Tek Bahadur Gurung, Sadhu Ram Basnet, Krishna Prasad Lamsal

Nepal is a predominantly mountainous country with most of its area covered by hills and highlands. Recently the population of Nepal has reached about 27.67 million and the ever-increasing population is one of the factors contributing to overwhelming poverty. To a great extent poverty reduction in the country will depend on how efficiently and effectively hill terraces and mountain ecosystems can be utilized in a sustainable manner. The Nepalese hills and mountains function as huge water towers. There are altogether 6,000 rivers originating from Nepalese hills and mountains, which ultimately drain into the Ganges River System. These waterways are a significant natural resource that can contribute to the economic development of Nepal.

The development of sustainable agricultural technologies for making use of steeply sloping hills and mountains is indeed challenging. Nuwakot District is located about 72 km northwest of Kathmandu, the capital of Nepal, and covers an extreme range of elevation from 457 to 5,144 meters above sea level. Here, we describe an approach adopted by farmers in hill terrace of Nuwakot for cultivation of rainbow trout (*Oncorynchus mykiss*) as a part of their family income utilizing land unsuitable for other purposes and nearby to cold water streams or springs originating from local hills. Fish farming in terraces has been used by farmers as a means of controlling soil erosion. Fresh, smoked and fried trout from their farm serve both local and international tourists, generating income for the farmers.

Trout farming in terraces

Cultivation of trout utilizing springwater in the highland terraces, which are generally unsuitable for other high value crops, is referred to here as trout farming in terraces. From the beginning of modern aquaculture development in Nepal, the Himalayas have been visualized as an area offering great potential for trout cultivation, as the abundant supply of cold, well-oxygenated water and local environmental conditions are well suited to the requirements of these fish (Gurung and Basnet 2003; Rai et al. 2004). Rainbow trout were introduced in 1988, and are now one of the most successfully cultivated of the introduced fishes in Nepal. To date, no detrimental environmental impacts have been reported as a result of trout introduction in Nepal.

Trout farming in terraces has been established as part of a decade-long participatory research program undertaken by the Trishuli Fisheries Station, Nuwakot (Basnet et al. 2002). Initially, farmers with suitable farming sites including adequate cold water sources were selected and provided with knowledge and training on feeding, water management and the importance of hygiene for successful trout cultivation. They were also provided with trout fingerlings for rearing into raceway ponds, with the construction cost of raceways subsidized on a loan basis from financial institutions. At the initial stage pellet feed for trout were supplied from the Trishuli farm as the cost of pellet machine was prohibitive to poor farmers. Later, with the financial benefits obtained from selling trout, many farmers have come to possess their own locally assembled pellet mill.

There are presently about 12 such farmers engaged in trout farming in terraces. The farmers that have had the most success tend to be those that are located closer to the roadside, and who have a regular and abundant cold water supply (<21°C) for rearing higher densities of trout throughout the year.

The characteristics features of the raceways in Nuwakot are their looping (rather than traditional straight) structure constructed to suit the turning of the landscape. The length of these raceways varies from 4-6 m depending on the location. These modified terrace raceways incorporate a water supply and discharge system, with depth typically maintained at 30-40cm and a width of around 1m. Despite their unconventional design, farmers have not found any problems with fish production in terrace raceways. At present the trout productivity in private sector farms ranges from 12-18 kg.m^2 of raceway area (Basnet et al. 2003).

Marketing of trout

At present farmers do not have any problems selling their produce. There is an ever-ready market in both Nuwakot or nearby Kathmandu, or in other locations such as Pokhara, Jomsom and Namche Bazar. There is some potential to export trout to nearby countries in the region that do not cultivate their own. However, the cost of feed is an issue for the industry, as the approximate cost of producing pellets with 30-34% of crude protein is estimated to be nearly 60 Rs. (nearly 0.85 US$) per kg (depending on scale of production), while the conversion ratio of pellet feed to trout is about 3:1. As a result, the production cost is relatively high, but this is currently supported by a high local market price of 300-500 Rs (nearly 4.2 - 7.1 US$) per kg.

Expansion of trout farming in hill terraces

At present, trout production in Nepal is low averaging about 20-30 metric tons per year. The local market still has substantial capacity to absorb additional production. Large-scale adoption of terrace farming of trout could be a means of scaling up trout production in the region. However, there is need to develop sustainable and more reliable mechanisms of trout seed and feed production, supply, distribution and more efficient marketing channels. Presently, seed availability is one of the bottlenecks for the expansion of the trout farming in the country. At present there is only one trout hatchery producing about 200,000 fingerlings per annum. The number of fingerlings produced by this hatchery could be increased but there are some issues with siltation of the hatchery water supply that are constraining production. Thus, establishment of another trout hatchery in more feasible location for trout seed production has been recommended. If additional hatcheries facilities can be established and seed becomes more widely available more private farmers can be expected to commence trout cultivation in the hill and mountain regions. At present the local production cost of trout is high, however, greater production will allow economies of scale that will lead to cost reductions. There is an approximately 800 kilometer-wide belt of the Himalayan range that would offer suitable environmental conditions for trout culture in Nepal.

Conclusions and recommendation

The potential for successful trout culture in the hill and mountain areas of Nepal has been successfully demonstrated through the establishment of the first commercial farms. However, the industry is still at a very early stage of development and further investment is required to support its expansion. Key issues that need to be addressed, including through private investment, include:

i) Enhance hatchery and seed production facilities.
ii) Increase commercial feed production capacity.
iii) Initiate a trout producers association.
iv) Active promotion of trout production by extension agencies and relevant NGOs.

We expect that the mountain regions of Nepal have the potential to be able to produce sufficient trout to bring new taste to the people in the region, contribute to fulfill the anticipation of "fish for all", and improve the productivity and economic well being of the people in the high hill and mountain regions.

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Sugar industry by-products as plankton boosters and yield enhancers in carp culture systems

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Organic manures play a vital role in plankton production and are widely used to increase production of carps and many other fishes under culture. Upon decomposition organic fertilizers release nutrients that in turn stimulate phytoplankton growth. Aside from organic manures, industrial by-products also play a major role in increasing the fertility of ponds. Different forms of these industrial products (liquid and solid manures used in these trials) influenced phytoplankton and zooplankton productivity in farm ponds to help increase fish production.

Methodology

Two experimental cement ponds with the size of 0.03ha were stocked with carp seeds. The details of stocking are given in Table 1. In Pond A, the RSCL Mahasakthi Aqua Tonic (MAT) and in Pond B, the RSCL Green Plus Organic Manure (GPOM) were applied.

Apart from the routine parameters to estimate the growth and population of fishes, water quality parameters such as DO, pH, ammonia, nitrite, nitrate and phosphate were analysed. Transparency was measured daily as an index of fertilisation. Further, the qualitative assessment of plankton population produced due to fertilization was also analysed at weekly intervals.

Water quality parameters in trial ponds

Water quality parameters viz. hardness, alkalinity, ammonia, nitrite, nitrate and phosphate were analysed at regular intervals in the culture systems. High values of hardness were observed from ponds fertilized with MAT. Phenolpthalein alkalinity was higher in GPOM fertilized ponds while total alkalinity was higher in MAT fertilized ponds. Ammonia levels were observed to be

Table 1: Stocking density of carp seeds in trial ponds.

Species	Pond A	Pond B
	RSCL - MAT	RSCL - GPOM
Catla catla (Catla)	150	150
Labeo rohita (Rohu)	50	50
Cirrhinus mrigala (Mrigal)	50	50
H. molitrix (Silver Carp)	75	75
S. idella (Grass carp)	25	25
C. carpio (Common Carp)	25	25
Total no. stocked	**375**	**375**

Table 2: Estimated water quality parameters on daily basis in pond A (RSCL - MAT).

Date	PH	Temperature (°C, 9.30AM)	DO (ml/lit)	Transparency (cm)
March	9.35 – 9.74	33 – 36	12.8 – 13.76	20 – 25
April	9.05 – 9.5	31.5 – 35	12.1 – 13.37	20 – 24
May	8.39 – 9.12	30 – 34	12.2 – 13.76	15 – 25
June	8.17 – 9.62	28 – 32	12.6 – 13.57	15 – 20
July	8.17 – 9.62	28 – 31	12.1 – 13.26	25 – 35
August	7.18 – 8.73	28 – 31	5.65 – 9.92	35 – 45
September	8.15 – 8.64	29 – 31	6.48 – 6.89	15 – 30
October	8.15 – 8.37	27 – 31	6.53 – 7.14	20 – 40
November	7.85 – 8.32	26 – 30	6.53 – 8.37	30 – 40
December	6.83 – 8.21	27 – 31	6.15 – 7.27	20 – 40
January	7.67 – 8.29	28 – 31	6.29 – 7.21	30 – 35
(RSCL - MAT)				

Table 3: Estimated water quality parameters on daily basis in pond B (RSCL – GPOM).

Date	pH	Temperature (°C, 9.30AM)	DO (ml/lit)	Transparency (cm)
March	9.15 – 9.69	32°C – 34°C	12.8 – 13.44	32 – 35
April	8.91 – 9.25	32 – 34	12.8 – 13.76	25 – 30
May	8.3 – 8.99	28 – 34	12.5 – 13.23	25 – 30
June	8.58 – 9.32	28 – 32	12.8 – 13.44	20 – 30
July	8.58 – 9.32	28 – 32	10.88 – 13.44	10 – 15
August	7.35 – 8.53	28 – 32	5.32 – 12.16	20 – 40
September	8.37 – 8.81	29.5 – 32	6.43 – 6.87	20 – 25
October	8.07 – 8.31	27 – 31	6.23 – 7.13	20 – 35
November	7.15 – 8.97	26 – 29	6.68 – 7.31	25 – 30
December	7.67 – 8.31	28 – 31	6.73 – 7.34	20 – 30
January	7.64 – 8.17	28 – 31	6.71 – 7.19	20 – 25
(RSCL – GPOM)				

Limited water exchange growout pond with central drain facility.

Adding algal concentrate to raceways.

Fish catch from treatment pond.

Treatment pond.

within the permissible limits in GPOM and MAT ponds. However, an abrupt increase of ammonia level was noticed during February to April in MAT applied ponds. This may be due to the excess release of nutrients by the Aquatonic. Nitrite, nitrate and phosphate levels were relatively higher in GPOM fertilized pond but within permissible limits.

Impact of RSCL products on plankton production

Plankton production, an index of fertilization, was measured in terms of transparency in the treatment ponds. Though MAT and GPOM recorded almost an equal performance in terms of plankton production during the first three months of the crop, subsequently GPOM showed a relatively a better performance. The results clearly demonstrated that the performance of GPOM was better than that of MAT with respect to plankton production in carp culture systems.

Net primary productivity (NPP) and Gross primary productivity (GPP) were lower in both the treatment ponds during the initial period. However, both NPP and GPP showed increased productivity in the subsequent two months. Further, after every fertilizer application an increase in productivity was also observed.

Initially, a greater number of plankton species were recorded in the pond fertilized with MAT (65%) to that of the pond fertilized with GPOM (35%). However a steady increase in the number of plankton species was found in the GPOM fertilized pond. Finally a higher percentage (64%) of plankton species was recorded in the GPOM - fertilized pond compared to the 36% of plankton recorded in the pond fertilized with MAT. Dominant and desirable plankton species viz. *Pediastrum* sp., *Anabaena* sp., *Closterium* sp., *Volvox* sp., *Scenedesmus* sp., *Spirulina* sp. and *Mesocyclops* sp. were found in larger numbers in GPOM fertilized pond to that of MAT - fertilized pond.

Aclimatisation of shrimp seed in raceways.

Fish yield in relationship with fertilization

Mortimer (1954) was of the view that fertilization will generally cause an increase in fish production. He reported that while unfertilized carp ponds in Germany yielded 20 – 50 Kg/ha/yr;

Table 4: Plankton species recorded in trial ponds.

Sampling period	MAT		GPOM	
	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton
Initial	*Closterium* sp. *Scenedesmus* sp. *Cosmarium* sp. *Spirulina* sp. *Coelosphaerium* sp. *Synedra ormosa* *Asterionella* sp. *Micronella* sp. *Microcystis* sp. *Oscillatoria* sp. *Myxophyceae*	*B. fulcatus* *B. havensis*	*Pediastrum* sp. *Anabaena* sp. *Oscillatoria* sp. *Chlorella* sp. *Closterium* sp. *Spirulina* sp.	*K. tropica*
Final	*Closterium sp.* *Cosmarium* sp. *Spirulina* sp. *Oscillatoria* sp. *Anabaena* sp. *Chlorella* sp. *Pediastrum* sp.	*Euchlanis dialata* *Philodina* sp.	*Scenedesmus* sp. *Spirulina* sp. *Chlorella* sp. *Microcystis* sp. *Coelospharium* sp. *Oscillatoria* sp. *Cladophora* sp. *Ulothrix* sp. *Cosmarium* sp. *Desmidium* sp.	*Euchlanis dialata* *Mesocyclops hyalinus* *Brachinus forficula* *Rotaria vulgaris*

Table 5: Estimated growth parameters in trial ponds.

Species	MAT*		GPOM*	
	Total Weight (kg)	SGR	Total Weight (kg)	SGR
Catla	29.112	0.015	30.1266	0.016
Rohu	24.034	0.016	24.350	0.017
Mrigal	28.328	0.016	34.920	0.017
Silver Carp	23.128	0.015	19.120	0.015
Grass Carp	17.088	0.017	17.032	0.019
Common Carp	13.035	0.017	15.420	0.018
Total	134.725		141.008	

MAT – Pond fertilized with Mahasakthi Aqua Tonic
*GPOM – Pond fertilized with Green Plus Organic Manure
MAT: 134.725 kg/0.03 ha/yr = 4,466 kg/ha/yr
GPOM: 141.008 kg/0.03 ha/yr = 4700.26 kg/ha/yr
Control (Pond with cow dung as fertilizer) = 4,000 kg/ha/yr
Duration of culture: 365 days

Table 6: Significant growth rate in MAT fertilized pond against the control.

ANOVA	At 5% level (P<0.05)				
Source of Variation	SS	DF	MS	F	P-value
Between species	370145.7	5	74029.13	230.3726	6.64E-06
Against control	7739.888	1	7739.888	24.0859	0.004444
Error	1606.726	5	321.3452		
Total	**379492.3**	**11**			

fertilized carp ponds yielded 200 – 400 kg/ha. Tropical lakes produced 2,240 kg/ha of fish, but fertilized ponds in tropical Africa yielded 5,135 – 9,000 kg/ha of fish.

The economic implication of the relationship between fertilizer rate and yield has been established. The fertilizer cost per unit weight of crop increases with each successive unit of fertilizer applied. Because of the diminishing returns, a point is soon reached where the cost of an additional unit of fertilizer is greater than the value of the incremental increase in productivity. This study confirms that sugarcane byproducts have the potential to be a cheap and effective source of fertilizer for the aquaculture sector. Hence, the sugar industry's byproducts tested through farm trials can be utilized effectively as fertilizers in carp ponds to boost primary and secondary production.

The treatment ponds recorded fish yields at the rate of 4,466 kg/ha/yr and 4,700 kg/ha/year for MAT and GPOM treatments respectively. The fish yield from conventional fertilization will be around 4,000 kg/ha (as per our Institute's farm data). Therefore we conclude that both the ponds ferti-

Table 7: Significant growth rate of MAT fertilized pond against the control.

ANOVA	At 5% level (P<0.05)				
Source of variation	**SS**	**DF**	**MS**	**F**	**P-value**
Between species	515057.5	5	103011.5	11.80214	0.0085
Against control	59327.58	1	59327.58	6.797226	0.047834
Error	43641.02	5	8728.205		
Total	**618026.1**	**11**			

lized with sugar industry byproducts showed significantly better growth rate ($P<0.005$) against the control. A yield enhancement of 12% and 17.5% were recorded for MAT and GPOM treatments respectively. Among the two products tested, the carp pond fertilized with GPOM recorded a better yield than the MAT fertilized pond.

Conclusion

The water quality parameters were found to be within the desirable limits in both treatment ponds fertilized with Mahaskthi Aqua Tonic (MAT) and Green Plus Organic Manure (GPOM) respectively. The plankton species diversity demonstrated the effect of these products on the culture system. Both products favoured plankton production within optimum water quality parameters and did not cause excessive plankton blooms under the dosage and conditions of this trial. There was an increase of 12 to 17.5% in fish production with use of these products respect to the control pond. This clearly established the positive effect of these by-products on fish yield. The results of growth rate in both treatments (fertilized ponds) were significantly higher ($P<0.05$) than the control (Table 6 and 7) indicating that the RSCL products have better influence on plankton productivity and fish yield.

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A note on the growth and production of *Penaeus monodon* in low saline culture systems of Kerala

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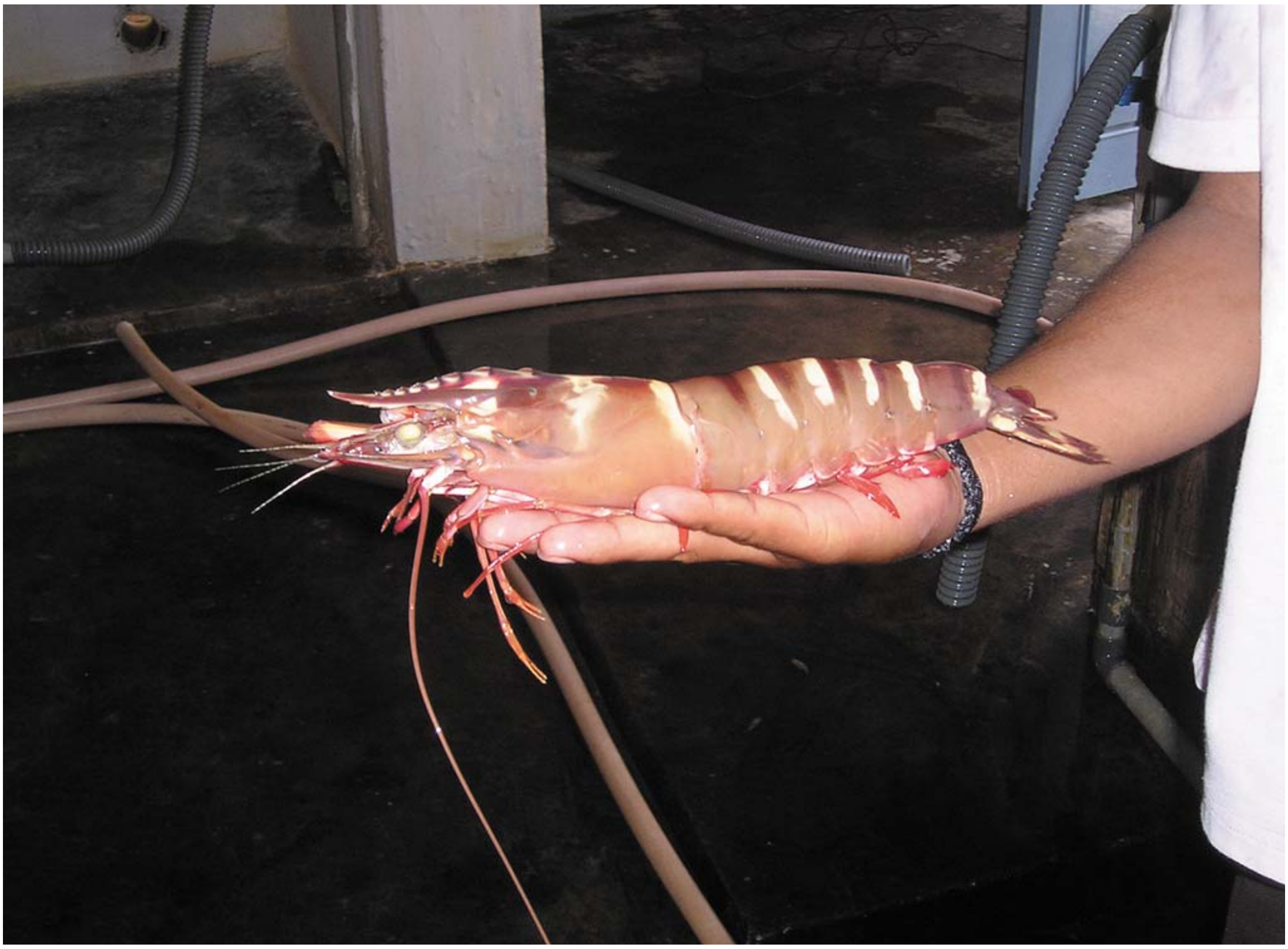
The tiger shrimp *Penaeus monodon* is universally recognised as one of the most important cultured species, particularly in the Asian countries. It is a fast growing, euryhaline, omnivorous and hardy species well known for its delicious flesh and high commercial value. Hence it contributes to the major share of shrimp production from farming. Different ranges of salinity have been reported to support the survival and better growth of this shrimp. Muthu (1980) and Karthikeyan (1994) recommended a salinity range of 1-35 ppt, while Rajyalakshmi (1980) and Chanratchakool et al. (1994) recommended a salinity range of 15-20 ppt and 10-30 ppt respectively for rearing this species. Chen (1984) reported that a salinity range of 15-22 ppt is optimal for culturing *P. monodon* in coastal areas. However, it has been generally accepted that *P. monodon* can grow as well in freshwater conditions (ASEAN 1978). A high rate of survival and good growth for this species in freshwater lakes has been reported from the Philippines (Pantastico 1979). Monoculture of *P. monodon* in rivers, irrigation channels and ground water has been successfully accomplished in Thailand (Raghunath et al. 1997). Athithan et al. (2001) reported the production of *P. monodon* in hard water systems.

The traditional brackish water shrimp culture is an age-old practice in Kerala, the southern most state of India. More than 1,000 ha of low-lying water area in the northern part of Alleppey District adjacent to Vembanad Lake in this tiny state. This area receives a low tidal influence from January to the middle of May, and hence a low saline condition prevails in this season with salinity typically ranging from 2-7 ppt. Some enthusiastic farmers in this area are engaged in monoculture of *P. monodon* with varying degrees of management practices in small culture ponds. A preliminary study was undertaken to assess the growth and production of *P. monodon* in these low saline ponds under two different stocking densities.

Approach

The study was undertaken in two adjacent low saline ponds in Vayalar in Alleppey District of Kerala. Culture practices following in both ponds were similar and included drying on pond bottom, tilling and liming at the rate of 500 kg/ha, filling the ponds with tidal water to a depth of 60cm and application of mahua oil cake at the rate of 200 ppm to kill predators and weed fishes.



P. monodon broodstock.

The ponds were stocked with 20 day old post larvae (PL 20) of *P. monodon*, average weight 0.02g obtained from a local hatchery. Stocking was carried out at two densities, 4 and 15 individuals/ m^2. Factory produced dry pelleted feed containing 30% protein was applied as the supplementary feed. The initial feeding rate was 20% of the body weight, which was gradually reduced to 2% as the culture progresses. Daily feed quantity was adjusted based on estimation of biomass, monitoring check trays and feeding behaviour of the animals particularly during molting periods. 20-25% of the water was exchanged every day with tidal water and an average water depth of 80T was maintained in the rearing period.

On the 30th day and thereafter every 15th day average body weight of the animals was estimated by considering 250 shrimps collected by cast net from different parts of the ponds. Harvesting was carried out by netting and hand picking after 120 days. Survival was estimated from the number of shrimps harvested and specific growth rate and biomass were estimated following the approach of Dash and Patanaik (1994) and New (1976) respectively. Water quality parameters such as pH, dissolved oxygen and salinity were monitored with an electronic water quality checking apparatus and transparency was determined with a Sechi disk once per week.

Outcomes

The ponds are closely situated and the source of water is the same, hence there were no significant differences in the water quality parameters of the ponds except transparency. The salinity values ranged from 3.6 to 6.4 ppt. The pH was alkaline throughout the culture period, ranging from 7.4 to 8.2. Mean dissolved oxygen values ranged from 480 to 6.86 ppm. Secchi disk transparency was high in the less stocked pond (35-44 cm) than the high stocked pond (26.5-32.4 cm). The results of the observations are presented in table 1.

The average body weight of *P. monodon* at harvest after 120 days of culture was higher in the low-density pond (28.0g) compared with that of the high-density pond (18.5g). The specific growth rate also showed the same patter, being higher in the low-density pond. However, the total biomass increase was greater in the high-density pond (12.5 kg/ha/day) than in the low-density pond (5.42 kg/ha/day). This difference in biomass increase between the ponds is a function of the stocking density of the culture ponds. In the present study the average growth in the low-density pond is 28.0 g in 120 days of rearing which is a higher value than the earlier reports for similar types of systems (Guru et al. 1993, Saha et al. 1999, Athithan et al. 2001). The high growth rate obtained in the present study may be because of the better utilization of pelleted feed as well as the natural food available in the system.

The growth is comparatively low in the high-density pond. The low weight and comparatively low survival rate in this pond could be due to the high stocking density of the animals, which may have resulted in overcrowding.

Table 1: Results of the farming of *P. monodon* in low saline conditions.

Pond	Area of pond (ha)	Stocking density (No. / m^2)	Survival rate (%)	Size at harvest (g)	SGR (%)	FCR	Increase in biomass (kg/ha/day)	Yield (kg/ha)
1	0.2	15	54.2	18.5	15.5	1.85	12.5	1500
2	0.2	4	58.1	28.0	23.3	1.71	5.42	650

The gross production after 120 days of culture was 1500 kg/ha in the high-density pond and 650 kg/ha in the low-density pond. The results obtained in the present study for the high stocking density are similar to the observations of Saha et al. (1999) for similar conditions. Manik et al. (1978), Saha et al. (1990) and Athithan et al. (2001) have also reported that satisfactory growth of *P. monodon* is possible in low saline water, thanks to the wide salinity tolerance of this species. It can be concluded that the vast low saline low lying uncultivable areas / paddy fields adjoining the Vembanad backwater system in the Alleppey District of Kerala can be effectively utilized for the culture of *P. monodon* in the summer months of the year. In the rest of the period either paddy or fresh water fishes and prawns can be cultured so that the farmers can raise income throughout the whole year.

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Peter Edwards writes on

Rural Aquaculture

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Poor households raise prawns for export

Prawns harvested from a community-level pond.

In March I had an opportunity to visit the Greater Noakhali Aquaculture Extension Project (GNAEP) in Bangladesh, a Danida-funded project in which my former colleague at AIT, Harvey Demaine, is currently Extension & Training Advisor. Harvey and I literally passed each other in the air as he was on leave in Bangkok during my visit to Bangladesh but Reshad Alam, Programme Manager, was a most effective guide during my 3 day visit to Noakhali.

I confess to being amazed at what I saw: the intensive farming by poor and sometimes women-headed households of a crustacean and for export. Readers may recall that Harvey (I shouldn't "let him off the hook") and I defined rural aquaculture about 10 years ago as "the farming of aquatic organisms by small-scale farming households using mainly extensive and semi-intensive husbandry for household consumption and/or income". We were criticized for such a narrow view of rural aquaculture during the discussion of the role of aquaculture in rural development at the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium in 2001 (see my column in Aquaculture Asia Vol. 6, No. 4, pp. 14-15) which was re-enforced in my mind visiting GNAEP.

The overall goal of GNAEP is to improve the lives of poor fish farmers by raising income from improved and sustainable aquaculture practices. The project originally focused mainly on carp polyculture in the small ponds available to most households but it was found that even improved culture of carps did not significantly increase household income. Therefore GNAEP is now promoting culture of high-value

A typical seasonal ditch in a rice field used to nurse PLs to juveniles during the rainy season.

giant river prawn (Macrobrachium rosenbergii) for export and this has lifted some farming households out of poverty within two years. In doing so the project has switched its attention towards the so-called “hard-core” poor, most of them located in new settlement areas on the charlands in the southern part of the project area. A char is land that has emerged from the river over the past few decades through siltation. GNAEP is targeting women-headed households as at least 16% of the households in the char area settlement villages are headed by extremely poor women.

These households have either a small pond or ditch constructed to raise the level of their homestead or a ditch in the ricefield. Such shallow water bodies are not suitable for either carp or prawn grow-out as they are seasonal, retaining water for only a few months, but can be used for nursing. Prawn post larvae (PLs) are stocked and nursed for 2 months to juveniles and are then sold to better-off farmers and groups of households managing community ponds. Two prawn nursery cycles give a huge average net return of Tk. 8,000 (US$1 = Tk. 70 approximately) for the two crops even though the level of feeding is quite small, only a total cost of Tk 2,000-3,000 per crop. Several households used the money earned in the first year of nursing to get back their land from money lenders with whom they were forced to mortgage the land as a result of household emergencies. Subsequently, they have invested in other enterprises such as vegetables and small-scale livestock, which have further improved their livelihoods.

The GNAEP is also promoting prawn grow-out in polyculture with carps in community ponds in formal settlement villages in the charlands. Thanarhat cluster village was visited, with 2 ponds each of 4,000 m^2 with 30 households farming each pond as well as Ashrayan cluster village with 9 ponds, the one visited managed by 50 households. Harvested prawns at a size of 3-4 pieces/kg were worth TK. 730/kg, an incredible 12-14 times higher than the price for carps. Although formulated feed is being provided to the community ponds, the level of feeding is again quite small, Tk 5,000-8,000 per pond, and is mainly obtained as

A wife and her husband with prawns harvested from a household-level pond.

Women members of a CBE, some with their prawn farming registration documents.

credit-in-kind. It is remarkable the size the prawns had attained during my visit after stocking for 8-9 months.

The GNAEP has developed an extension strategy involving the establishment of community-based organizations (CBOs) (or more appropriately named community-based enterprises, CBEs) and partnership with various private entrepreneurs. The project has now organized 3,500 farmers in 85 CBEs to create what should eventually be a sustainable extension service for the farmers with the participation of the private sector, which is involved primarily to promote its own business. Although the actual membership of the CBEs is 3,500, they served up to 8,000 prawn farmer clients in 2005. This is an alternative extension strategy to the usual one in Bangladesh involving NGOs, which is not sustainable in the long term as they rely on finite donor funding and sometimes create a dependency relationship with their farmer clients.

Input supply (seed and feed) is carried out through the farmer managed CBEs. The CBEs determine the demand for PLs from the farmers in their area. The hatcheries produced 7.9 million in 2005, of which 5.5 million

Prawn farmers with prawn farming records and certificates.

The Upakul Freshwater Prawn Hatchery in Noakhali.

were sold through the CBEs. This year the demand is clearly more and production of PLs is underway. By the end of April, 4.6 million had been distributed of which 4.2 million went out through the CBEs. They also determine the demand for feed. Last year the pelleting factory sold 800 tonnes of feed to GNAEP farmers and the predicted demand is for 2,000 tonnes this year based on CBE reports. The private sector also provides a commission on sales to the CBEs as an incentive that should ensure their sustainability as well as credit-in-kind to hardcore poor farmers.

The GNAEP has established a partnership with poor inshore coastal fishers on the island of Hatiya to provide a supply of pesticide-free sun-dried small marine fish which is ground at the Noakhali Gold Agro Feeds feed mill in Noakhali to produce "fish meal" (actually fish powder) as an ingredient for the pelleted feed. In return the 80 boats involving 800 households in 2006 get a fair price for their fish as they are now able to by-pass exploitive middlemen. Noakhali Gold Agro Feeds has bought 350 tonnes of dried fish in the 2005-2006 season for inclusion in prawn feed.

The Noakhali Gold Foods Ltd. Processing Plant in Noakhali.

Partnerships have been established with two private hatcheries with a combined capacity of about 14 million PLs annually. GNAEP is providing technical assistance to the hatcheries to produce PLs without the use of antibiotics. The hatcheries sell PLs at Tk. 1.25 per piece, half the price previously charged by the hatcheries of the large NGO BRAC, thus making them affordable to poor farming households.

The third major private sector investment is an HACCP approved processing plant of 10 tonnes/day capacity, Noakhali Gold Foods Ltd., the construction of which has been facilitated by the Royal Danish Embassy Private Sector Development Programme, recently renamed B2B which stands for Business to Business. The plant is currently processing white fish but has agreed to center its local marketing strategy on collection of prawns through the CBEs for export to the EU, Japan and the USA.

The Noakhali Gold Prawn Industries Association comprising the various private sector partners has recently been established to ensure overall quality control in the system as well as with a view to eventually taking over from the GNAEP technical assistance. As there is traceability of inputs (pesticide-free fish powder and antibiotic-free PLs), as well as in prawn grow-out, marketing and processing, attempts are being made to secure formal certification to gain a premium price. It is hoped that discussions on small farm clustering for certification to be held in Bangkok in June, under the auspices of the Global Aquaculture Alliance, will facilitate this effort.

Asia-Pacific Marine Finfish Aquaculture Network

Magazine

Marine fish marketing systems in coastal Bangladesh: Potential for development

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Bangladesh's coastal waters contain diverse fisheries resources, with 475 recorded species of finfish including the cartilaginous fishes - sharks, skates and rays (Mazid, 2005). However, only 90 fish species are commercially important. These fall under the common groups of hilsa (herring), pomfret, marine catfish, tuna, coral fish, marine eel, jawfish, ribbonfish, bombay duck and shark (Fisheries Sector Review, 2003). The majority of the commercially targeted stocks are reported to be over-exploited and there were significant declines in catches after around 1997 (Kleih et al., 2002).

The marine fisheries sector has been recognized as an important part of the economy. Marine fisheries production has marginally increased over the last 10 years but its relative share in fisheries production has declined from 31% in 1991 to 22% in 2004. The total fish production in Bangladesh was 2.1 million tons in 2004 of which 43% was from freshwater aquaculture, 35% from inland fisheries and 22% from marine sources (DOF, 2005).

In terms of volume, value and employment, the marine fish market in

Typical fishing boats in the Patuakhali coast, Bangladesh.

Bangladesh is large. The fish marketing system is traditional, complex, and less competitive but plays a vital role in connecting the fishermen and consumers, thus contributing significantly in the 'value adding' process which otherwise would have been unused or underused and consequently in the earnings of the fisherfolk (Chowdhury, 2004). In Bangladesh, the market for fish is associated with strong demand, driven by continued increases in rural and urban populations, real term growth in income amongst key consuming sectors, and a traditional and continuing preference for fish in the diet. Fish play an important role for the population of Bangladesh as indicated by the proverb 'mache bhate Bangali' (fish and rice make a Bengali). However, fish consumption appears to have fallen marginally because fish prices have been increasing faster than prices

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Auctioning fish by an aratdar.

of other commodities (Fisheries Sector Review, 2003).

Fish prices have increased due to the middlemen in the marketing sector, as they have established a new marketing chain based on the exploitation of the fishing communities by setting up an artificial pricing chain through intermediaries at different levels (Kleih et al., 2001). The most serious marketing difficulties seem to occur in remote fishing communities, which lack regular supplies of ice, have poor transport facilities and where the fishermen are in a weak position in relation to intermediaries (Kleih et al., 2003). In such locations, many fish are processed into lower valued cured products and the process of curing often involves considerable losses due to spoilage. Post-harvest losses also occur in all fish distribution and marketing systems. Due to the growing gap between fish supply and demand it is important to reduce losses as much as possible for the benefit of poor marketing people and consumers.

This study sought to broadly understand marine fish distribution and marketing systems in the Patuakhali area of southern Bangladesh. Primary data were collected for six months from July to December 2005 through a field survey employing questionnaire interviews, rapid market assessment, cross-check interviews with key informants, and participatory rural appraisal tools such as focus group discussion and SWOT analysis (Strengths, Weakness, Opportunities and Threats). Fifty questionnaire interviews were carried out, which included 20 assemblers, 10 wholesalers and 20 retailers. This paper provides information on commercially important marine fish distribution and marketing systems, marketing costs, prices of fish, marketing margins and profits, incomes of traders, and constraints of fish marketing. It also provides some recommendations for further development of marine fish marketing systems in coastal Bangladesh.

Catch composition of marine fish

A large number of people, many of whom live below the poverty line, find employment in the coastal fish marketing chain as fishermen, assemblers, processors, traders, intermediaries, transporters and day labourers, including women and children. Coastal fishing in Bangladesh is highly seasonal, with the main hilsa (*Tenualosa ilisha* – the national fish of Bangladesh) season taking place between June and September, and other fishing during the calm weather from October to May. Hilsa is the main species caught in the Bay of Bengal. A breakdown of the catch of commercially important marine fish is presented in Figure 1.

Fishermen work on their own boat or other people's (locally known as mahajans) boats. Fishermen who work on mahajans' boats tend to have

Icing of fish at the landing center.

an arrangement with the boat owner regarding the share of the catch. Usually the owner of the boat retains about 50-60% of the catch and the fisherman keeps the remainder. The boat owner, who may not necessarily join the fishing at sea, sells the entire catch himself and keeps the sales proceedings. The owners have got full control over the fishermen as they have extended credit for the purchase of their nets and other fishing equipment. Fishermen often feel exploited by the mahajans – believing that the prices they receive for their catch do not adequately reflect the prices paid for fish in the wholesale or retail markets where they are subsequently sold.

According to the survey, 88% of the marine catch in the study area is marketed internally for domestic consumption while the remaining (12%) is exported to the international market. Bangladesh exports frozen fish primarily for overseas ethnic markets. There is a demand for fish by Bangladeshis living outside the country (e.g. UK, USA, Middle East, etc). They demand good quality hilsa, pomfret and other fish. Export of hilsa also takes place to India (Kleih et al., 2003).

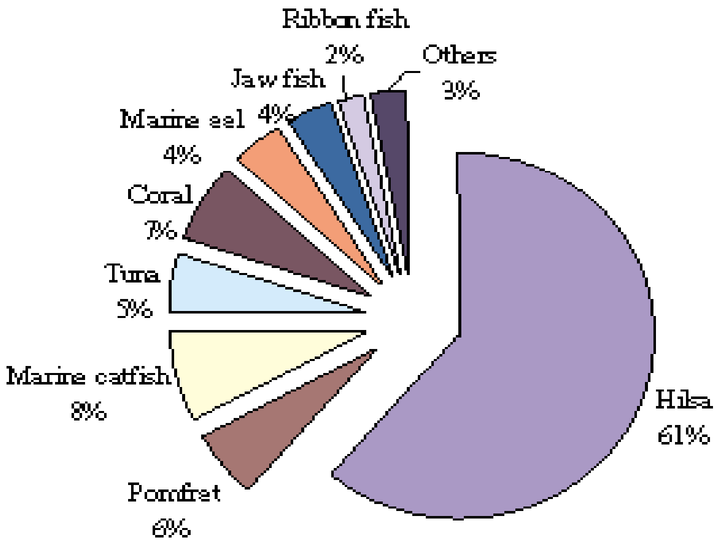
Fish marketing systems

In the study area, fish marketing is almost entirely managed, financed and controlled by a group of powerful intermediaries. The market chain from fishermen to consumers encompasses mainly primary, secondary and retail markets, involving sales agents, suppliers, wholesalers and retailers (Figure 2). Fishermen are the primary producers in the fish marketing chain. With a few exceptions, fishermen never directly communicate with wholesalers, retailers and consumers. Fishermen tend to sell their catch at the landing centers (primary markets) to suppliers (locally known as baperies or paikers) with the help of commission-based sales agents (aratdars). Aratdars play a leading role in the fish marketing systems at primary markets. As soon as the fishermen land the fish in the primary market, the aratdar takes care of landing, handling, sorting and auctioning by species and size-groups. Normally, the auction sale is made by heaps. In general, aratdars follow the incremental price system. It is the most competitive form of auctioning and ensures better prices for fishermen. Auctioneers call out the bid by the bidders loudly in the presence of the buyers. Aratdars get commission at different rates of the sale proceeds, normally 2 to 5% of the auction price, for their services and costs involved.

In the present fish marketing system, the auctioneers and baperies (local or non-local traders) play a crucial role in determining prices for marine fish at the landing centre. Communication between the aratdars and baperies is generally good and takes place by mobile phones. Baperies are a form of intermediary traders who supply fish from primary market to wholesale market. In general, baperies are tied to a limited number of aratdars. A few labourers work with the aratdars and baperies. They perform post-harvest tasks that include cleaning, sorting, grading, icing and transportation. Baperies commonly use boats, trawlers, micro-buses, buses and trains to transport fish from coastal areas to the wholesalers at urban fish markets who then sell to retailers.

Two main categories of fish retailers have been encountered: market-based retailers and itinerant retailers (fish

Figure 1: Catch composition of marine fish in the Patuakhali area (Source: survey data, 2005).



A registered worker at primary market.

vendors, hawkers, etc). Retail sales are made at stalls in fish markets and to door-to-door to household customers. Fish are traded whole, ungutted, and fresh without processing apart from sorting and icing. More than 75% of the total marine catch is actually consumed in distant places, so it requires processing, icing and transportation. A large number of day labourers including women and children are involved in the process. The travel duration between primary markets and retail for urban markets is usually less than 12 hours. People in Bangladesh generally prefer fresh fish without icing. The next preference is for iced fish (Chowdhury, 2004). Fish is iced with consideration of transportation, space and time. If the transportation time is less than six hours from primary market to retail point the fish is not iced, or if iced, it is not done properly. Other forms of fish products are frozen, salted and dried.

According to the survey, the percentages of fish product forms were 35% fresh, 45% iced, 12% frozen, and 8% dried. As there is a large gap between supply and demand, fish marketing, or selling of fish, is very easy in primary, secondary and retail markets. The demand for fish is high in markets but supply is limited, and a strong network has developed with intermediaries and traders intervening between fishermen at one end and the consumers at the other end.

Marketing costs

Fish marketing costs include expenses such as rental of the market place, ice, electricity, transport, and labour etc. The costs of fish marketing depend on the species, volume of fish, market distance, market infrastructure, mode of transportation, form of marketed fish (i.e. fresh or iced), and labour required. The average marketing costs for marine fish in different markets are shown in Table 1. The highest average marketing cost per kilogram of fish was found in the secondary market (Tk 5.10 or US$ 0.07 per kg) followed by the primary (Tk 3.90 or US$ 0.05 per kg) and consumer markets (Tk 3.10 or US$ 0.04 per kg).

Figure 2: Marine fish marketing channels from fishermen to consumers (based on survey).

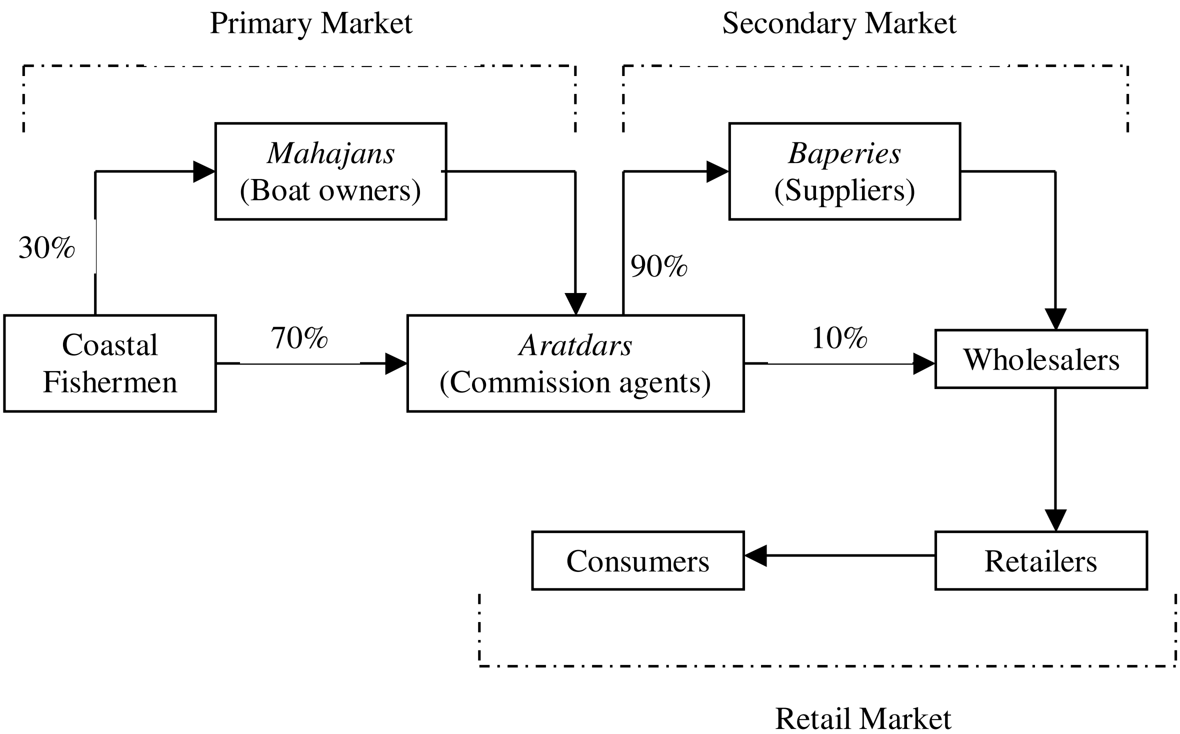


Table 1: Average marketing costs (Tk/kg) incurred for marine fish in different markets.

Marketing cost component	Primary market	Secondary market	Retail market
Icing	0.20	0.40	0.30
Transportation, loading and unloading	0.30	0.50	0.20
Rent of market place	0.30	0.40	0.60
Electricity	0.40	0.30	0.60
Weight loss/damage	0.20	0.50	0.40
Wage and salaries of workers	0.60	0.90	0.60
Commission for auctioneers	1.60	1.80	---
Others (market toll, water for washing fish, etc.)	0.30	0.30	0.40
Total	3.90 (US$0.07)	5.10 (US$ 0.05)	3.10 (US$ 0.04)
Source: Survey data (2005)			

Table 2: The average sale prices of commercially important marine fish in different markets.

Fish	Primary market		Secondary market		Retail market	
	Tk/kg	US$/kg	Tk/kg	US$/kg	Tk/kg	US$/kg
1. Hilsa	70	1.02	95	1.39	110	1.61
2. Pomfret	120	1.76	150	2.20	175	2.57
3. Marine catfish	40	0.58	55	0.80	65	0.95
4. Tuna	75	1.10	105	1.54	120	1.76
5. Coral fish	70	1.02	95	1.39	105	1.54
6. Marine eel	35	0.51	50	0.73	60	0.88
7. Jawfish	50	0.73	60	0.88	70	1.02
8. Ribbonfish	40	0.58	55	0.80	65	0.95
9. Bombay duck	25	0.36	40	0.58	50	0.73
Source: Survey data (2005)						

Table 3: Percentage shares of total value to marketing people for commercially important marine fish.

Fish	Fishermen share	Baperis (Suppliers) Share	Wholesalers Share	Retailers Share	Total
1. Hilsa	55%	9%	22%	14%	100%
2. Pomfret	57%	10%	19%	14%	100%
3. Marine catfish	46%	16%	14%	15%	100%
4. Tuna	54%	9%	25%	15%	100%
5. Coral fish	57%	10%	23%	10%	100%
6. Marine eel	42%	16%	25%	17%	100%
7. Jawfish	57%	14%	15%	14%	100%
8. Ribbonfish	49%	13%	23%	15%	100%
9. Bombay duck	40%	10%	30%	20%	100%
Source: Survey data (2005)					

The price of fish depends on species, quality, size and weight, season, market structure, supply and demand, and consumption behaviour of consumers (i.e. taste). Fish prices are known to follow a seasonal pattern. When supplies are scarce fish prices increase. Demand behaviour may also contribute to inter-seasonal price fluctuations. There are many factors affecting the price of fish through demand and supply. On the supply side, fish prices are affected by the seasonality of production, and weather conditions which cause the seasonality of the market supply, i.e. the quantity of the product available on the market (Briones et al., 2004). In the study area, prices are generally lower between August and December, rising during the following four to five months. Table 2 shows the average prices of commercially important marine fish from landing site to retail level. Over the last ten years, fish prices have increased dramatically, at a rate of 2.3% annually (Fisheries Sector Review, 2003).

Prices also vary from market to market. Prices in town markets tend to be higher than in coastal markets due to a larger concentration of consumers and superior family incomes. Moreover, market prices differ according to species and size. For the same species, price depends closely on the size of the fish, with larger fish fetching significantly higher prices per kilogram. The present study found that higher value fish such as hilsa, pomfret, tuna and coral fish can only be afforded by wealthier consumers. On the other hand, lower income groups depend on cheaper fish such as bombay duck, marine eel, jawfish, and marine catfish etc.

Marketing margins and profits

There exists a wide variation in the price received by fishermen for various marine fishes in different marketing

Fish landing site in Kolapara, Patuakhali.

Child labour in fish market.

channels over distance and time. The factors influencing such variation include marketing costs, marketing margins, numbers of intermediaries in the marketing channel, distances between the landing points and consumers' locations and prices. The margins received by intermediaries involved in the process of marine fish trade significantly discriminate against the fishermen on price in the Patuakhali area. Table 3 shows the percentage of value accruing to fishermen, suppliers, wholesalers and retailers. In almost all cases, fishermen received the majority share of the market value (40-57%). In the cases of hilsa, pomfret, tuna, coral fish and jawfish, fishermen received over 50% of total value. However, fishermen received less than 50% of total value for marine catfish, marine eel, ribbonfish and bombay duck. Amongst the intermediaries, the highest margins were received by wholesalers. These margins ranged from a low of 14% for marine catfish to a high of 30% for bombay duck.

Marketing margins and profits vary for different groups of fish. Table 4 provides an overview of hilsa (national fish which accounts 61% of total market share) traded between Patuakhali and Dhaka. The highest average marketing margin per kilogram of fish was found in secondary markets (Tk 25 or US$ 0.36 per kg) followed by retail (Tk 15 or US$ 0.22 per kg) and primary markets (Tk 10 or US$ 0.14 per kg). Similarly, the highest average marketing profit was found in secondary markets (Tk 19.90 or US$ 0.29 per kg) followed by retail (Tk 11.90 or US$ 0.17 per kg) and primary markets (Tk 6.10 or US$ 0.08 per kg).

It is calculated that fishermen receive 55% of the final retail price. The total marketing margin is 45%, which is sub-divided into: 1) primary market: 9%, 2) secondary market: 22%, and 3) retail market: 14% (Table 4). It should be mentioned that in this case the marketing margin is relatively high due to the long distance between Patuakhali and Dhaka, which involves several transport stages and trader categories. Compared to the above figure, Kleih et al. (2003) identified a fisherman share of 60-65% and a middleman share of 25-40% for hilsa sold in Chittagong and Cox's Bazaar markets.

Income of traders and associated groups

Fish trading is a profitable business and almost all traders reported that they had made profits and increased income. According to the survey, the average daily income of a fish trader (retailer) was calculated at Tk 190 (US$ 2.79) which is higher than fishermen and day labourers, but lower than wholesalers, aratdars and baperies (Table 5). Survey results showed that a wholesaler makes an average net profit of Tk 310 (US$ 4.55) per day. The average net profit of wholesalers was higher than any other marketing people due to access to capital, higher education levels, greater experience of fish trading, and control of fish marketing systems (i.e. powerful intermediaries). Fishermen stated that their average daily income was Tk 150 or US$ 2.20, and varies with fishing rate, weather conditions and the market price of fish. Increasing population pressures may aggravate the problem of meager incomes of fishermen.

Marketing constraints

In general, facilities at fish markets are minimal, with poor hygiene and sanitation. There are currently no stand-

Table 4: Calculation of marketing margin and profit for hilsa in different markets.

Markets	Items	Tk/kg	US$/kg	Percentage
Primary market	Purchase price (PP)	60	0.88	55%
	Marketing costs (MC)	3.90	0.05	
	Sales price (SP)	70	1.02	
	Marketing margin (MM=SP-PP)	10	0.14	
	Marketing profit (MP=MM-MC)	6.10	0.08	
Secondary market	Purchase price (PP)	70	1.02	64%
	Marketing costs (MC)	5.10	0.07	
	Sales price (SP)	95	1.39	
	Marketing margin (MM=SP-PP)	25	0.36	
	Marketing profit (MP=MM-MC)	19.90	0.29	
Retail market	Purchase price (PP)	95	1.39	86%
	Marketing costs (MC)	3.10	0.04	
	Sales price (SP)	110	1.61	
	Marketing margin (MM=SP-PP)	15	0.22	
	Marketing profit (MP=MM-MC)	11.90	0.17	
Consumer purchase price		110	1.61	100%
Source: Survey data (2005).				

Table 5: The average daily income of fish marketing actors.

Market actors	Daily Income	
	Tk/day	US$/day
1. Fishermen	150	2.20
2. Aratdars (commission agents)	220	3.23
3. Baperies (suppliers)	255	3.75
4. Wholesalers	310	4.55
5. Retailers	190	2.79
6. Women traders	110	1.61
7. Day labourers	80	1.17
8. Children	50	0.73
Source: Survey data (2005).		

Table 6: SWOT analysis for the development of marine fish marketing systems.

Strengths	Weaknesses
• Diversity of marine fisheries resources • Almost all Bangladeshi people eat fish • Large number of people involved in fish marketing • Traditional and less competitive marketing systems • Strong network of marketing people • Environmentally friendly activities	• Poor market infrastructure • Unhygienic conditions • Inadequate ice facilities • Lack of concern from the government and NGOs • Weak fishermen's cooperative societies and traders' associations • Poor socio-economic conditions of traders & associated groups
Opportunities	**Threats**
• High demand for marine fish • Employment opportunities • Export potential • Increase in fish price will increase incomes • Improvement of socio-economic conditions of marketing people	• Inadequate supply of fish • Controlled by powerful intermediaries • Comparatively long marketing chain • Higher marketing costs • Lower marketing profits • Almost total lack of credit facilities

ard practices for handling, washing, sorting, grading, cleaning and icing of fish. Most of the landing centers are set up by fish traders' associations or the fishermen's cooperative societies, thus most of the fish landing sites have a limited support infrastructure, and are perceived by some to be ill-managed and unhygienic. There are no facilities such as sheds in some landing centers for auctioning and preserving the fish. At the primary market level, the main constraints for fishermen are a lack of bargaining power and market information. The marketing infrastructure, including cold storage, ice and transport facilities is generally inadequate, unhygienic and in disrepair. Political disturbances (i.e. strikes, road blocks, etc.) also affect fish transportation as well as marketing. During survey visits in the study area, it was found that the damage of fish occurs mainly in the process of transportation from the landing centre to the retail points. Wholesale markets have better facilities, but in general conditions in primary and retail markets are far from satisfactory with regards to stalls, parking, spacing, sanitation, drainage and management. Quality control at landing, handling, distribution and marketing places is only periodically carried out. This is largely because of a shortage of Quality Inspectors and the absence of emphasis on quality control for domestic markets.

Development of marketing systems

SWOT analysis was carried out for the development of marine fish marketing systems in coastal Bangladesh (Table 6). A number of issues are important for the development and sustainability of marine fish marketing, including:

- Infrastructure: improvements of fish landing, transport, handling, and preservation facilities are essential to supply quality products.
- Supply of ice: insufficient supply of ice in markets is one of the most serious problems for fish preservation. Ice is fundamental for good quality fish storage and preservation. Having ice readily available on the premises would facilitate the enhancement of appropriate fish handling. It is therefore necessary to establish a sufficient number of ice factories for marketing of quality fish.
- Hygiene and quality: there seems to be very limited knowledge amongst fishermen, traders and intermediaries with regard to sanitary standards and fish quality. It is also imperative that the fish markets are kept clean. Proper management with regard to day-to-day maintenance of the premises from a sanitary point of view has to be ensured. Improvements to hygienic conditions of fish landing centers and markets are essential for producing good quality products. Thus, training of fish market operators in areas of preservation, handling, icing and curing should be provided.
- Credit facilities: fishermen, traders and associated groups do not have easy access to bank and NGO credits due to too much official paperwork and collateral arrangements. Therefore, assisting traders to obtain cheaper adequate bank credit for market operating costs should be considered.
- Government policy: a positive policy at government level should be considered for sustainable marine fish marketing systems.

A baperi with a queen fish.

Fish markets provide employment for young and old.

Day labourers are involved in unloading of fish from fishing boats.

Conclusions

Marine fish marketing plays an important role in the economy of Bangladesh, contributing to increased food production, diversification of the economy, increased employment opportunities, and maintained rural communities. However, concerns arise about the long-term sustainability of marine fish marketing due to poor road and transport facilities, poor supplies of ice, lack of money and credit facilities, poor institutional support and inadequate extension services. It is therefore necessary to provide institutional and organizational support, government support, extension services, and more research and knowledge of fish marketing. In addition, the establishment of modern wholesale markets in large urban areas, and establishment of well-functioning assembly markets at important fish landing sites may help sustainable fish marketing systems in coastal Bangladesh.

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