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AQUACULTURE ASIA

Greenwater techniques for hilsa larvae

Freshwater mollusc collection livelihoods

Stinging catfish

Ornamental fish livelihoods

AQUACULTURE ASIA

Aquaculture Asia

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

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NACA

An intergovernmental organisation 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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International Artemia Aquaculture Consortium

Our big news is that NACA will host the International Artemia Aquaculture Consortium (refer to the NACA Newsletter, this issue). The idea for the consortium came from a November 2019 meeting of *Artemia* experts in Kuala Lumpur. NACA's involvement in the consortium began in September 2021, when it convened the Webinar on Status of the Use of *Artemia* Cysts in Fish/Crustacean Hatcheries Around the World, as an event at the Global Conference on Aquaculture Millennium +20.

NACA contributed to several follow-on regional webinars, culminating in the offer for NACA to host the consortium, which the organisation was most pleased to accept. As part of hosting arrangements, NACA has established a new website for the consortium, https://artemia.info, which I would like to invite you to visit. An occasional email newsletter service is available for the consortium if you'd like to stay in touch with developments, the sign-up page is located at: https://artemia.info/newsletter/

We have prepared video recordings of the technical presentations at all the webinars thus far; these are available on website (and via a dedicated playlist on YouTube). But I would like to draw your attention to the recordings of the Webinar on Management of the *Artemia* Resources of the Great Salt Lake, which is available at https://artemia.info/news/?id=33.

This webinar is of particular interest as it provides a rare, possibly unique, insight into the evolution of an exceptionally well managed aquatic ecosystem. As we in the field all know, water bodies are used for many purposes by many different stakeholders, with fisheries and aquaculture usually ranking low, if at all, on the priority list. Despite the considerable economic value of *Artemia* cysts, the Great Salt Lake is similarly an important resource to many stakeholders. Yet industry, science and government have come together and devised management arrangements to maintain the utility of the resource. The degree of regulation is surprisingly light and effective in supporting management of the resource, compared to other high profile aquatic resources around the world. I commend the recordings from this webinar to anyone with an interest in aquatic resource management.

The consortium has an impressive line-up of research priorities, which include the conservation of *Artemia* biodiversity, improved management of wild resources, the characterisation and selection of strains for specific aquaculture applications, selective breeding of improved strains, and investigation of *Artemia* biomass as a high-value protein ingredient in human diets.

Another focus of the consortium will be on updating good aquaculture practices for the use of *Artemia* in hatcheries and in feeds, along with local extension initiatives for same. A key finding of the SDG-aligned *Artemia* workshop was that over time industry practices have drifted away from good practices outlined in the early *Artemia* manual, and there is considerable room and need for improvement.

Simon Wilkinson

AQUACULTURE ASIA

CONTENTS

Dynamics of small-scale aquaculture development in India: A review

Himansu K. De, Gour S. Saha, Abhijit S. Mahapatra and Simantini Shasani

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Development of small-scale aquaculture has dominated development discourse because of its potential to fight malnutrition and poverty, to ensure food security and enhance the socio-economic condition of people living at the bottom of the pyramid. There are two fundamental approaches to applying aquaculture in developing countries: Improving small-scale, subsistence-level operations to meet immediate local needs or establishing large-scale, commercial industry based on the production of expensive species for export. The latter approach, geared towards increasing cash flow and thereby foreign exchange, may provide some employment for the poor, but mainly benefits only a small sector of society. The former strategy, however, directly benefits a larger number of people, especially the poor, by providing jobs and a modest income as well as a source of inexpensive protein. These two basic approaches are not mutually exclusive, but small-scale aquaculture is the more appropriate approach for rural communities[1]. In addition, small scale aquaculture has been characterised variously as family owned and operated, reliant predominantly on family labour, utilising small areas of land and/or water, and spanning a range of systems; from those involving limited investment in assets and operational costs and comprising but one segment of diverse livelihood portfolios, to others requiring more substantial investments in time, labour, infrastructure and capital.

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world (FAO, 2016). Presently India is the second largest fish producing and second largest aquaculture nation in the world after China. Aquaculture is the world's fastest growing food producing sector. The rapidly growing fisheries sector in India has an annual growth rate of over 7%. India's total fish production rose from 0.75 MT in 1950-51 to 13.75 MT during 2018-19, and inland fisheries presently represents 71% of total fish production of the country. Foreseeing high potential, a "blue revolution" has been initiated in the fisheries sector in order to focus mainly on increasing fisheries production and productivity from aquaculture and fisheries resources, both inland and marine, with the objectives of ensuring food and nutritional security, generating employment and export earnings, ensuring inclusive development and empowering fishers and aquaculture farmers.

Milestones in aquaculture development in India

Year	Milestone
1960	• Induced breeding of carps through hypophysation developed. • Seed rearing protocols developed.
1970	• Grow out technologies of carp and catfish developed. • Government owned and operated hatcheries established. • Fry and fingerling rearing in small ponds promoted. • Cage and pen culture initiated.
1980	• Fish Farmers Development Agency established. • Fish based integrated farming systems popularised. • Pond ecology and water quality studies initiated.
1990	• Synthetic hormone Ovaprim, an alternative to pituitary gland extract, becomes available; private hatcheries started coming up in many parts of the country. • Carp seed production increased manifold: stunted yearling stocking began in Andhra Pradesh. • Genetically improved 'Jayanti' rohu developed.
2000	• Intensification of carp production system. Sardar Darshan Singh of Ludhiana achieves record fish production of 13 tonnes/ha/year. • CIFAX developed as a cure for EUS. • Concept of One stop Aqua Shop emerged from DFID funded project. • Celebration of National Fish Farmers Day started.
2005	• Formulated fish feed industry proliferated. • NFDB established; seed production for diversified fish species gained momentum. • Farm made fish feed popularised for small scale aquaculture.
2010	• FRP carp hatchery becomes popular. • Private entrepreneurs drawn to establish hatchery, farms. • Aquaculture for empowerment of women, livelihood support for economically challenged section of society emphasised. • Aquaculture Field School promoted as a model of farmer-to-farmer extension.
2015	• Business incubation in aquaculture started for promoting entrepreneurship. • Mission fingerlings launched to give boost to larger sized seed production. • Aqua One Centre: An ICT enabled aquaculture support centre established. • Farmer Producer Organisations in aquaculture promoted. • First fish farmer in the country to be awarded with Padmashri: Sri Sultan Singh.
2020	• Ministry of Fisheries formed at the Centre. • Pradhan Mantri Matsya Sampada Yojana launched with a budget of Rs 200.5 million. • Bio-floc/recirculatory aquaculture system started gaining popularity. • Entrepreneurship development in fish value chain stressed. • Sri B.K. Sahoo, CIFA adopted farmer nominated for Padmashri award.

What is small scale aquaculture?

The term small scale aquaculture is often used interchangeably with rural aquaculture. Rural aquaculture is defined as the farming of aquatic organisms of economic importance by small-holders or communities using low external input technology suitable for their resource base. The fish production level in rural aquaculture is generally low and can only be sufficient for household use and family income[2]. To achieve significant production as well as income potential in rural aquaculture sector, the use of chemical fertilisers rather than formulated feed should largely be emphasised. The growth of the aquaculture sector mostly depends on two factors: i) Increasing the area under culture and ii) intensifying production in existing culture systems. The area under culture can be increased by utilising derelict or under-utilised water bodies viz., swamps, saline soils, natural as well as man-made lakes, reservoirs and rivers[2].

Aquaculture being a fast-growing sector in India, contributes a lion's share to the fish requirements of the country. The Fish Farmers Development Agency (FFDA), one of the flagship schemes of Department of Animal Husbandry and Dairying (DAHD), Ministry of Agriculture, Government of India, has made remarkable contributions in improving the average productivity level to 3,000 kg/ha/year as of 2018-19. However, the ponds not covered by the FFDA have a very low productivity. Popularisation of scientific fish farming in such areas is highly recommended.

Freshwater aquaculture represented 34 percent of inland fisheries production in the mid-1980s and has now increased to about 80 percent in recent years (DADF, 2019). India is bestowed with 3.15 million ha of reservoirs, 2.42 million ha of ponds and tanks as well as 0.19 million ha of rivers and canals. This indicates the huge potential for the development in aquaculture in India. However, only around 50% of ponds and tanks are being used currently for aquaculture. These resources may be used for enhancing fish production. Production packages developed for perennial water bodies are required to be suitably modified to suit the culture environment for seasonal water bodies. Location-specific package of practices also need to be developed for remote places.

Paradigm shift in small scale aquaculture

Components	Small scale aquaculture – then	Small scale aquaculture – now
Aim	Food security	Improving farmers' income level
Focus	Enhancing productivity	Profitability
Major players	State department of fisheries	Multiple stakeholders – public as well as private; donor agencies
Transfer of technology approach	Input intensive Blanket recommendation of practices	Knowledge intensive Location specific technology modules/business plan
Role of farmers	Farmers are seen as passive recipients of technology	Farmers are seen as innovators and entrepreneurs
Outreach activities	Focused on men	Emphasis on mainstreaming women
Dissemination of technology	Poor participation of stakeholders	Active stakeholder participation Farmer to farmer extension through aquaculture field school
Source of fish seed	Wild collection from river, mixed seed, bundh breeding	Hatchery produced seeds, small indigenous freshwater fishes, off-season availability
Size at stocking	Spawn/fry (15-20 mm)	Advanced fingerlings (40-60 mm) / stunted yearlings (150-250 g)
Culture technique	Traditional/extensive culture	Semi-intensive culture
Supplementary feeding	Broad casting/ball feeding	Farm made feed, floating pellets
Average yield	400-500 kg/ha/year	3,000 kg/ha/year
Types of aquaculture technologies	Hapa breeding, fish seed rearing, poly-culture/ composite fish culture, integrated farming	Circular/FRP hatchery, mixed carp culture, culture in seasonal water bodies, ornamental, value addition, organic aquafarming, species diversification, bio-floc/RAS

Aquaculture for rural livelihood development

Aquaculture has contributed to strengthening livelihoods and food security in southeast Asian countries, contributing to the livelihood of the poor farmers through improved food supply, income and employment. Effective extension services have contributed to increased aquaculture production and have the potential to contribute to the economic development of rural fish farmers. The rural women of south 24 Parganas perform many fishery activities starting from fish seed collection up to fish marketing and have contributed to improving the income of their families. Aquaculture is a viable option for rural development and plays quite a substantial role in improving the livelihoods of the fish farmers in Vietnam in terms of increasing satisfaction with economic gain. Poor households exhibited high adoption of aquaculture technologies in rural Vietnam although researchers are sceptical about the introduction of alien technologies.

A small-scale aquaculture project implemented in Nepal has resulted in improved nutrition and income for rural house-holds. The project 'Women in Aquaculture in Nepal' has led to a seven-fold increase in per capita consumption. Community management of fisheries received a boost from the Cambo-dian government and participation of women therein has also strengthened governance of fishery resources. Several researchers in India too have documented the contribution of small-scale aquaculture in strengthening rural livelihoods.

Aquaculture Field School - a novel extension approach.

Dimensions of small-scale aquaculture development

Promoting the spirit of entrepreneurship

Farmers usually experiment with their limited resources and available technologies for maximising returns. The next generation of fish farmers are increasingly bringing in new techniques and are willing to take risks. The characteristics of present-day aquaculture are quite different from the past. Candidate species and the combinations reared by fish growers have changed. Composite carp culture in its strict sense has probably become a thing of past. Consumer prefer-ences too are increasingly shifting towards non-conventional species which is probably driving farmers to introduce diversi-fied species. It's the market and profit consideration that decide the rural aquaculture landscape. Promoting the spirit of entrepreneurship in aquaculture is emphasised. Fisheries-

Harvesting in a community pond.

based start-ups and enterprises are already attracting rural youth to be part of the entire fisheries value chain. With the state doing its bit, now it is time for the farmers to switch from semi-intensive culture to commercial production, from household-level production to fishery-based enterprises, and to migrate from small-scale production to embrace the entire value chain: Fish breeding, seed rearing, feed manufacture, input supply, marketing, and value addition.

Horizontal extension – the Aquaculture Field School way

To facilitate farmer-to-farmer extension the ICAR-Central Institute of Freshwater Aquaculture (CIFA) has piloted a few aquaculture field schools (AFS) in the states of Odisha, West Bengal and Chhattisgarh. AFS is a school without walls for improving decision making and problem solving by the fish farming community. The AFSs are becoming popular destination for the fish farmers. Farmer-to-farmer approaches are recognised by FAO as a key aspect of participatory extension methods. This approach of extension with no physical inputs would certainly be sustainable in the long run. As a novel approach for facilitating horizontal extension, AFS needs scaling up so that it benefits more and more fish farmers.

Plugging research extension gaps with Aqua One Centre

Aqua One Centre, a new initiative of National Fisheries Development Board (NFDB), Hyderabad, is an ICT enabled aquaculture support service that facilitates the wider dissemination of newer aquaculture technology and innovation to the

Fish farmers' collective, Maa Kharakhai Farmer Producer Company, Kendrapara.

Bhargavi Fish Farmers Producer Company, Khordha.

Women beneficiaries collecting harvested carps.

fish farming community. It will function in complementarity with existing public fisheries extension systems. Aqua One Centres will provide aquaculture support services such as pond monitoring, input management, health diagnosis, water analysis and advisory services. It is expected that the centres will bridge the research-extension gap and make aquaculture support services available to fish farmers and seed growers at their doorstep. ICT tools are poised to play a major role in this endeavour. During 2018-19, total 96 Aqua One Centres were established in 14 states (NFDB).

Harnessing the potential of women

Rural women are involved in aquaculture production activities including composite carp culture, seed rearing and integrated fish farming for their socio-economic improvement and self-employment. However, a lack of focus coupled with cultural and social constraints limit the participation of women in training and empowerment. The role of women is mainly confined to subsistence aquaculture in India, taking care of fish after stocking. Aquaculture, as a tool for empowering women is increasingly being recognised for its noteworthy contribution even in the most difficult areas. The initiatives of the government as well as non-government actors have also helped in bringing them closer to government establishments and banks. Office bearers of self-help groups have to deal with the management and financial aspects of pond management viz., purchase of inputs - fingerling, lime, feed, fertilisers and so on - and selling table fish. The additional income generated from fish culture has improved the socio-economic status of women. Appropriate methods of aquaculture extension and customised technologies can draw more rural women towards aquaculture.

Farming as business - the era of producer companies

Farmer producer organisations (FPOs) are registered bodies with farmers and producers as shareholders in the organisation. They deal with business activities related to the farm produce and it works for the benefit of the member producers, focusing on enhancement of farmer's capacity through advanced agricultural practices to increase productivity. FPOs facilitate access to fair and remunerative markets including linking of producer groups to marketing opportunities through market aggregators. They undertake many activities starting from the procurement of inputs to the disposal of produce and acts as a bridge between production and marketing. The Government of India is promoting FPOs by mobilising the farmers and helping them in registering as companies through the Small Farmers' Agribusiness Consortium, National Bank for Agriculture and Rural Development and National Cooperative Development Corporation. Presently, around 7,374 FPOs are registered in the country. Though fisheries FPOs are a small number at the moment, their numbers are steadily growing.

Seed rearing in backyard ponds is a profitable business.

Conclusion

Small scale aquaculture has undergone considerable changes over the years. These include aqua farmers turning into aqua entrepreneurs; farmer-to-farmer dissemination of technologies through aquaculture field schools; gender mainstreaming taking centre stage; producer companies being formed for fish farmers; and a new market-orientation to fish farming. The Union Government has recently launched Pradhan Mantri Matsya Sampada Yojana to turn India into a hotspot for fisheries and aquaculture products through appropriate policy, marketing and infrastructure support. The Government of India aims for national production to reach 20 million tonnes of fish by the year 2022-23. It has also set a target of forming 10,000 FPOs in agriculture with 500 FPOs in the fisheries sector. It would be desirable to think beyond production and lay an adequate emphasis on input supply, advisory services, and the entire fisheries value chain. With the government extending enormous support for fisheries sector development, the onus is now on the farmers and entrepreneurs to take up the latest techniques in fish farming and realise the true potentials of the blue economy.

Acknowledgements

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Green water technology as an essential support to larval rearing of hilsa shad

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A mature hilsa, Tenualosa ilisha.

'Green water technology' is a technique that promotes phytoplankton to grow profusely, making cultured water turn a lush green colour, hence its name. The term 'green water technology', sometimes referred to 'green-water culture' or simply 'green water' includes several methods by which desirable microalgae are produced for the purpose of rearing larval fish and crustaceans. Naturally occurring phytoplankton, which serve as feed for fish and crustacean larvae, are grown and proliferate under a controlled system. Single celled microalgae are produced in green water culture because they have useful features such as natural dispersion, remain buoyant in the water column for a long period, and do not cause fouling in the cultured water. *Chlorella* is one of the best of a few microalgae commonly used in the production of large amounts of green water. Green water is efficient and can be used in diverse culture methodologies including extensive, intensive, and mesocosm systems used in larval fish rearing across the globe. It is productive and helps to maintain desired oxygen levels.

Microalgae as a means of suitable food to feeding larvae

Being autotrophs, microalgae are the first link in the food chain of the aquatic trophic system and are harnessed in aquaculture as a direct food source for fish and crustacean larvae. The role and benefits of microalgae are to:

- Provide a direct nutrient source to the larvae.
- Contribute to the maintenance of other live foods and their nutritional balance.
- Enhance environmental conditions of the culture water, enhancing larval feeding by increasing turbidity, scattering and attenuating light, and enhancing visual contrast.
- Lower the stress level of larvae.
- Ameliorate water quality due by stripping of excess nitrogenous substances and increasing dissolved oxygen level.
- Provide digestive stimulants.
- Assist in diversifying the microflora of the larval gut.
- Provide beneficial antibacterial properties.

Certain microalgae add essential fatty acids to the rearing water. These fatty acids, which may eventually transfer to fish larvae through prey, promote larval growth and survival. Microalgae contain a vast number of highly bioactive compounds including amino acids, vitamins, pigments (including antioxidants), and minerals. These provide an immense benefit to the health of fish larvae through the food chain. The overall larval rearing system benefits from

Application of green water in hilsa fry rearing pool.

microalgae either as a direct food source or an indirect food source by stimulating the production of rotifers, *Artemia* and copepods, and other zooplankton used as food for the larvae of a variety of carnivorous fish species.

Larval rearing of hilsa shad vis-à-vis role of microalgae

Hilsa – a food fish of sheer importance

Hilsa shad, *Tenualosa ilisha*, a euryhaline fish species, undertakes long migrations crossing diverse water bodies from river to sea to fulfil its life cycle. Adult hilsa travel from the deep sea and travel up estuaries to reach freshwater rivers, where they breed. Juveniles then undertake a reverse journey, following the path of the adults from the rivers to reach deep sea habitat. Hilsa have been recorded in India, Bangladesh, Myanmar, Pakistan, Sumatra, Indonesia, Iran, Iraq, Kuwait, Sri Lanka, and Vietnam, occurring in waters such as the Bay of Bengal, Indian Ocean, Persian Gulf, and Arabian Sea. Hilsa is highly nutritious, being rich in protein, fat, vitamins and minerals, including essential amino acids, and n-3 polyunsaturated fatty acids (n-3PUFA), particularly eicosapentaenoic acid and docosahexaenoic acid.

Rearing hilsa larvae

To culture hilsa in captivity, one important factor among others is to rear larvae up to fry stage in freshwater. The main obstacle is the lack of knowledge on the biology of the larvae, including different stages of larval development, for example:

- The age when the larval mouth opens.
- The size of the mouth aperture.
- The age when larvae first accept food.
- The kind of foods larvae will accept.
- The size requirements for foods to enter the mouth.
- The suitability and favoured or preferred foods of larvae.
- Are the larvae active or passive feeders.
- Favourable water conditions to facilitate feeding and growth.
- The condition of alimentary tract and its capacity to accept and digest different types of food.

These and many other questions must be studied when a new species is considered for aquaculture. The most critical task is to choose preferred natural foods in the early stage of larval growth on which the larval survival is greatly dependent and assured.

Chlorella vulgaris – microalgae – suitability as larval feed

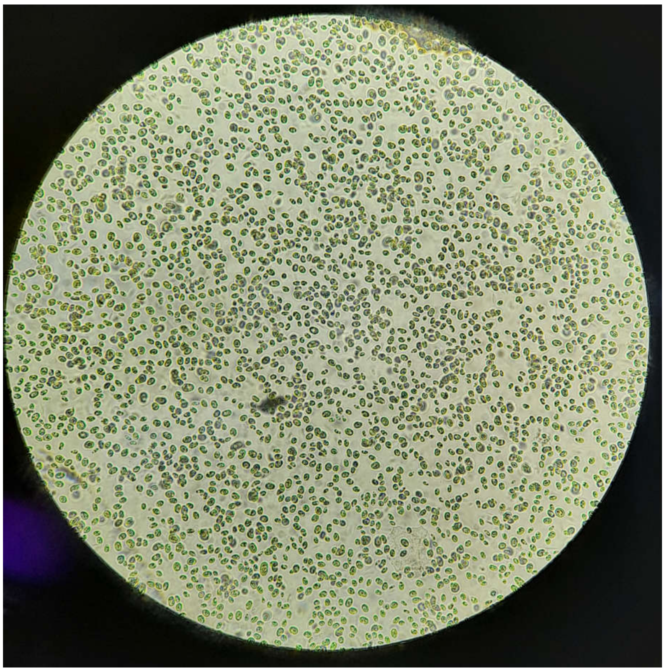
Chlorella vulgaris is a single-celled protein source, with a diameter of approximately 3-10 μm. It is the best choice for single cell protein production because it has simple and inexpensive growth requirements chiefly nitrogen, and phosphorus, and grows rapidly under sufficient light. It is known to be an effective, economical, and preferred source of protein since it has a short life cycle, good tolerance to environmental variations, and its cell size is appropriate for the demands of many fish larvae. *C. vulgaris* has an adequate nutritional value and high digestibility as a food for rearing fish larvae. It contains the following nutrients (%): Protein, 40-50%; lipids, 10-15%; and carbohydrate, 12-16%, apart from n-3 highly unsaturated fatty acid (HUFA), poly unsaturated fatty acid (PUFA) including a significant concentration of eicosapentaenoic acid (EPA, 20:5n-3) and of docosahexaenoic acid (DHA, 22:6n-3). Hilsa larvae will accept *Chlorella* at first feeding, grow well and survive satisfactorily, when larvae have still a rudimentary digestive system and lack a developed stomach. Much of protein digestion takes place in the hind gut epithelial cells. Such a digestive system usually prefers receiving easily digestible and highly nutritious food; in such cases, *Chlorella* is a most preferred source.

Green water as the basis of co-feeding larvae

Co-feeding is the application of two types of foods – a method of feeding found to be effective compared to single feeding in the early stages of larval growth. It has shown improved growth and survival of hilsa larvae as per experiments conducted in RRC, ICAR-CIFA, Rahara. *C. vulgaris* was produced as green water and applied to larval feeding, in combination with other zooplankton foods.

The schedule of co-feeding for different ages of hilsa larvae was undertaken during 46 days of larval rearing (Chattopadhyay et al., 2019). In the experiment, feeding started on the 4th day of rearing and continued until the 50th day. The 46 day feeding period was demarcated into five stages:

- 1st stage: Day 4-50. Daily application of green water (*C. vulgaris*).
- 2nd stage: Day 6-10: Feeding with *Brachionus calyciflorus* of lower population density.
- 3rd stage: Day 11-25: Feeding with *Brachionus calyciflorus* at a higher population density.



A microscopic view of Chlorella vulgaris, single cell protein.

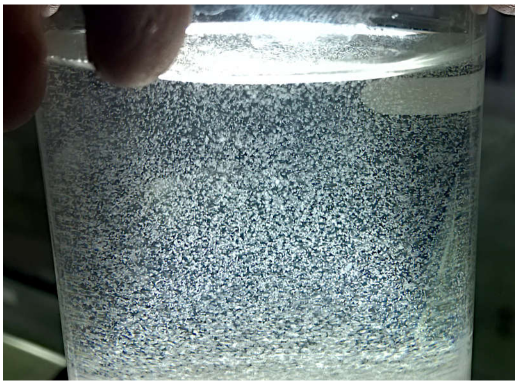
- 4th stage: Day 8-50: Feeding with mixed phytoplankton (diatoms, *Pandorina*, *Scenedesmus*, *Closterium*)
- 5th stage, 26-50: Feeding with mixed zooplankton (*Cyclops*, *Diaptomus*, *Diaphanosom*).

Selected plankton were produced separately in sterilised circular and rectangular FRP tanks in an outdoor system, while a few others were produced in ponds.

Scientists observing the density of Chlorella culture.

Above: Rotifer culture in cemented raceway with green water. Below right: Dense rotifer population displayed in a glass.

Co-feeding as a potential nourishment of larval rearing



Co-feeding serves to improve the nutritional condition of the larvae. In this feeding technique, larvae get necessary nutrients from different categories of plankton. In natural habitats, where a variety of live food resources are available, the larvae can have balanced nutrients to promote their growth and survival. In captive rearing of larvae, the co-feeding strategy has been adopted to simulate their natural habitat with regard to the availability of a variety of natural foods. The particular importance of co-feeding is that different live foods are the main source of nourishment of cultured fish larvae. Live foods contain an appropriate energy content and required nutrients. Live foods can also be easily enriched with additional nutrients through dietary manipulation during culture. Despite the recent progress in the development of inert diets for fish larvae, the aquaculturists still rely on live foods during the early life stages of larval growth, particularly at the first-feeding stage of most species of interest for aquaculture. Due to the poorly developed digestive systems of first feeding stages, most of the larvae are unable to digest formulated diets, while live foods are generally preferred and give better growth and survival. The early stages of fish and prawn larvae are inherently attracted towards live foods, because their instinctive behaviour drives them towards organisms that are easily detected and captured while swimming, especially those that move or have any type of motility in the water column. Larvae are believed to be visual feeders adapted to capturing moving prey; the movement of live food is likely to stimulate larval feeding responses. Live foods that have a thin exoskeleton seem more palatable to the delicate soft bodied larvae once taken into the mouth, compared with hard ones and dry formulated diet. Live foods with a body size in the range of 70-350 μm are suitable for co-feeding larvae. The high population growth rate of live foods is also advantageous for larvae, which feed upon them by filtration or capture from suspension.

Chlorella culture in a series of outdoor FRP tanks.

Production of green water – a farmer-friendly cost-effective technique

Mass production of *Chlorella* – easy to do

The tanks or containers in which *Chlorella* culture takes place need to be cleaned with bleaching powder so that containers are free from unwanted microorganisms, algae or any other plankton (Chattopadhyay et al., 2019). Cleaned containers are put under bright sunlight for 12 hours so that the action of bleaching powder disappears. The containers are then filled with bore water, assuming that water is not contaminated with other algal species. Culture water is to be prepared with the addition of inorganic fertilisers such as ammonium sulphate $(NH_4)_2SO_4$, urea CH_4N_2O, and single super phosphate $Ca(H_2PO4)_2$ with the ratio of 10:01:01, respectively. In amount, ammonium sulphate, urea, and single super phosphate are to be added in each tank @ 0.1 g/L, 0.01 g/L and 0.01 g/L, respectively. For example, for 1,000 L production of green water, one should add 100g, 10g, and 10g of ammonium sulphate, urea, and single super phosphate, respectively. All these fertilisers are available commercially in fertiliser shop. After addition of fertilisers the culture water need to be stirred thoroughly and kept as such for 12 hours. *Chlorella* is then inoculated @0.025 ml/L (17 x 10^6 cells of *Chlorella* per ml of stock as counted under the microscope, but there is no strict norm of stock inoculum to have such measured cells into fertilised water. All the cultured tanks should be put in bright sunlight and aerated continuously. The tank water usually turns green four days after inoculation due to increase in cell density. It may also vary and take a few days more, if the inoculum does not have a sufficient *Chlorella* mass. After 6-8 days of culture, green water can be harvested.

Chlorella inoculum maintained in a conical flask.

Strategic culture practice of *Chlorella* – a preferable method

Batch culture is preferable as a strategy for *Chlorella* culture. In open outdoor systems there is no control over contamination of culture water. In such case, continuous culture may not be suitable because many other phytoplankton and zooplankton, particularly *Brachionus* and *Asplanchna*, may grow in peak *Chlorella* production and deplete to near zero within 2-3 days. In an indoor lab under controlled conditions, mass culture of *Chlorella* can be maintained with fluorescent light for more than 15 days with a high population density, but this is costly. Now, it is the option of farmers to adopt either method, based on the available infrastructure and their cost bearing capacity.

Growth curve of *Chlorella* – an established scientific principle

Growth and development of *Chlorella* (as with most of the microalgae) in batch culture follows a typical growth curve. It starts with four sequential phases as (i) an inoculation phase where population growth initiates, (ii) an exponential peak growth phase (iii) a stationary phase where population growth ceases, and (iv) a declining phase as mortality rate

Chlorella culture in an indoor laboratory setting.

exceeds growth rate. In the case of mass culture, batch culture may not be suitable from a commercial point of view. After a certain period of continuous culture, tanks need to be cleaned thoroughly as before and a new set of fertilisers added, otherwise cell deformity may occur, and the quality of *Chlorella* cells may deteriorate.

Conclusion

There are several techniques as well as growth media available for production of green water on a mass scale. However, RRC, ICAR-CIFA, Rahara has developed its own technique as easy as to follow that enable farmers to produce a colossal amount of *Chlorella vulgaris* as a green water in outdoor system, which is reliable, economical and sure to achieve. CIFA's is a much tested technique used in hilsa shad larval rearing as evidenced to achieve above 88% larval survival through green water application and co-feeding with other planktons and formulated diet as well.

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Collection of freshwater molluscs and sale of meat by women in Purba Medinipur, West Bengal, India

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Retail women traders extracting meat from freshwater molluscs (Pia globosa) at Mecheda point.

Economic benefits of common freshwater molluscs

The common freshwater snail *Bellamya bengalensis*, golden-coloured Indian apple snail *Pila globosa* and freshwater pearl mussel *Lamellidens marginalis* are naturally found in almost all Blocks of Paschim Medinipur[1] and Purba Medinipur districts in West Bengal. As gastropods, *B. bengalensis* and *P. globosa* have a spirally coiled univalve shell, while the bivalve *L. marginalis* is completely enclosed by pair of lateral shells. The meat of freshly collected adult *L. marginalis* is used by progressive *Macrobrachium rosenbergii* farmers in villages of Purba Medinipur as 25% of the daily supplementary feed ration. The meat is finely chopped, cooked with salt and turmeric, and softened. The chopped meat of these molluscs is used by small-scale catfish (*Clarias magur*) farmers in grow-out and broodstock ponds mostly in combination with other feed ingredients. Crushed *B. bengalensis* with shell is used to meet the protein requirements of farmed ducks in Purba Medinipur and other districts; others use boiled *B. bengalensis* and *P. globosa* with added salt to feed ducks. Crushed shells of *L. marginalis* are used @ 6-8% in formulated feed of three-month-old ducks. Machine-powdered shells of the molluscs are used in chicken feed in West Bengal as a calcium source, causing the eggshells to become desirably thick. Burnt shell lime (CaO) is produced from great numbers of shells of *P. globosa* and *L. marginalis*; that of the latter is used by women on riverbanks to segregate riverine *Penaeus monodon* seeds from other species. Live freshwater molluscs are natural biological purifiers, accumulate pesticide and heavy metal residues in the body from their habitat, and are used to assess and monitor the health of environment of open freshwater bodies.

More significantly, these are the “low-priced poor man’s meat”, aiding in rural nutrition. The Scheduled Tribe population in West Bengal comprises forty ethnic groups and

Paschim Medinipur, including Jhargram, is the most tribal-populated district in West Bengal (2011 census). Preparation of 'health food' from the meat of freshwater molluscs is frequent in homes of impoverished, underprivileged, and economically disadvantaged Scheduled Tribe and some Scheduled Caste people in villages of these two districts for meeting the daily protein needs of family members, traditionally preferred since long past. Owing to good nutritional value and taste, this unconventional animal protein is gaining popularity and acceptance amongst elderly middle- and high-income people in suburban areas, towns, and cities in West Bengal, who are conscious about its ethno-medicinal value. After collecting these molluscs, the elderly women of different Scheduled Tribe communities prepare soft mollusc-based family meals and sell small quantities of the raw meat in local fish markets after shell removal to generate some earnings. They eat cooked molluscan meat, wild edible mushrooms, pond mud dwelling *Amphipnous cuchia*, small riverine crabs, tubers, and *Moringa oleifera* flowers to derive necessary nutritional elements, not as pleasing tasty recipes.

Author with four tribal freshwater mollusc collectors.

Use in traditional medicine

Nutrient-rich molecules beneficial for human health are obtained from these edible benthic aquatic invertebrates. These 'village foods' are an under-exploited resource. Soup prepared from *B. bengalensis* meat used as a traditional remedy to treat asthma, arthritis, and joint swelling. Cleaned whole-bodied individuals are kept in water for few hours at home, and the water used as eyedrops to treat conjunctivitis. Consumption of the cooked meat is recommended for those suffering from vision problems and stomach upsets. Curry and soup prepared from *L. marginalis* meat is used as a traditional medicine to treat cardiac ailments and high blood pressure[2]. Freshwater snail meat used ethno-medicinally for treatment of poor eyesight, whooping cough, hypertension, arteriosclerosis, kidney-related diseases, and mineral deficiency[3]. Soup prepared from *B. bengalensis* foot is traditionally consumed by the tribespeople of Jharkhand state against bone and joint inflammation[4], a prestigious item of food here. In suburban areas of West Bengal, for children and elders, physicians recommend eating *B. bengalensis* to treat vitamin deficiency in body and nerve-related problems respectively[5]. Local experts opine that the slimy extract and meat of these species contains essential vitamins, allantoin, elastin, lectin proteins and minerals that may reduce the occurrence of human cancer and skin diseases; oligosaccharide serum secreted from body is used to treat pimples, maintain normal fairness of skin, and protect skin cells from harmful sunrays. Consumption of *B. bengalensis* and *P. globosa* meat is reputed to maintain proper distant vision.

Bellamya bengalensis.

Large Pila globosa.

According to some elderly women in Purba Medinipur and Paschim Medinipur districts with whom author met, men and women of Scheduled Tribes and Scheduled Castes use clear bluish slimy water contained inside *B. bengalensis* shell (4-5 drops/snail) just after extracting the meat as eye drops after getting up from sleep in morning, which they believe aids in clear vision. This information is passed down locally from ancestors to family elders to the next generation. Women during early period of pregnancy are advised to eat boiled *L. marginalis* with coriander leaves; the meat should be cooked for a minimum of 15 minutes. It is good for sportspersons and daily labourers as the meat contains retinol, tocopherol, cobalt, and high amount of zinc that facilitates increase in

Adult Lamellidens marginalis.

spermatozoa count in humans. In few fish markets in Kolkata city, molluscan meat is sold @ INR 200-300/kg and bought by elderly sections of society. Being a remedy for gout (a form of arthritis) in elderly men and women in urban and suburban areas of West Bengal, widows prefer to eat cooked meat during continuing 4-days observance of 'Ambubachi' in last week of June. These species are very good source of iron, that keeps away anaemia in children.

Collection of freshwater molluscs

During July 19-23, 2022, the author documented the state-of-the-art of large-scale collection and sale of these freshwater molluscs and retail trade of the meat for human consumption, conducted separately by two groups of professional village women on almost daily basis. Elderly Scheduled Tribe women belonging to BPL category, residing at Polanda Village (10-12 km from Akandi-Mondolpara village and in between Mecheda and Tamluk towns) under Raghunathpur-II Gram Panchayat in Sahid Matangini Block of Purba Medinipur; Balichak Village in Debra Block of Paschim Medinipur; and Shyamchak Village in Kharagpur-II Block of same district, collect these molluscs from natural stock as income-generating activity. Scheduled Tribe and Scheduled Caste women in a few other Blocks also involved in it, with the activity originating in 1978-1980.

In early morning, women enter static freshwater bodies in nearby and distant locations and move along slowly searching the bottom for *L. marginalis* and *B. bengalensis* with both hands. Handfuls of those picked up are kept temporarily in a sack-like small space made near abdomen and down to knee out of a portion of their traditionally worn folded cotton saree; it is termed '*sareer kochhor*' in local dialect. They are also kept inside a space made by folding an ankle-length outer skirt tied at the waist. Some *L. marginalis* collectors fit a cement- or gunny-bag on their back near the hip. For collection in depth of 1.2 m and above, Scheduled Tribe women dive and remain underwater for five seconds or more up to their capability with their eyes closed, but in less deep (waist-high water), hands are extended down after bending with head kept above the water level. *L. marginalis* is also collected from water hyacinth-infested areas of shallow wetlands. Tribal boys and youths dive into deep water bodies to collect them; less are available in shallow areas and more towards the middle. From medium-sized ponds with a good quantity of *B. bengalensis*, the women can collect around 5 kg in two hours.

With their sarees turning heavy, they put collected animals over the embankment of the water body. Until around 2.00 pm, each collector goes on moving from one area to another in the same water body and in those nearby. The entire collection of one or both species (10-50 kg/woman/day), are placed in 1-2 cement sacks of 25-50 kg capacity, light in weight made from woven polypropylene fabric. The women's eyes turn reddish after working for continuing 5-8 hours and they face hardship and bodily pain. Scheduled Tribe women of Polanda, Balichak and other villages collect molluscs from ponds and larger water bodies (4,000-5,000 m^2) existing in the same village. Or else, they board a local train at nearby railway station at 3.30-4.30 am, and travel to pre-planned sites in distant villages in Purba Medinipur and Paschim Medinipur and begin routine work from morning.

Tribal women collecting snails from a medium-sized pond.

Close view of collection of B. bengalensis.

Large carp culture water bodies at Moyna - good source of L. marginalis.

Some Scheduled Tribe women choose less-deep large pisciculture water bodies ('jheels' or 'jheel fishery' in local dialect) as *L. marginalis* and *B. bengalensis* collection sites, and able to get more every day; 2-4 women may work in single such water body. The owners of jheels are paid an amount of money, thereafter collectors are permitted to enter. Such water bodies are located at villages such as Moyna and Srirampur in Moyna Block; Ramtarak in Sahid Matangini

Block; Ranichak in Haldia Block and other places in Purba Medinipur. The jheel fishery of Moyna, Sutahata, Panskura, Sahid Matangini, Haldia Blocks in Purba Medinipur and the 'Moyna model' are well-known destinations practicing of major carp farming through-out West Bengal[6], and a good source of *L. marginalis*. Some women individually 'hunt' for these species every day in 8-10 small- to medium-sized ponds. Collection is easy during March-June as the water level recedes. The depth of such village ponds, typically older and a good source of *B. bengalensis*, is greater than that of jheels in Purba Medinipur. Many professional major carp farmers don't prefer their presence in fishponds.

P. globosa is collected by women from paddy plots in villages, which is easily done singly by hand-picking from low-lying water-logged plots (10-20 cm depth) with planted paddy saplings from early monsoon season. It emerges out from beneath the soil after the first rain in the season, remains alive up to 12 months in moist earth, and can survive in completely dried soil in main plot and marginal areas near narrow earthen embankments. After harvest of rabi paddy during April-May & May-June and another crop in November-December, experienced elderly Scheduled Tribe women collect *P. globosa* from the dried earth on the side of embankments using the sharp end of an iron sickle. Dry soil 10-15 cm deep is scooped out and live adults located; they are also collected from partially aquatic grass-infested and water-logged village lowlands, around 15-22 cm deep. Collection of the other two species is difficult during the monsoon months till September (though the availability of *B. bengalensis* is more) as the water depth increases in ponds and large water bodies; *B. bengalensis* are hand-picked from the less deep village ponds, canals, and water hyacinth-infested wetlands during the monsoon.

All three species are also found in littoral vegetation areas in the margin of beels, where they are collectively considered part of the 'weed-associated fauna'. During summer, *L. marginalis* and other species of edible freshwater mussel are obtained more from shallow sandy-bottom zones of slowly flowing rivers in villages and may be collected @ 4-20 kg/person in 4-5 hours. According to the women, these mussels contain more meat with regards to their body size, in comparison to *L. marginalis*.

Above: Woman collecting B. bengalensis from a backyard pond. Below: Cleaning P. globosa for cooking at home.

Arrival at common point and sale of meat

Between 2.00-3.00 pm every day, around 6-9 women, each with 25-90 kg of freshly collected shellfish, arrive near the junction of Mecheda Central bus stand and National Highway-116 at Mecheda road bridge. Molluscs are brought in sacks loaded on a Matador Goods Carrier four-wheel and 10-seater 'Magic' vehicle, in the luggage compartment of a long-route luxury bus. Beside a road adjoining NH-116 (about 150 m from Mecheda bus stand and railway station), collectors from different villages ranging from 10-50 km away, and women buyers-cum-mollusc traders (retailers) gather and stay till 5.30-6.00 pm. *P. globosa*, *L. marginalis* and *B. bengalensis* are weighed all separately and sold to 12-15 women buyers every day, who are residents of Akandi-Mondolpara village (4 km from this point) under Santipur-II GP, Sahid Matangini Block, Kolaghat Police Station, Purba Medinipur. They typically belong to poor Scheduled Caste or Other Backward Class households and are of 45-65 years in age.

They buy whole-bodied *P. globosa* and *L. marginalis* @ INR 10-12/kg with price increasing to INR 12-15/kg in winter months, sometimes up to INR 25-30/kg, and pay instantly to collectors. *B. bengalensis* meat has the most protein content; sold normally @ INR 14-15/kg. Buyers reach Mecheda railway station carrying live molluscs (15-35 kg for every time; selectively single species or any two in total) in sacks at 2.30-3.00 am the next day. They board into the vendor compartment of the first Mecheda-Howrah local train, reaching places such as Santragachhi, Tikiapara, Dasnagar, Kadamtala, Sankrail, and Ramrajatala in Howrah district, West Bengal

(42-50 km from Mecheda railway station); regular sale and good demand for molluscan meat exists in fish markets of these suburban regions.

Excluding Saturdays, these women molluscan meat traders sit on the market grounds and roadsides at 7.00 am and cut open the shells of *L. marginalis* individually with a steel knife. The outer lip and peristome of hard operculum (aperture) plate of *P. globosa* and *B. bengalensis* is cut by hammering with the pointed end of an iron sickle. Soft meat from individuals brought out one after another, is sold to general buyers (customers) @ INR 10-15/100 g for *P. globosa* and *L. marginalis* and INR 15-20/100 g for *B. bengalensis*. Around 100-250 g of raw meat fit for human consumption is obtained per 1 kg of whole-bodied *B. bengalensis* and *P. globosa* after discarding the blackish non-edible portions of the whole flesh, and 250-350 g/kg for *L. marginalis*. Fresh meat of the three species is sold separately. A few women individually buy up to 45 kg from collectors during evening, with half used the next morning for extraction of meat and sale; the rest stocked at home in big water-filled earthen vessels 'maateer mejla' for a second day's use. After buying, some of them patiently cut the operculum of all *P. globosa* at Mecheda point till 6.00 pm. It remains alive, water comes out from shell, *P. globosa* sacks turn lighter in weight, and become easier to be carried to the marketplace next morning. Meat is extracted and sold quickly.

Some women observe fasting 'Upobash' for religious reasons on Thursdays and Saturdays, then buying and selling of molluscs occurs on a smaller scale at Mecheda point. Sometimes women traders bring out meat from whole-bodied individuals separately during 5.00-6.00 pm here, preserve it in crushed ice overnight, for sale to buyers at dawn @ INR 60-100/kg at Sankrail. During 1988-1995, women of Akandi-Mondolpara village bought molluscs @ INR 1-2/kg and *B. bengalensis* meat sold then @ INR 5-6/100 g. They make return train journey to Mecheda boarding at Santragachhi, Tikiapara, Sankrail, Ramrajatala railway station at 12.30-1.30 pm. Before coming home, women traders stay at Mecheda point till 5.30-6.30 pm to buy and ensure the lot of fresh molluscs for the next day in desired amount. Good understanding, communication and faith exist between regular women collectors and buyers-cum-vendors (retailers), i.e., meat traders in money matters and assured supply of molluscs, with experience in the profession. Women traders wait for collectors to arrive; some sell meat of one species and some sell two species separately.

Cooking molluscan meat and other facts – women's point of view

The author was informed by women of Akandi-Mondolpara that from 5.00 pm up to 8.00 am next day, *B. bengalensis* (that bought by women traders) remains alive but *P. globosa* can survive for a much longer time. *B. bengalensis* resides in deeper portion of backyard homestead and other small- to medium-sized village ponds (600-2000 m^2) and jheels during winter (thus collected in lesser amount), coming up to the water surface and pond margin in spring, summer, and early monsoon months in the morning hours. It inhabits areas with thick deposition of decomposed organic matter on mid-pond bottom and towards the periphery, attaches to submerged hard objects, thin portion of tree roots, and stem of macrophytes under the water, sloping down to soil junction


Collectors unloading sacks of freshwater molluscs at Mecheda point.


Separation of B. bengalensis and L. marginalis after collection.

in knee-deep peripheral waters. It moves down in forenoon and later hours and becomes difficult to collect. During winter evenings, women place 2-3 large dry palm tree leaves over the mid-pond bottom; good numbers of *B. bengalensis* attached to its surface, which is lifted after 24-48 hours to get the animals. Of the three species, the least amount of meat is obtained from it, but it is collected abundantly by women in some village ponds, seemingly endless in number.

At the front yard of homes, women place freshly collected *B. bengalensis* over a large banana leaf, the opposite end of a 7-10 cm sewing needle or safety-pins used to extract meat after detaching the operculum (aperture) singly in 3-5 seconds. Meat is washed in water after adding common salt, again in hot water. *B. bengalensis* and *P. globosa* are kept intact in hot water for 5-10 minutes, with the operculum manually detached from the body easily. Cream-white *P. globosa* meat is extracted out with the pointed end of sickle; 40-50% of its inedible interior-most flesh separated and fed to ducks at home. The blackish portion of *B. bengalensis* flesh also fed, which improves egg yield. *L. marginalis* meat is extracted by women using 'boti' (30 cm high curved cutting blade held down on wooden platform) or a sharp knife. *L. marginalis* and *B. bengalensis* are caught in good numbers during dewatering of ponds and jheels or drag netting for harvest of freshwater fishes from it. *L. marginalis* is found more in medium- to large-sized clean water bodies, slightly greenish, maintained for pisciculture with less clay percentage in the bottom soil.

In some village households, before cooking, whole-bodied *L. marginalis* is boiled for a few minutes and the meat extracted. Women spoke about *P. globosa* falling prey to exotic openbill stork *Anastomus* sp., which gather in good numbers at early morning in shallow wetlands and water-logged fields in Purba Medinipur. They draw long beaks into the bottom mud to get it, break open the shell in the mouth between the arched upper and recurved lower mandible and eat its flesh. The migratory brahminy ducks and herons also enter weed-infested wetlands in winter to feed upon *B. bengalensis*, *P. globosa* and other aquatic creatures. Large triangular-shaped split bamboo frame nets with wooden handles are used to collect *B. bengalensis* and *L. marginalis* from shallow wetlands for cooking at home, pushed forward over aquatic vegetation or the bottom. Animals are directly kept in an aluminium hundi or bucket.

As an instance of traditional heritage, even three centuries ago, very poor women collected *B. bengalensis* and *P. globosa* from narrow freshwater canals (near Damodar River) and local ponds in eastern Bardhamaan, West Bengal using ‘gamchha’ and ‘jhuri’ and ate its cooked meat during food scarcity. Less-spicy gravy-based curry is prepared using its meat, the edible vine of green gourd, *Asteracantha longifolia* plant (‘kulekhara sak’), papaya, fig fruit, raw banana, and potato - a traditional health recipe for sick and recuperating persons at homes in Scheduled Tribe (Adivasipara) and Scheduled Caste dominated villages. *L. marginalis* meat is eaten by Scheduled Caste households after making a thick and tasty gravy with onion, garlic, potato, and spices.

Quicklime production

Towards the end of market hours in Howrah at noon, women traders sell empty shells to local people @ INR 100-120/50-70kg, for clear white quicklime (CaO) production in Amta Block, Howrah and other places. In village conditions, heaps of sun-dried *L. marginalis* and *P. globosa* shell are burnt producing burnt shell lime or quicklime, superior in quality than limestone powder, used routinely by progressive major carp farmers as an essential input in jheels and fishponds under their possession. In small units in Purba Medinipur and other districts in West Bengal, pieces of fuelwood, dried cowdung cakes and kerosene oil are used in traditional circular big clay ovens termed ‘chulha’. Dried shells are stacked inside chulha in layers over bricks as a base, and burnt at a very high temperature for 20-25 minutes with continuous waving of big hand fan to blow air inside it and keep up the intensity of the fire. Thermal decomposition of $CaCO_3$ occurs, burnt shells are pulverised, sieved and powdery CaO is produced; about 30 kg obtained from every 38-40 kg sun-dried shells.

Weighing and selling of P. globosa (above) and B. Bengalensis (below) to women retailers.

Woman extracting B. bengalensis meat.

Limestone powder is harmful for human health but quicklime is edible with betel leaf when converted into slurry-type $Ca(OH)_2$; 150-180 kg produced from every 50 kg powdered burnt shell. It can treat jaundice in youths when eaten with sugarcane juice, may be consumed in wheat grain size daily by healthy adults. Since *L. marginalis* is collected in lesser amounts during the monsoon months, burnt-shell lime is not produced in this period. Treatment of its meat-extracted fresh shells with bleaching powder (@ 200-250 g/2-3 kg shell) and water eliminates the blackish brown colour, thereafter, made to burn. CaO neutralises water and bottom soil acidity in fishponds and disinfects the pond bottom.

News on women mollusc collectors

News appeared in a Bengali newspaper dated 9/5/2019 on daily collection of these freshwater molluscs by tribal women in the summer and early monsoon months from wetlands and other water bodies of Howrah district as means of living. The Lodha-Sabar people, an Adivasi of Munda ethnic group tribe, are less involved in crop cultivation and dependent on capture and collection of economically important living resource for food and livelihood.

From Kharagpur in Paschim Medinipur, 5-15 Sabar women go to Kharagpur-Howrah on the local train every day at dawn, and get off separately at Phuleswar, Abada, Bagnan, Mourigram railway stations in Howrah. After a thorough search and collection till late afternoon with full effort, they return and sacks of collected molluscs (either whole-bodied or extracted meat) are sold at Gidhni fish market in Jamboni Block and other markets in Jhargram and Paschim Medinipur. They collect molluscs from nearby water bodies in afore-mentioned stations or travel again by bus to villages at farther distances. Since recent past, they pay INR 4,000 for five months to owners of each large fish culture water body, and thereafter are allowed to enter for collection. At platform areas of Panskura, Haur and Radhamohonpur railway stations on their way of return, women traders (retailers) buy a portion of whole-bodied *P. globosa* and *L. marginalis* from them @ INR 5/kg and *B. bengalensis* @ INR 8/kg. Women collectors get cash in hand; the rest is sold to traders near Kharagpur station. Many mollusc collectors live at Chak Sahapur village near Balichak railway station in Paschim Medinipur. As these are much less abundant in seasonal water bodies in water-scarce regions in Jhargram District, Scheduled Tribe women travel to Howrah to collect. They also eat the cooked meat at home.

During and after the COVID-19 induced lockdown period since March 2020, many day labourers and low-income persons in rural West Bengal, as in Bispur village of Hingalganj Block, North 24 Parganas district, West Bengal, lost their jobs while in work outside West Bengal and had to depend upon these freshwater molluscs and leafy vegetables as a two-time meal daily. Local Scheduled Caste and Scheduled Tribe women seriously collected *B. bengalensis* from nearby ponds (Source: Anandabazar Patrika, 18/5/2021). In 'no work' circumstances in north Bengal, hundreds of Scheduled Tribe adults that are normally tea garden workers and their children depended on edible riverine snails, mussels, and crabs to combat nutritional deficiency (Source: ETV West Bengal, 4/4/2020).

End note

From a publication in 2008, we know that Scheduled Tribe and Scheduled Caste women of Pakui and Chak Sahapur villages in Debra Block, Paschim Medinipur, earn a living by selling *B. bengalensis* after collecting from natural sources in afore-mentioned places of Howrah. They either sold extracted meat in fish markets in Howrah @ INR 40-50/kg, or whole-bodied material to retail traders at Panskura and other places directly @ INR 2-3/kg. Each of them collected at least 20-30 kg of molluscs (three species in combination) every day; their income was INR 400-2,000/woman/month. At Gate Bazar in Midnapore town in Paschim Medinipur, 250-400 kg of *P. globosa* and *B. bengalensis* is available every day

Different method of extracting B. bengalensis meat.

for sale. Whole-bodied and meat-extracted material is sold here @ INR 4/kg and INR 50-60/kg respectively. Every day 60-70 kg of freshwater molluscs is sold at Miya bazaar in this district[5]. Makhanbabur bazaar in Haldia is a prominent place in Purba Medinipur where molluscan meat is sold. During February 2010 to January 2013, *B. bengalensis* meat was bought by general consumers in five different markets in Midnapore town @ INR 9-12/100 g and whole-bodied animals @ INR 6.90-9.80/kg, both retail rates, during pre-monsoon, monsoon, and post-monsoon periods. Daily income of *B. bengalensis* collectors at Pakui and Chak Sahapur villages was in the range INR 250-300 and for retailers (meat traders), it was INR 300-350[7].

In West Bengal, these freshwater molluscs are sold in markets of districts Purulia, parts of Bankura, undivided Midnapore (Purba Medinipur, Paschim Medinipur and Jhargram), Jalpaiguri, Howrah and parts of Kolkata. In a regular market in Jhargram, more than six bags (about 250 kg) of whole-bodied *B. bengalensis* sold @ INR 5-7/kg and *P. globosa* @ INR 4-5/kg. In some markets in Kolkata, extracted meat out of 10-20 kg whole material is sold every day in fish and vegetable markets with shell @ INR 10-12/kg and meat @ INR 40-50/kg[8]. At Gangnapur village in Nadia district, West Bengal, male *B. bengalensis* collectors sell extracted meat to traders @ INR 50-60/kg. They opined that it is easily available in local ponds, caught from turbid waters after clearing bushy water hyacinth, with meat squeezed out after hammering the operculum. Its meat costs INR 70-80/kg in market - much lesser than the price of the same amount of chicken, mutton, other non-vegetarian items that they can't afford to buy everyday (Source: G. Singh, The Quint, 10/4/2018). Sri S. Singh Roy, proprietor of Makalpur organic farm, Polba-Dadpur Block, Hooghly district, West Bengal informed the author that *B. bengalensis* helps as 'floor cleaner' and in removal of silica from village ponds. It is a zero-cost protein, easily digestible, a wonderful nutritional supplement in villages that needs to be promoted and may be included in the Mid-day Meal programme for primary and upper-primary stage children in schools in suburban and rural West Bengal in near future.

About 5,000 villagers inhabiting in vicinity of East Kolkata Wetlands and Canning-I Block in South 24 Parganas District, West Bengal collect *B. bengalensis* from medium- and large-sized freshwater bodies as means of livelihood. The meat is sold at Ultadanga, Ballygunge, Dum Dum, and Garia fish markets in Kolkata city and outskirts @ INR

100-250/kg (Source: Eisamay News channel, 27/3/2017). After collecting molluscs in a thin, coarse cotton towel worn at the lower abdomen (termed 'gamchhar kochhor') and split bamboo basket, non-professional Scheduled Tribe women sell *B. bengalensis* meat to a few customers in local markets in Purba Medinipur only in small quantities @ INR 50-70/kg, along with edible roots of wild terrestrial plants having medicinal importance. As additional daily income, a few elderly women at Akandi-Mondolpara collect common edible freshwater plants *Marsilea minuta*, *Enhydra fluctuans*, *Ipomoea aquatica*, *Asteracantha longifolia*, *Cantella asiatica*, and *Nymphaea* sp. from natural freshwater bodies near home beforehand and keep small amounts with them for sale in Howrah markets in addition to molluscan meat, the main item. Often most of it remains unsold even being low-priced and good quality leaves. Many general buyers in city and suburban markets may not be aware of the health benefits provided by edible green aquatic plants. These poor Scheduled Caste women know much about it by virtue of their indigenous technological knowledge, work very hard for a decent living.

Meat of these three freshwater molluscs has a good market value in the south-western districts of West Bengal, with demand rising among middle and high economic classes, and provides an essential source of income for both poor women collectors and meat traders in Purba Medinipur and Paschim Medinipur. But the continuous capture of resources available in nature on a large scale and their supply for human consumption may cause marked depletion of stock soon. For *P. globosa*, predation by waterfowl and application of insecticide in wet paddy fields adds to the cause. In shallow and clean 160-600 m^2 backyard village ponds and 'doba', cultivation of *P. globosa* and *B. bengalensis* may be taken up after creation of a favourable environment for their natural breeding and adults stocked from outside. Scheduled Tribe and Scheduled Caste women in general and rural youths can do it with technical guidance of experts, little investment, and effort.

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A success story of ornamental fish farming as a tool for alternative livelihood of tribal women in Keonjhar District, Odisha, India

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Pragati Self Help Group Ornamental Fish Breeding Unit at Bhatunia Village, Keonjhar District, Odisha.

The ornamental fish industry represents an essential section of international trade, expanding in all dimensions and providing aesthetic pleasure and financial openings. About 7.2 million houses in the USA and 3.2 million in the European Union have an aquarium and the number is increasing day by day throughout the world. Ornamental fish farming is also growing to meet this demand. The fact is that USA, Europe and Japan are the largest markets for ornamental fish but more than 65% of the exports come from Asia (Ghosh et. al., 2003). Day by day, ornamental fish culture is becoming an increasingly important source of income for rural people. Some people in Odisha, and more broadly in India, are maintaining their livelihood through this practice. Ornamental fish keeping is the most popular hobby in the world and it is considered to be easy and stress relieving. At the dawn of the 21st century aquaria feature as an integral part of modern interior decoration (Katia Oliver, 2001). Ornamental fish farming, culture and seed production are included as different

Scientists, Senior Research Fellows and ornamental trader owner interacting with self help groups.

activities of self help groups and also play an important role in maintaining the livelihoods of poor people. The objective of self help groups is to bring poor families above the poverty line by ensuring an appreciable sustained level of income over a period of time through the process of social mobilisation, training and capacity building, and provision of income generating assets. India's share in the global ornamental fish trade is 0.008 percent. The major part of the export trade is based on wild collection from the north eastern states. These capture based exports are not sustainable and are a matter of concern. Hence, the focus should be on culture based production systems. There is a very good domestic market based on domestic breeding exotic species. The overall domestic trade in this field crosses Rs.100,000,000 and is growing at the rate of 20 per cent annually (Susan, 2014). The earning potential of this sector is hardly understood and under exploited. Considering the relatively simple techniques involved, this activity has the potential to create substantial employment opportunities in rural areas, including for women, as well as generating additional income with minimal risk and time. With the inception of the National Agriculture Innovation Project (NAIP) in Keonjhar District, ornamental fish culture was introduced with an initial investment from the project by supply of FRP tanks and some inputs, while cement tanks were constructed with their own savings money. Women self help groups were trained and visits to gain experience were arranged by ICAR-Central Institute of Fresh water Aquaculture, Kausalyaganga, Bhubaneswar, to establish ornamental fish farming units. This study discusses the role of tribal women involved in the popularisation of ornamental fish farming in Bhatunia Village. Self help groups have been effective in popularising ornamental fish farming and marketing and in improving livelihood security for rural tribal women. Knowledge dissemination through capacity building programmes and demonstrations in the field have helped many women in Keonjhar District adopt improved technologies.

Approach

Pragati Self Help Group, a group of seven women and three men in Bhatunia Village, was established in 2005. Members of this group are from tribal communities and most of them are housewives of farmers. The elected president is Mrs Mamata Dehury and the secretary is Mrs Basanti Dehury. Initially this self-help group was provided with some financial aid from the block headquarters to run activities in microfinance and agriculture. With the arduous efforts of the members, this group became one of the active in the district.

Ornamental fish breeding unit and live bearers fish tank.

Above, below: Live food collection from nearby village ponds with demonstration by Senior Research Fellow.

Outcomes

In order to create awareness of ornamental fish breeding and culture techniques to improve and sustain livelihoods, a combined effort of NAIP and CIFA (ICAR) was made under the livelihood project (Component 3). Several village level training activities were conducted through screening of films on successful farming practices. Meetings and other related activities were carried out for capacity building among the villagers, especially the self-help groups. A two day exposure visit to CIFA was facilitated on 28th and 29th September, 2010 for members with the main aim to familiarise them with the field work and practical aspects of ornamental fish farming. In addition, lectures were also delivered in simple way to create interest in ornamental fish breeding and culture. The self-help group members had opportunity to interact with the scientists, and Senior Research Fellow field demonstrations of breeding techniques were also conducted in order to encourage them to take up ornamental fish farming.

The efforts of NAIP-CIFA catalysed the members of Pragati Self Help Group to establish an ornamental unit in the Bhatunia Village. Prior to establishing the unit a meeting was conducted among the scientists, Senior Research Fellows (SRFs) and members of the self-help group, and detailed discussion was made on the know-how of setting up an ornamental unit. Each and every aspect from initial preparations to marketing of the produce was discussed threadbare and a layout diagram of the unit was provided. The owner of the AQUA WORLD shop at Keonjhar market, Mr Sachikanta Behera, who deals with all the necessities for ornamental fishes was introduced to the members. He promised to purchase their produce at a remunerative price.

Breeding and culture

In the meeting it was also decided that initially the self-help group on their own expense had to invest some amount for a cement platform and a few tanks. To make them involved and develop ownership of the project, as a public-private

Self help group members packing fishes for market.

partnership, the self-help groups were advised to construct a cement platform of 7.5 x 5 metres and six tanks each of 1.5 x 1 x 0.6 metres. The members agreed to it readily without any reservation. Similarly, NAIP-CIFA provided eight rectangular FRP tanks of 450 litres capacity and a circular hatchery was specially designed for breeding of live bearers and some egg laying species. At first, the site for setting up the unit was selected and the SRFs were simultaneously asked to monitor the work. The construction work as per the required size was completed at a total expense of Rs. 10,000/- (US$ 158) drawn from the savings of the self-help group.

Once the facility was ready the scientists visited the unit to provide technical guidance for stocking of fish. The unit was provided with livebearers such as guppy (*Poecili reticulata*); molly (*Poecilia latipinna*), swordtail (*Xiphophorus helleri*) and platy (*Xiphophorus maculatus*). Livebearers release advanced young in batches and are easy to breed throughout the year except the winter months and the members were then taught about the breeding behaviour and rearing. Prior to release of fish in the tanks the members of the self help group were asked to fill the tanks and plant *Hydrilla* twigs in pots inside the tanks. This work was supervised by the SRFs. CIFA provided shade nets and accessories like nets, sieves, pipes for siphoning purpose, plastic ware such as mugs, buckets, feed containers etc. When the full unit was ready, fish and feeds were provided to them by the institute. The SRFs supervised all the activities including breeding and feeding, method of siphoning, health and hygiene care. With the effort of self help group members and constant supervision the ornamental fishes started to breed. After seeing the fry the members were excited and started taking all possible care as per instructions. The group members were performing efficiently. All of them take utmost care of the fishes and the production. The details of the production and other activities are monitored by SRF and noted in reports. Apart from this the group members also keep a record of their activities.

Feeding

Live food is essential for achieving good survival rates of larvae. In addition to live food like cladocerans collected from nearby ponds, they were provided with powdered prepared feed made from groundnut oilcake and rice polish.

Once the larvae reach 10 mm in size they were provided with live food like *Tubifex* or sludge worm, mosquito larvae and chopped earthworm. Records of feed use, frequency of feeding, growth, feed intake, mortality and the labour put by the women farmers on the job were recorded in note books. The details of the production and other activities were monitored by Senior Research Fellows engaged under the project. They were asked to use feeds provided by CIFA and were also taught on producing feeds at a cheaper cost using ingredients such as rice bran, groundnut oil cake, soya bean and fish meal. In the meantime they were also trained to collect plankton from the pond as live food for the fish larvae, and earthworms were also given as food. By following the

Table 1. Average cost and return of a breeding and rearing unit of live bearers.

Cost (Rs)	Rate (Rs)	Total value (Rs)
Capital cost		
Cement platform 7.5 × 5 m		3,500
6 cement cistern 1.5 × 1 × 0.6 m	1,000	6,000
8 numbers FRP tanks 450 litres	Supplied by the project fund	
Shade nets, aerator, pipe, other equipments like hand nets, buckets & mugs	Supplied by the project fund	
Total		9,500
Culture cost		
400 hundred females	Supplied by the project fund	
100 hundred males	Supplied by the project fund	
Feed	Supplied by the project fund Natural food collection by SHG members from local ponds	
Others		500
Total cost (Rs)		10,000
Production: Monthly production 2,600 pieces Yearly production (average) 37,500 pieces		
Sale		
37,500 fishes	5	187,500
Total sale		187,500
Annual profit = Rs. 187,500 – Rs. 10,000) = Rs. 177,500 **Monthly profit = Rs. 14,792**		

proper rearing and management practices, two crops were harvested by the self-help group members in the first year. Dull-coloured fishes were generally culled from time to time as one of the management practices.

Marketing and economics

Once the fry attain a marketable size, members contact the trader to market the ornamental fish. The fishes are sold per piece at a remunerative price. For delivering the fish to the market, the members have appointed a villager Mr Sanatan Dehury who takes their produce for sale to Mr Behera at AQUA WORLD shop. The fishes fetch a good price and this has created even more interest among the members. The profit depends on the carrying capacity, candidate species and infrastructure. In an average month production is about 2,600 young and the yearly average is 37,500 pieces. The expected revenue from the ornamental fish breeding unit is estimated at Rs.177,500/unit/year during the first year. The average cost and return of a minimal breeding and rearing unit of live bearers is in Table 1.

More income could be generated in subsequent years. The amount of money generated from the sale of fishes is deposited in the joint bank account of self-help group members.

There are a number of indigenous fish species which can be cultured as ornamental fish (Panigrahi et. al., 2009). A few works have been done regarding the involvement of women in ornamental fish culture, breeding, management and marketing, such as Ako et. al., 2000, Sinha et. al.2004, and Patra, et. al., 2006. Women nurture the tiny fish with care and have shown interest in different activities of backyard culture of ornamental fish (Sinha et. al., 2012). Now women from different self help groups are engaged in this small scale industry. The State Government has taken a policy decision to set up self help groups as a major poverty alleviation initiative with a view to ensuring a robust economic growth that would be labour intensive and equitable, combined with development of the social sectors, and specially directed towards the groups living below the poverty line. Various programmes administered by different departments of the Central and the State Government, such as the Self Help Group Bank Linkage Programme initiated by NABARD, and the social intermediation programme followed by NGOs have accelerated the process of organising the poor, and particularly women, into self help groups. Now the State and Central Government are giving a special emphasis to ornamental fish farming through different self help groups for socio economic development. In India, many women have taken up ornamental fish breeding or farming as a backyard activity especially in rural areas (Sahoo et al. 2011). From this investigation we have found that the self help group is a process-oriented scheme which involves organisation of rural poor, their training and capacity building, to enable them to evolve into a self managed organisation. In the present investigation we found that ornamental fish farming can be a viable alternative livelihood for rural tribal women. The main influencing factors were community norms and social hierarchy, and capacity building.

Needs of self help groups

In our experience, to establish ornamental fish culture operations, a self help group requires:

- Training on breeding techniques of egg laying fishes.
- Field training and demonstrations.
- Exposure visits.
- Technical support from the authorities for efficient production and propagation.
- Better marketing facilities.

Factors contributing to success were:

- Technical support and co-operation of the NAIP-CIFA team.
- Timely supply of inputs and, from time to time, suggestions and motivation.
- Co-ordination and keenness among the self help group members.
- Ready availability of suitable water.
- Growing demand for aquaria in urban areas.

Lessons learnt

The ornamental fish unit has proved to be a boon as livelihood option for the economically challenged tribal community. This endeavour has lead to capacity building as well as income generation of the less privileged members of society. The skills learned assure them of self employment and have secured their financial status.

Future strategies

Looking forward, our ongoing work to improve the initiative include:

- Capacity building of farmers for technological improvement in production of egg layers has been initiated and successful farmers have been encouraged with technical support for large scale production.
- New interested farmers are being encouraged for adopting the technology through horizontal expansion under the NAIP programme.
- The farmers are encouraged to take the benefits prevailing under existing government schemes and linkages with State Fisheries, ATMA, and KVK for improved support and income.
- Better marketing linkages with the pet shops in the local and distant towns have been envisaged. A buyback trade linkage with local traders has proved profitable for farmers. An aquarium making capacity building programme has been initiated for more income generation.

Conclusion

Ornamental fish farming can be adopted anywhere in Odisha as an option to enhance and support livelihoods. The development of local farms will assist with adaptation of ornamental fish farming to suit local conditions and help to establish commercial small scale farming under a harsh environmental regime (low and high temperatures) with low investment requirements.

More opportunities must be created for women, predominantly through collection and dissemination of information and transfer of technology between different districts of our state and country. Ornamental fish farming can be a promising alternative for many self help groups due to the low space and capital requirements. The success of women in developing homestead ornamental fish farming businesses is encouraging other self help groups to initiate such enterprise. The government has also recently declared that special packages may be provided to unemployed women to assist them to adopt ornamental fish farming.

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Recent trends in seed production of stinging catfish, *Heteropneustes fossilis*, in India

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The search for potential new aquaculture species for pond culture has been continuing under different aquaculture research and development programs. These studies gather knowledge about candidate fish species and their performance during production. Many times, hatchery owners and farmers have faced failure after adopting a new fish for production without adequate knowledge of its needs and characteristics. It is essential to know the habit, habitat, feeding and effective husbandry practices of a species before attempting commercial culture. Successful research on new candidate species should be followed by training and demonstration, as key activities during the broad adoption of any species for aquaculture in India.

India is considered a “carp country” due to its sizable carp aquaculture production, owing to effective research and development programmes undertaken over the last four or five decades. In addition, the wild harvest of different varieties of prawns, air-breathing fishes and catfishes also represent a considerable share of the total freshwater fish production of India. Catfishes are in high demand among Indian consumers, but due to cumbersome management, many species are yet to be adopted by farmer communities even after successful research and demonstration. The wide adoption of *Pangasianodon hypophthalmus* and tilapia in recent years has been facilitated by their high growth and production from the pond culture. The indigenous *Clarias magur*, *Heteropneustes fossilis*, *Ompok bimaculatus* and *Mystus* spp. are also coming up to a lesser degree. The demand for *H. fossilis* seed is increasing as it is a good fish species with high protein and less fat. Many hatchery owners that produce *C. magur* are also producing the seed of *H. fossilis* following a similar procedure pertaining to captive production of *C. magur*. However, seed production is sub-optimal without complete knowledge of *H. fossilis*. Hence, this article summarises what is known of its biology and effective husbandry, to improve production of seed of this valuable catfish.

Healthy broodstock of H. fossilis.

Stripping of female for the collection of eggs.

Brief biology

H. fossilis is distributed throughout many Asian countries including India, Pakistan, Bangladesh, Nepal, Burma, Sri Lanka, and Cambodia. This freshwater catfish inhabits ponds, tanks, swamps, paddy fields and low-lying impoundments. It is a dark purplish brown in colour with a small head that is greatly depressed. The mouth is small and terminal with vomerine teeth. The dorsal fin is small and without spine, and present just opposite the pelvic fin. The pectoral fin is serrated and dreaded for its poisonous nature. The anal fin is continuous and extends up to the caudal fin. Respiration can be achieved via a combination of the gills, skin and through an accessory respiratory organ, which is a tubular structure extending from gills to the dorsal side of the body. This catfish is omnivorous in nature and feeds on insects, worms, small fish, and fish remains, plants, and organic debris. It grows to 20-30 cm during 2-4 years of life. It is considered to be a monsoon breeder and matures in its first year both in nature and in captivity. Sexual dimorphism is prominent during the spawning season.

Broodstock management

The production of healthy broodstock is an important activity for successful breeding of any fish. Breeding failure is minimised due to sufficient knowledge of maturation, type and dose of hormone used, time needed for stripping and so on during induced breeding operations. The researchers or farmers raise the broodstock in confinement after collecting wild or stocking hatchery produced juveniles. Care must be given to avoid injury during transportation. Similarly, high-density transportation may be discouraged to avoid stress during post-stocking. The chance of disease incidence in stressed or injured fish cannot be ruled out after few days of release in the rearing tank or pond. It is always better to rear the fish in an indoor system for few days before final release to the broodstock pond for rearing. The broodstock are reared in cement tanks or earthen ponds at a population size of 3-4/ m^2. High density rearing may invite feeding disparity among the fish and has an adverse impact on water quality. These conditions contribute to disease outbreaks during the winter months.

The catfish needs at least 30-32% protein it its feed. Sinking feed in the pelleted form is provided through feeding baskets in multiple places to avoid crowding. This feeding method also reduces the wastage of feed to a larger extent. Feeding once @ 2-3% of body weight or twice daily with a divided meal is sufficient to raise healthy broodstock. We have also often observed that left over feed and faecal matter will cause the water quality to deteriorate, so intermittent water changes are necessary to maintain good conditions.

Fish should be harvested from the pond just prior to the breeding season to avoid problems in obtaining broodstock during the monsoon months. The greater height of water in ponds during the monsoon months and bottom dwelling nature of the fish may make it difficult to collect sufficient broodstock for breeding operations. Hence the harvest of broodstock during the pre-monsoon time and rearing them in tanks can avoid such problems.

Induced breeding

H. fossilis is a monsoon breeder. The species is found gravid in the wild during July-September. The sexes are well differentiated morphologically during breeding season. Suitable females and males are distinguished by a bulging abdomen with round genital papilla, and slender abdomen with pointed papilla, respectively. The uniform size of intra-ovarian eggs collected through catheter also indicates the maturity of females. Researchers have successfully bred the fish by injecting pituitary extract, commercially available synthetic hormone (Ovaprim/Ovatide/Wova-FH), LHRHa and pimozide, 17α-hydroxy-progesterone and 17α, 20β-dihydroprogesterone. Hatchery owners try to use a synthetic hormone easily available on the market as inducing agent. An injection of up to 1 ml/kg body weight is sufficient to induce ovulation and the female is ready for stripping 10-11 hours post-injection. The male of this species does not ooze milt freely. Hence, sperm suspension is prepared by the maceration of dissected testes with normal saline solution. The ovulated eggs with sperm suspension are mixed with the addition of a little freshwater for fertilisation. Sperm suspension from one male is sufficient to fertilise the eggs produced by two females similar in weight to the male.

H. fossilis is a highly fecund fish, with10-15 thousand eggs obtained from 100-150 g fish. The eggs are deep green in colour and range in size from 1.4-1.6 mm. Eggs are incubated in containers with stagnant or slowly running water. Containers with stagnant water may be provided with a shower to avoid oxygen depletion during incubation. The fertilised eggs reach morula stage after about two hours of incubation and frequent twitching, or movement of the embryo is visible after 14-15 hours of incubation. Hatching starts after about 16-17 hours, when the water temperature ranges 27-28˚C. The newly hatched larvae are 2.5-3.0 mm size.

Operated testes before collection to prepare sperm suspension.

Feeding of larvae with compound feed during larval rearing.

Healthy fry before stocking into fingerling tanks.

Natural breeding

Natural breeding under hatchery conditions is possible in this catfish, in addition to induced breeding by stripping. This benefit of this method is that it avoids sacrifice of the males to fertilise the stripped eggs. Good broodstock of both the sexes are selected as described earlier. Males and females of similar weight are usually chosen during pairing and kept at a 1:1 ratio. The females are injected with synthetic hormone in the same manner as induced breeding. The males are injected with hormone at half the dose of the female fish. Use of additional males may not be of much benefit in in increasing the fertilisation or ovulation rate during peak breeding season. The same male can be used for breeding again after 15-20 days.

The fecundity in natural breeding usually ranges between 8 to 13 thousand eggs in females of 90 to 160 g. Winter breeding (November - January) of this fish is also possible and has been verified during hatchery breeding, but fecundity is reduced compared to fish bred during the normal breeding season. Females of 80-140g usually lay 4,000-9,000 eggs through natural breeding during the winter period. Hatching is also reduced during the off-season, which is an unacceptable factor for farmers as the net output of seed is low. We have observed that the larval growth and survival are drastically reduced due to low water temperature of <20˚ C during the winter months. The fish do not respond to attempts to induce breeding during February. While verifying the cause of failure, we observed that the ovary size was considerably reduced with the accumulation of fat in the abdomen of female.

Natural breeding has an advantage of not having to wait to strip female fish and not having to sacrifice the males for the preparation of sperm suspension to fertilise the eggs. Females were also observed laying eggs completely. Hence this method may be better for farmers to save time and may also be utilised for different aquaculture related works. Many farmers are undertaking breeding by this method. The eggs laid by the females in the tank are not disturbed further and the incubation of eggs continues till hatching. However, the spent male and females are taken out from the breeding tank after egg release. The water is reduced and renewed with water introduced by a showering method to maintain oxygen, helpful during embryonic development.

Larval rearing

The larvae are tiny, slender in appearance and active in nature. Their yolk sac is fully absorbed in the third day of life, which serves as reserve feed. The larvae are ready to accept feed after three days during captive rearing. Mixed zooplankton, *Artemia* nauplii or chopped *Tubifex* larvae remain the best feed during larval rearing. On many occasions we observed that provision of artificial feed after yolk sac absorption did not yield good growth and survival. Early weaning with artificial feed leads to reduced growth rate and high larval mortality, which may be due to improper development of the digestive system as well as lack of digestive enzyme secretion. The continuous feeding of live feed for up

Haul of H. fossilis fingerlings.

Low-cost polythene tank constructed by farmer for raising fingerlings.

to a week followed by the supply of artificial larval feed with the gradual withdraw of live feed, has proven to be the best feeding strategy for the larvae.

A good rearing environment also plays a vital role for successful rearing. The larvae are completely dependent on good water quality to survive, and adequate dissolved oxygen levels aid them in respiration during their initial days of their life. There is every chance that water quality will deteriorate as the larvae are reared in stagnant water. The dead live feed and faecal matter of larvae on the tank bottom reduce water quality by lowering dissolved oxygen while increasing levels of toxic nitrite and nitrate. Larvae exposed to this type of environment remain in a stressed condition, which leads to secondary infection. Hence, cleaning of the tank bottom with replenishment of two-thirds of the water every day is very much essential for their further growth and survival.

We have also seen that high density rearing of larvae invites sudden mortality due to stress. This situation usually happens when there are a lot of hatchlings from the breeding operations and a limited number of rearing tanks. In such circumstances, larvae must be thinned out after few days to avoid the chance of sudden mortality. Larval growth is also affected by high density rearing. These weak larvae suffer from high mortality while on grown for fingerling production. Larval density is usually best maintained within 2,000/m^2 for high growth and survival. Many farmers also stock much less to promote high growth, which helps them to obtain a good sale price. Larvae grow to 20 mm in length and 20-25 mg in weight during a two-to-three-week rearing period.

Fry rearing

The fry obtained from larval rearing tanks are utilised for raising fingerlings. Farmers and researchers often rear them in cement or earthen nurseries. Survival is observed to be low in earthen nurseries due to early mortality of tiny fry. Hence farmers prefer to rear them to larger size in a cement nursery. Rectangular or circular nurseries formed from polythene sheets is less costly and is constructed by farmers to rear the fry for fingerling production. Recovery of fingerlings and their growth play a major role on the production and profitability of a hatchery as the fry of this catfish are sold occasionally. Hence it is necessary to stock within $200/m^2$ to get good growth and survival.

Good feeding practices also play a crucial role during the rearing of these tiny fry. The tank must be provided with shelter to satisfy their behaviour of hiding. Feed in the form of a sticky dough is provided to fry near their shelters to promote uniform feeding. Many fry do not utilise the shelter and spread in the rearing tank. Hence the dough must be placed in a few places dispersed over the tank, to ensure feed is available to all fry. Dough feeding must be changed to crumbled feed after 8-10 days of rearing.

Shooting growth among the fry is seen after 3-4 weeks. It is better to harvest the shooter fry to avoid unequal feeding between them. The water depth should be kept as low in the range 30-45 cm as this fish has an air breathing nature and comes frequently comes to the surface during the morning and evening hours. Higher depths may cause unnecessary consumption of energy, which may reduce the somatic growth of the fish.

Development of filamentous algae is often encountered in the rearing tanks due to rearing in clear and shallow water. It is necessary to remove algae at regular intervals to avoid oxygen depletion, difficulties in free movement of fish and during feed distribution as the feed can become entangled in the algae.

Observing the management measures described above will maximise growth and survival, and the harvest of healthy fingerlings.

Health management

It is always necessary to provide a good environment to reduce health problems. Stress induced disease incidence is often seen in different life stages of this catfish during their transportation or rearing in captivity. Long exposure in water containing high ammonia also invites disease. During these phases the fish show slow movement and loss of appetite. Hence it is necessary to maintain water quality through regular water exchange. We have observed that the fish are also more liable to get infected during the winter months. Common conditions are wounds on the body, loss of barbels and ventral or tail fins in fingerlings and adults due to bacterial infections. Fish can be treated with CIFAX @ 1L/ha water area, but recovery depends on the severity of the disease.

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NACA to host the International *Artemia* Aquaculture Consortium

Artemia remains a critical feed source for larval fish and crustaceans. As the global aquaculture industry continues to expand, so does demand for *Artemia* cysts, which underpin the hatchery production phase for around 10 million tonnes of aquaculture.

Around 90 percent of current *Artemia* cysts are naturally produced and harvested from inland salt lakes. This is a risk to a significant portion of the aquaculture industry. There is a need to assure the sustainable supply of *Artemia* cysts to support hatchery production, from both wild and farmed sources.

A new international and interdisciplinary approach is needed to tackle these *Artemia* issues and opportunities, as happened following the breakthrough in *Artemia* use in aquaculture following the 1976 FAO Kyoto conference.

In November 2019, a meeting of *Artemia* experts in Kuala Lumpur conceived of establishing the International Artemia Aquaculture Consortium, a network of scientists and institutions that would collaborate in exploring opportunities such as the conservation of *Artemia* biodiversity, development of science-based protocols for sustainable harvesting of wild sources, strain selection and selective breeding, and many more. A provisional Steering Committee was established, and a provisional website established courtesy of the Institute of Marine Biotechnology, University Malaysia Terengganu.

On 20 April Prof. Patrick Sorgeloos visited the NACA Secretariat to discuss cooperation, and it was agreed that NACA would host the consortium, playing a coordinating role and establishing a permanent website presence. Dr Huang Jie, Director General of NACA, indicated that the Secretariat was pleased to be involved in the initiative, which offers many exciting research opportunities of global significance.

NACA's first contribution as host to the consortium was to assist in convening two regional webinars on The History of *Artemia* Activities in Africa (4 May) and on Management of *Artemia* Resources of the Great Salt Lake (5 May, see meeting report this issue). These events led on from last year's NACA Webinar on Status of the Use of *Artemia* Cysts in Fish/Crustacean Hatcheries Around the World (2 September 2021) and the consortium's SDG-aligned *Artemia* Aquaculture Workshop (22 September 2021), which was held in conjunction with the Global Conference on Aquaculture Millennium +20 (the report of the workshop is available in the January issue).

Key conclusions and recommendations from these workshops were presented at the recent FAO Sub-committee on Aquaculture Meeting, held virtually from 24-27 May 2022, where they attracted favourable comments, the report will be considered by the FAO Committee on Fisheries in September.

The new consortium website will be published on https://artemia.info within a few weeks. An announcement will be made on the NACA website and in this newsletter when it is available.

Wenzhou virus 8 (WZV8) diagnosis by unique inclusions in shrimp hepatopancreatic E-cells and a molecular detection method

Jiraporn Srisala, Piyachat Saguanrut, Suparat Taengchaiyaphum, Rapeepun Vanichviriyakit, Kallaya Sritunyalucksana and Timothy F. Flegel

To assist shrimp pathologists worldwide we are providing an advisory containing photomicrographs of unique basophilic inclusions that are produced by Wenzhou shrimp virus 8 (WZV8) (Li et al. 2015) that was discovered in 2015 by wide screening of marine animals for RNA viruses using high throughput sequencing (GenBank record KX883984.1). The advisory provides people with the tools to recognize WZV8/PvPV which we refer to as WZV8, in H&E stained slides. We also offer a free RT-PCR method and a free positive control plasmid to anyone who asks for it. We hope that this will allow a global effort to find out the range of this virus and get some idea of its impact.

The advisory is available for download from:

https://enaca.org/?id=1213

A more recent publication from China (Liu et al. 2021) also gives the full sequence under GenBank record OK662577 that is highly similar to WZV8 (97% coverage and 95.4% sequence identity) but under the newly proposed name *Penaeus vannamei* picornavirus (PvPV). Although that paper contained no histological analysis, it did include an electron micrograph of a cytoplasmic viral inclusion within a vacuole of an unspecified hepatopancreatic epithelial cell type (Liu et al., 2021).

Using the sequence of KX883984.1, we designed PCR primers and in situ hybridization probes for detection of WZV8. Subsequent ISH assays with shrimp RT-PCR positive for WZV8 samples allowed us to identify unique inclusions described herein as linked to WZV8 in hematoxylin and eosin (H&E) stained tissues. In some of the specimens positive for WZV8 with ISH assays, positive ISH reactions were also seen in normal nuclei in the central region of the HP and in the subcuticular epithelium and underlying connective tissue (especially in the stomach) indicating that these tissues are of no use for histological diagnosis of WZV8 infection because of their normal appearance with H&E staining.

Going back over our previous histological reports and archived slides, we have found the unique WZV8 inclusions in E-cells of normal shrimp samples from several shrimp farming countries in Austral-Asia since at least 2008. More recently we have obtained samples of *P. vannamei* from the Americas that also show these inclusions. We have noticed these inclusions for many years as unique basophilic, cytoplasmic inclusions of unknown origin that occur mostly in E-cells of the tubule epithelia of the hepatopancreas (HP) of both diseased and normal, cultivated *P. monodon* and *P. vannamei*. In diseased samples, mortality was ascribed to bacteria or known lethal viruses. As a result, the additional presence of these inclusions of unknown origin and their relatively common presence also in shrimp with no signs of disease resulted in their relative neglect while efforts were focused on more urgent problems.

We urge shrimp pathologists to review their records and archived and current specimens for the presence of the unique WZV8 E-cell inclusions described herein. Hopefully, this will result in data that will provide a global view of the current prevalence and impact of WZV8-like infections.

Report on the Webinar on Management of *Artemia* Resources of the Great Salt Lake 5 May 2022

International Artemia Aquaculture Consortium

The International Artemia Aquaculture Consortium (IAAC) hosted a webinar on Management of the *Artemia* Resources of the Great Salt Lake, 5 May 2022, at 14:00 UTC. The purpose of the webinar was to familiarise participants with recent international developments in *Artemia* research cooperation, and to examine the Great Salt Lake as a case study in successful management of *Artemia* resources in a multi-stakeholder environment.

Summary of the webinar

Welcome and aims of the webinar

Patrick Sorgeloos (Artemia Reference Center, Belgium) gave an overview of the International Artemia Aquaculture Consortium (IAAC). The consortium is an informal network of research institutions and *Artemia* producers that have interests to consolidate and expand the sustainable use of *Artemia* in aquaculture. The present workshop had been organized with reference to a recommendation made at the SDG-aligned *Artemia* Aquaculture Workshop, held 22 September 2021 in association with the Global Conference on Aquaculture Millennium +20, to “Develop science-based protocols to assure sustainable harvesting of wild *Artemia* sources, especially in central Asia”.

History of sustainable harvest management on Great Salt Lake

Thomas Bosteels (Great Salt Lake Brine Shrimp Cooperative, Inc.) gave a presentation on the evolution of *Artemia* harvest management on the Great Salt Lake. By the early 90’s harvesting pressure had increased in the absence of formal state programs to manage, protect and researcher the resource, or to regulate the harvest.

Concerned about sustainability, industry approached the (then) Utah Division of Wildlife Resources (UDWR) regarding management of the *Artemia* resource, and agreed to pay increased fees in order to fund research on the lake’s ecology. As a result, the department:

- Established the Great Salt Lake Ecosystem Program to manage the *Artemia* resource and ecosystem.
- Established a Technical Advisory Group to review scientific data.
- Leveraged the research by entering into joint research programs with the United States Geological Survey and several universities.

Through these arrangements, the support of industry and the research data generated, the UDWR was able to determine the necessary escapement stock of *Artemia* cysts to assure optimal populations and establish a sustainable management model. After 25 years of implementation and sampling to verify recruitment, the optimal escapement stock has not substantially deviated from the original 21 cysts per liter implemented in 1997. Variability of harvest has decreased, while average dry weight equivalent harvest has increased, indicating successful management. Further study of the ecosystem and refinement of the model continues.

Initial policy efforts to protect Great Salt Lake

Timothy Hawkes (Utah State Representative, USA) gave a presentation on initial education and policy efforts to protect the GSL. Until around 2010 the GSL had not received much attention from policy makers. After peaking in the 80’s, water levels in the GSL fell significantly due to both a dry cycle and increased human utilization. In response to stakeholders concerns a

GSL Advisory Council (GSLAC) was established, with a broad membership including counties, state agencies, NGOs, companies interested in mineral extraction and *Artemia*. The GSLAC provided an effective forum for vetting issues, conducting research and raising awareness of issues such as the lake's health, economic value, costs of declining water levels and strategies for water management and other issues.

In 2018 a full time GSL Coordinator was hired, enabling a significant boost in reports and communications. In 2019 the GSL Integrated Management model was published concerning the water supply and ecosystem, which indicated that modest conservation of water would dramatically increase the chances that over time the lake elevation would stay within healthy and sustainable levels.

Another key report by the GSLAC concerned the costs and environmental consequences of declining water levels, such as dust-related impacts and local climate/rainfall effects, also drawing on examples from other terminal lakes from around the world that have experienced problems, such as the Aral Sea.

In 2019/2020 a brainstorming exercise gathered public input on strategies to improve water management, the most promising of which are beginning to be implemented. Recent studies have also examined the impacts of conservation measures, which are generally positive in that they increase water availability, and on measures to increase re-use of water, for example by treating sewerage treatment water (about 25% of usage) to a higher standard.

Managing salinity and nutrients on Great Salt Lake, a cooperative approach involving multiple stakeholders

Thomas Bosteels gave a presentation on a multi-stakeholder collaborative approach to managing salinity and nutrients in the GSL, which are two of the primary drivers of the *Artemia* population. The "safe" salinity for optimal production lies between 100-180 g/L. Lower salinity levels result in increased predation upon *Artemia* and increased prevalence of unfavourable phytoplankton assemblages, while higher salinity begins to impact *Artemia* survival, maturation and reproduction. Annual salinity swings can be as high as 20 g/L, narrowing the target salinity for management to 120-160 g/L.

The GSL is bisected by a man-made causeway. All drainage into the lake occurs in the less saline south arm, which has a strong salinity differential with the saturated north arm. Originally, two culverts allowed bi-directional flow between the north and south arms, but after the culverts failed, a new breach was constructed in 2016 to re-establish flows. The new breach was fitted with an adaptive management berm that could help regulate salinity by differentially restricting density driven heavy brine north-to-south flow, and density/hydraulic head driven lower salinity south-to-north flow.

Salinity management is overseen by a multi-stakeholder Salinity Advisory Committee (SAC). The SAC has developed standard operating procedures for GSL water density measurement and salinity calculation, developed a salinity matrix illustrating the benefits and impacts of different salinity levels on biota and industry, recommends a suitable salinity range (120-160 g/L) to maximise benefits, and reviews data and models to advise on berm geometry modification to maintain salinity within the recommended range.

The United States Geological Survey (USGS) has studied nutrient inflows and cycling in the GSL since the mid 90's. Inflows represent < 10% of dissolved nitrogen in the southern arm of the lake, with a high level of nutrient cycling between trophic levels and temporary nutrient peaks characteristic of the natural hypersaline ecosystem. The GSL is principally nitrogen limited, with some co-limitation of phosphorus, and has high capacity for additional nutrient enrichment, which provides protection of *Artemia* harvest against a reduction in lake volume. The lake volume is not the primary driver of the *Artemia* volume.

In 2011 the Utah Division of Water Quality (DWQ) created the multi-stakeholder Nutrient Core Advisory Team and Nutrient Technical Review Team to guide the development of management criteria based on nutrient concentration and ecological responses in Utah streams. The diversity of interests on the teams provides a balanced approach to development of nutrient criteria that allow beneficial uses of Utah streams to be protected while considering the needs of all aquatic ecosystems including the GSL. As a result, the DWQ has implemented solutions to maintain nutrient inflow into the GSL while protecting beneficial uses in less saline aquatic ecosystems.

More mature law and policy efforts to protect water supply enhanced stakeholder engagement: What does the future hold?

Timothy Hawkes presented on the maturation of the legal and policy response to protection of the GSL, with the legislature becoming more engaged in recent years. In 2019 a resolution was passed to address declining water levels of the GSL, mandating that state agencies should consult stakeholders to gather input on ensuring adequate water flows to the GSL and its wetlands. Sixteen opportunities and 60 recommendations emerged from this process.

In 2020 legislation was passed to enable water banking, and split season leasing, facilitating water sharing between traditional consumptive uses and the environment, promoting efficient utilisation using free market forces.

In 2022 the Governor of Utah announced the budget from the shore of the GSL to draw media attention to the lake. The House Speaker hosted a summit for policy makers and elected officials in January to draw media attention to the GSL. These have helped drive a significant policy response, with six new bills passed directly concerning GSL resource management, and four more with indirect implications for the GSL:

- The *Great Salt Lake Watershed Enhancement Bill* establishes the legal framework for a financial trust to protect the GSL and its water supply. The bill deposits US$40 million into the trust, of which US$30 million is for water and US$10 million for connected habitats.

- The *Great Salt Lake Amendments Bill* calls on the Utah Division of Water Rsources to develop and implement an integrated water assessment for the GSL, appropriating US$5 million to fund the assessment.

- The *Sovereign Lands Management Account Bill* restricts funds derived from the GSL to GSL and other sovereign lands owned by the State of Utah. It creates a new restricted account for royalties derived from lithium or other newly extracted minerals that can only be used to protect the lake's water supply.

- The *Instream Flow Amendments Bill* allows the Utah Department of Forestry, Fire and State lands to acquire and hod instream flow rights. It explicitly recognises the ability of the state and other entities to acquire and hold water rights to benefit the GSL and reduces legal obstacles for such water rights.

Closing remarks

Closing remarks were given by Mike Rust (National Oceanic and Atmospheric Administration, USA). He noted that while considerable research had been invested in microparticulate substitutes for *Artemia*, they had only been partially successful. *Artemia* remained a strategic resource for aquaculture.

The workshop had shown how a vision could become a reality, in terms of the industry pursuing a vision of long-term sustainability and committing financial resources to support it, with scientists providing tools for sustainable management and policy makers helping to establish a framework for governance of the resource. Management had turned out to be considerably more involved than just regulation of harvesting. It was significant that while management started with good harvest management, to accomplish the vision for long term sustainability, management of other ecosystem processes became just as important, such as salinity, flows and nutrient management, overwintering, genetics and ecosystem interactions and services, and engineering of berms. Scientific input remained an ongoing need for resiliency, to guide adaptive management, with the western US in a persistent long-term drought condition.

Coordination of stakeholders requires an effective governance structure and the GSL provided a good example of industry and government partnership. Initially driven by industry, government partnership had provided a place and structure to allow industry, science, and other stakeholders to interact and has added financial and scientific resources to that effort. Further policy and then legal frameworks were then justified to introduced tools such as water banking and others for sustainable ecosystem-based management of the GSL.

In addition to providing around one third of the *Artemia* used by the world's aquaculture, the GSL provided a great example of a collaborative, ecosystem-based, sustainable management of a strategic resource for the long term.

Participants were advised that the presentations and report from the webinar (this document) would be made available on the IAAC website in due course. The report and its conclusions would be tabled at the forthcoming virtual meeting of the FAO Sub-Committee on Aquaculture, which would be held from 24-27 May 2022.

Acknowledgements

The International Artemia Aquaculture Consortium would like to thank the speakers, Patrick Sorgeloos, Thomas Bosteels, Timothy Hawkes, Mike Rust, and moderator Simon Wilkinson for their time and contribution to the webinar.

Twentieth Meeting of the Asia Regional Advisory Group on Aquatic Animal Health

This report summaries the proceedings of the 20th meeting of the Regional Advisory Group on Aquatic Animal Health, held 4-5 November 2021. The role of the group is to review trends in disease and emerging threats in the region, identify developments in global disease issues and standards, to evaluate the Quarterly Aquatic Animal Disease Reporting Program and to provide guidance on regional strategies to improve aquatic animal health management. The meeting discussed:

- Progress on NACA's Asia Regional Aquatic Animal Health Program.
- Updates from the OIE Aquatic Animal Health Standards Commission.
- Aquaculture biosecurity.
- Progressive Management Pathway for Improving Aquaculture Biosecurity activities relevant to Asia.
- A systematic approach for quantifying biosecurity measures in aquaculture.
- Aquatic Animal Health Strategy.
- Updates on OI Regional Collaboration Framework on Aquatic Animal Health.
- Updates on QAAD Reporting and Disease List.

Members of the Advisory Group include invited aquatic animal disease experts in the region, representatives of the World Animal Health Organisation (OIE) and the Food and Agricultural Organization of the United Nations (FAO), collaborating regional organisations such as SEAFDEC Aquaculture Department (SEAFDEC AQD) and OIE-Regional Representation in Asia and the Pacific (OIE-RRAP), and the private sector.

The report is available for download from the NACA website at:

https://enaca.org/?id=1209

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