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Exploration of canals for aquaculture

Live foods boost survival of climbing perch larvae

Air-breathing fish

Isopod host expansion

AQUACULTURE ASIA

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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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How the climbing perch got its name

We have a couple of articles on climbing perch (*Anabas testudineus*) in this issue. While trying to clarify the taxonomic status of this genus I had cause to examine the original descriptions of *A. testudineus* (Bloch, 1792) and it's cogener, *A. cobojius* (Hamilton, 1822). Fortunately, these venerable and exquisitely illustrated publications have been scanned and published online.

Bloch's original description of *A. testudineus*, in German, concerns morphology with little information about the habits of the fish. But Hamilton's description of *A. cobojius* includes a somewhat amusing story that may shed some light on how the climbing perch got its (English) common name:

"This fish is the *Lutianus scandens* of La Cepede…who seems to have borrowed his account from that given of the *Perca scandens* by Captain Daldof…a Danish and not an English officer, as La Cepede supposes. He was a worthy man, very incapable, I believe, of advancing any thing that he thought untrue, and able enough to describe what he saw; but he did not possess those faculties which enable a man to reason on what he observes, or to take into account the collateral circumstances that might lead to an explanation of any thing extraordinary. Accordingly, he gravely assures us, that he saw one of these fishes climbing a palm-tree, and advancing up by the same means that are employed in moving along the ground. The French naturalist, to my utter astonishment, seems to think the circumstance merely curious; nor does he appear to have any doubt concerning the fish possessing the power of climbing trees. Nature, it is true, often gives faculties to animal, by which they are led to actions highly dangerous and pernicious to themselves; and moralists, and other dealers in trash, have therefore often declaimed against the ways of Providence, without reflecting, that these same faculties enable animals to procure the highest enjoyments of which their natures are capable. To what enjoyment this dangerous faculty of climbing trees could lead a wretched fish, I am totally at a loss to imagine, and I therefore believe that Daldorf was mistaken, but to what circumstance, neglected to be noticed in his narrative, the error should be attributed, I cannot take upon myself to say."

Day (1878) added some additional detail concerning Lieutenant Daldorf's original account, which was that the Lieutenant had "...reported having captured one five feet from the ground, from the cleft of a palmira tree, the leaves of which commence from the bottom of its stem."

There is more of interest in these accounts, including speculation on how the capacity to survive out of water for extended periods may have contributed to folklore concerning "fish rains" of *Anabas*; its use as a food store by boatmen on the Ganges who would keep it live in pots until needed; its reputed medicinal properties; and advice on how to remove a climbing perch that has become lodged in the mouth due to locked out spines!

There is one noteworthy thing missing from Hamilton's 1822 book: Any mention of the previously described (1792) *A. testudineus*. Given that Hamilton states *A. cobojius* "…is found every where in the marshes, ponds, and ditches of India", one wonders if he may in fact have been (re)describing *A. testudineus*, for which this description would seem more accurate?

Simon Wilkinson

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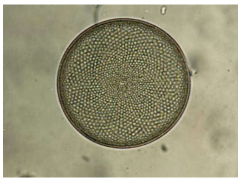


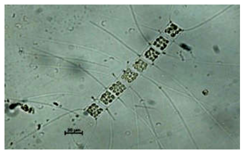

CONTENTS




Exploration of canal resources as a potential source for fish production in the Indian Sundarbans

Archana Sinha, Aparna Roy, Pranab Gogoi, Tasso Tayung, Mitesh. H. Ramteke, Arunava Mitra, Subhendu Mondal and Basanta Kumar Das

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Making additional use of canal resources for fisheries and aquaculture can contribute to income generation and food security for rural people.

Canals are the second most important (26%) source of irrigation, covering about 17.0 million ha in India (Agricultural Census 2010- 2011). There are two types of canals viz., inundation canals and perennial canals. These canals can support fish productions at various levels. Canal water sources vary and may be from an associated reservoir, river, well, spring or lake. The type of water source is reflected by the natural flora and fauna in the canal and is also influenced by the chemicals used on the irrigated land within the catchment. Thus, the environment of canals differs from the surrounding natural waterways substantially. Usually, canals have flowing water but during the lean season it may have a static environment for a certain period of time. This tends to lower planktonic growth in comparison to static water bodies, because the nutrients and plankton are continuously flushed out of from the system.

The main autochthonous production in many flowing canals is in the form of aquatic macrophytes and not the phytoplankton community. Although the production of aquatic macrophyte biomass is very high in canals it is not immediately available to the fish, and frequently they are removed from the system during canal maintenance. This will limit the naturally available fish species in the canals as there are species such as grass carp that are able to directly utilise the plant materials. Thus, the trophic status and hydraulic characteristics of the canal habitats are significantly different from that of the natural waters.

Irrigation canals with suitable flow rates, water quality and depth, have considerable potential for fish production, especially in tropical areas where primary productivity is higher. Water bodies such as dams, lakes and rivers become part of irrigation system and have been extensively studied for their productivity and ecology. However, the canal systems themselves have been given little attention in terms of their potential fish production. Various studies have shown that channelisation or irrigation canals exhibit lower species diversity than nearby static water bodies which are influenced by temperature and low primary producers. In Thailand, there is extensive culture of bighead carp, grass carp and Nile tilapia in irrigation canals. Physico-chemical parameters in canals are strongly correlated with the phytoplankton abundance. The NO_2, NO_3, SIO_3, HCO_3, PO_4, Ca and Mg are important variables in shaping the benthic assemblage in Upper Ganga Canal; zooplankton is primarily dominated by rotifers, cladocerans and protozoa in Ganga Canal. Limnological variations of the Sirhind feeder channel (Hanumangarh) are characterised by shallow, turbid, alkaline and well oxygenated water. Investigations on culture practices in Indian canals are scarce. Research is required to understand the ecology and development of suitable techniques in canal systems and to achieve sustainable production from these resources.

We conducted an exploratory survey was conducted in the canals of Indian Sundarbans, West Bengal for fisheries development and nutritional security of the community. Three canals in different areas of Indian Sundarbans were selected for the study and seasonal sampling was conducted for water, sediment, plankton and fish diversity.

Bishalakhi canal

The canal is located in Krishnanagar, Sagar Island and is tidally fed through its connection with the Mooriganga River. The total length of the canal is 2.5 km, and the width is 22 m (approximately), with a depth ranging from 90 cm to 3 m.

Bhetkimari canal

The canal is located in Madanganj, Namkhana and is tidally fed via a connection with the Hathenia and Dewania rivers. The total length of the canal is 1.5 km. It is approximately 30 m wide and has a depth ranging from around 1.2 – 2.7 m.

Bharua canal

The canal is located in Shibpur, Fraserganj. Like the other two canals it is tidally fed, through a connection to the Hooghly river. The total length of the canal is 2 km and it approximately 45 m wide, with a depth of around 90 cm to 2.4 m.

Ecology of the canals

The environmental parameter of canals in Sundarbans varies seasonally and temporally. Bhetkimari canal is a brackish water canal with a very high fluctuation of salinity from 1.26 ppt in monsoon season to 18.2 ppt in pre-monsoon. pH was slightly alkaline (8.1-8.4) and total alkalinity was moderate (110 mg/l). Dissolved oxygen ranged from 6.0-7.2 mg/l, suitable for fish culture practices. Nutrient parameters such as nitrate did not fluctuate much at Bharua and Bishalakhi canals, but in Bhetkimari canal the nitrate concentration was significantly diluted in the monsoon season (from 0.1 ppm to 0.01 ppm). Phosphate-P in Bhetkimari canal increased significantly during the monsoon with mixing of agricultural field run-off as the probable cause. Silicate was in conformity with other quality parameters; the highest silicate was observed during post-monsoon and in the pre-monsoon the concentration was much lower. The soil quality of the selected canals is mentioned below.

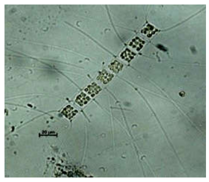
Plankton availability

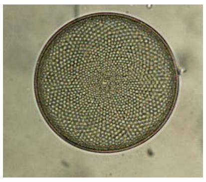
The plankton population exhibited significant seasonal variation. The mean phytoplankton abundance was 2.32 x 10^3 (± 1.0 x 10^3) ml^{-1}, with four major algal groups dominating the sampling stations. Among microfloral elements, cyanophyceae dominated in terms of abundance and bacillariophyceae in diversity. The phytoplankton community in the Bishalakhi, Bhetkimari and Bharua canal was distributed across 62 species (54 genera), 77 species (66 genera) and 71 species (63 genera) respectively during the overall study period. The richness and Shannon diversity were found to be >2.95 in all canals indicating a moderately rich phytoplankton diversity of the systems. The zooplankton community was mainly dominated by crustacean naupliii (26%), followed by calanoida (24%), cyclopoida (14%), cladocera (6%) and rotifera (3%). The most zooplankton was recorded in Bharua canal (1,918 ± 97 individuals/l) followed by Bishalakhi (661 ± 142 individuals/l) and Bhetkimari canal (547 ±138 individuals/l).

Fish diversity in Bishalakhi canal

A total of eighteen finfish species were recorded under ten families, of which twelve were small indigenous fish species. Two species of prawns were recorded (one penaeid and one non-penaeid) contributing 8.6 % of the total catch. Seasonal diversity was observed to be highest during the post-monsoon season (15 species). The family-wise percentage relative abundance of fishes revealed the dominance of

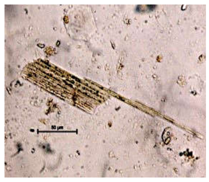

Oscillatoria princeps


Chaetoceros loranzianus


Coscinodiscus centralis


Planktionella sol


Ditylum brightwelli


Bacillaria paradoxa


Helediaptomus sp.


Oithona sp.

family Cyprinidae (88%) followed by Polynemidae (5.75%), Ambassidae and Channidae (5.1% each), Mugilidae (4.3%) and Bagridae (2.7%). Small indigenous fishes were found to be the major component of the fish catch in Bishalakhi canal contributing 76% of the total catch whereas other species contributed only 24%.

Fish diversity in Bhetkimari canal

The fish diversity of Bhetkimari canal was lower than that of Bishalakhi canal. A total of sixteen finfish species under nine families were recorded during sampling, thirteen of which were small indigenous fish species. Five species of prawns were recorded (three penaeid and two non-penaeid) contributing 10% of the total catch. No exotic fish species were recorded. The seasonal diversity observed was highest during the monsoon season, with thirteen species sampled. Analysis of catch structure revealed the dominance of family Cyprinidae (60.5%) followed by Mugilidae (9.2%), Anabantidae (8.4%), Aplochelidae (5.6%), Polynemidae (4.2%) and Bagridae (3.3%). In Bhetkimari canal small indigenous fishes were also found to be the major component of fish catch contributing 83%.

A canal net partition system.

Fish diversity in Bharua canal

A total of sixteen species were recorded under seven orders and ten families. The canal was dominated by fish of family Cyprinidae (60%) followed by Bagridae (13%), Ambassidae (9%), Channidae 97%), Notopteridae (4%), Gobidae (2%), Mastacembelidae (2%), Anabantidae (1%), Megalopidae (1%), and Schilbeidae (1%). The major component of the fish catch was contributed by small indigenous fishes. The seasonal diversity was observed to be highest during the monsoon season.

Status of fish diversity in Sundarbans canals

The fish diversity in Bharua canal was highest in terms of the Shannon Wiener diversity index (H') and Margalef's richness (d') value (2.32 and 2.62 respectively) followed by Bishalakhi canal (1.88 and 2.4). The lowest was recorded in Bhetkimari canal (1.026 and1.02). The highest Pielou'sevenness index (0.85) was recorded in Bishalakhi canal followed by Bharua canal (0.73) and Bhetkimari canal (0.52). The common fishes recorded in the selected canals were *Puntius sophore*, *Puntius ticto*, *Amblypharngyodon mola*, *Salmophasia bacaila*, *Macroganthus pancalus*, *Mystus gulio*, *Mystus vittatus*, *Rasbora daniconius*, *Glossogobius giuris*, *Chanda nama*, *Channa punctata*, *Channa striata*, *Anabus testudineus*, *Notopterus notopterus*, *Chelon parsia*, *Terapon jarbua*, and *Boleopthalmus boddarti*.

Gear used in the canals

The following gear was used to sample fauna in the canals:

Bishalakhi canal

- Seine net: 10.5 m length, 2.1 m height, mesh size 0.5 cm.
- Cast net: mesh size 0.5 cm.
- Bamboo trap: Locally named as *atal*. Large: About 80 cm height, 104 cm length with a 30/30 cm opening; small 40 cm height, 30 cm length and 20/20 cm opening.

Bhetkimari canal

- Bag net: 10 m length, 4 m width, 1.2 m height and mesh size: upper panel 2 cm, middle panel 1.5 cm, lower panel 0.5 cm.
- Seine net: 10 m length, 1.5 m height, mesh size 1 cm.
- Traps: Locally named as *banki*, small in size and made of bamboo. It is triangular in shape and usually placed between two nets.

Bharua canal

- Cast net: mesh size 0.5 cm.
- Seine net: 10 m length, 1.5 m height, mesh size 1 cm.

Above, below: Indian major carps from the net partition system in Bharua canal, Fraserganj, captured together with prawn and small indigenous fishes (overleaf).

- Gill net: 7.5 m length, 1.8 m height, mesh size 2 cm.
- Traps: Large *atal* 80 cm in height, 104 cm in length with a 30/30 cm opening and banki/i, a small trap of 40 cm height, 30 cm length with a 20/20 cm opening.

Net barrier partition system as a tool to enhance fish production from canals of Sundarbans

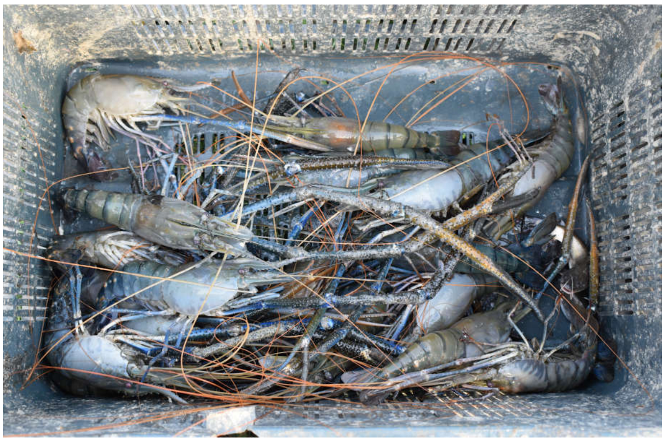
On the basis of suitable water and soil quality, plankton availability and the productivity of canals, Bharua canal in Shibpur, Frasergunj and Bishalakhi canal on Sagar Island of Sundarbans were selected for raising fishes in net partitions. This was done to enhance production for the improvement of local stakeholder livelihoods and social status. A Memorandum of Understanding was signed between the local stakeholders and ICAR-CIFRI regarding culture of fishes in these canals. The net barrier partition system, a new form of enclosure culture, was used as a tool to enhance fish production and livelihoods. The canal was partitioned by installing HDPE net screens as a barrier across with the help of bamboo poles. These were installed with community participation. The partitions were made with locally available poles, net screens and mosquito nets to reduce construction cost. Three net partitions were constructed with dimension of 50 m length × 45 m width each, covering a total area of 2,250 m^2. Indian major carp fingerlings *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* were stocked in addition to the native fishes of the canals. Different stocking ratios, feeding rates and strategies were tested. The best result was observed with stocking @ 2 individuals / m^2 using a stocking ratio of 50 : 40 : 10 *C. catla* : *L. rohita* : *C. mrigala* respectively.

After six months of culture, the maximum sizes reported were 1.2 kg for *C. catla*, 1.0 kg for *L. rohita* and 0.8 kg for *C. mrigala*. A good quantity of small indigenous fishes such as *Puntius sophore*, *Puntius ticto*, *Amblypharngyodon mola*, *Salmostomo bacaila* and freshwater prawn *Macrobrachium rosenbergii* were also harvested. Freshwater prawns were eye catching. The total harvest was 250 kg of fish including 10% share of indigenous fishes available in the canal.

Harvested fishes were sold in local markets at a high price. The results of this project have encouraged the community to culture fish in canals of Sundarbans.

Perception of the beneficiaries and non-beneficiaries regarding canal fisheries development through net pen barrier

A perception-based study was conducted with the objective to identify the people's attitude and perceptions regarding canal fisheries development in that area. A three-point continuum scale (agree, neutral and disagree) with the scores 3, 2, 1 respectively was used to assess the perceptions. Both beneficiaries (30) and non-beneficiaries were taken as respondents. We found that the perception towards canal fisheries development differed between the beneficiaries and non-beneficiaries. More than 50% of the sampled beneficiaries (86%) and non-beneficiaries (56%) perceived that the initiative of canal fisheries development would enhance production and that it would help in income improvement, although they opined that it could create conflict between fisheries and aquaculture.



Above, below: A good quantity of prawns and small indigenous fishes from the net partition system in Bharua canal, Fraserganj.

Beneficiary going to sell fish at the local market.

Governance mechanism for sustainable canal fisheries

Co-management and community-based management are the most viable options for governing irrigation water bodies for livelihood improvement through fish production. Group-based approaches can be the best option to govern the canal fisheries and will facilitate the exclusion of outsiders. For sustainable canal fisheries, environmental, social and economic aspects should be taken into consideration and equilibrium should be maintained.

Canals are important for both capture and culture-based fisheries. Conceivably, the major limitation to fisheries development in canals is assurance of a regular flow of water throughout the culture period. Since canals are made primarily for agricultural purpose, a conflict may arise between the stakeholders. In aquaculture, the question of ownership of the cultured fish is quite clear. But, in the case of canal fisheries, ownership of fish may be set in participatory mode before the canal fisheries starts.

Conclusion

The canals of Indian Sundarbans have been proven as a potential source of fish production with community participation using net barrier partition systems as a tool to enhance fish production. However, the adoption of viable technical interventions for the fisheries development needs to address the potential for conflicts among various stakeholders as part of the planning and design process. Viable options for better governance and people's participation were identified by conducting participatory rural appraisals and an awareness programme to boost canal fisheries.

We identified that awareness and sensitisation to canal fisheries would attract the local populace towards enhancement of fish production. People also perceived that group-based approaches may help to amplify community participation in canal fisheries development. Moreover, better linkages and improved coordination among research institutes, state departments, village panchayats, self-help groups and fishers will support canal fisheries development in that particular area. More emphasis on the field demonstrations, training and capacity building programmes and extension will help in diffusion of the knowledge and practice of canal fisheries. Consequently, sustainable canal fisheries will be achieved by amalgamating management and strategies across social, ecological, biological, political and economic dimensions.

Expansion of new host range of isopod *Tachaea spongillicola* infestation to fish species could pose a risk to aquaculture food industry in southeast Asian countries

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Fish and fisheries products are recognised as the healthiest animal source of protein on the planet and their role is being considered in national, regional and global food security with a view towards eliminating hunger and malnutrition. Current global fish production is 179 million ton (MT) of worth US$ 401 billion[1]. Cage aquaculture is being hailed as a means to increase aquaculture production for nutritional and livelihood security in southeast Asian countries[2,3]. Cage aquaculture has grown in popularity over the last decade, and it is now used as an alternative to land-based fish farming in southeast Asian countries including India. India has 3.5 million hectares of reservoir resources with tremendous potential for increasing fish output through cage culture technology expansion. Cambodia is a pioneer in cage culture and at present this technology has been spreading and excelling since its inception in other southeast Asian countries also.

Disease outbreaks are a bottleneck in all types of diversified aquaculture. It has been estimated that bacteria (55%), followed by viruses (23%), parasites (19%) and fungi (3%) are the most common causes of diseases in aquaculture[4]. As a case study, the authors have recorded for the first time an isopod parasite *Tachaea spongillicola* infestation in three freshwater fish species viz. *Labeo rohita*. *Cirrhinus mrigala* and *Notopterus notopterus* in reservoir ecosystems (Dhanei reservoir, Odisha.

The specimens were deposited in National Repository of Zoological Survey (ZSI) Kolkata, India, with registration number, C 8037/2. The severity of the pathology and prevalence of the parasite in these three species have been recently published in Aquaculture (https://doi.org/10.1016/j.aquaculture.2021.737436)[5].

The major concern of this correspondence is to highlight two important issues, namely:

- Expansion of parasitism to new hosts.
- Infestation in diversified fish species as a threat to fish farmers undertaking cage aquaculture in inland open waters.

T. spongillicola was recorded for the first time as a commensal of freshwater sponges, *Spongilla carteri* in the Indian Museum Tank in Kolkata in 1907[6]. Since this first

Tachaea spongillicola (inset) infestation on Indian major carp.

record the parasite has been reported as infesting three freshwater prawn species, *Macrobrachium lamerrei*, *M. malcomsonii*, and *M. nobilii*[7,8]. The expansion of parasitism from freshwater sponges and freshwater prawns to freshwater fish as we have reported is of concern to researchers with regards to the factors responsible for its host expansion.

We hypothesise that water flows could be one of the factors that may influence the degree of parasitism by *T. spongillicola*. Water flows have been found to be affected by global climate change. As aquaculture is linked to water availability and quality, it is likely that the aquaculture industry will be impacted by climate change[9]. Furthermore, expansion of parasitism to new host is also a matter of concern, particularly if linked to climate change. Although we have recorded a fish as a new host, a deeper investigation is required to establish the role of climate change in expansion of parasitism.

Diversification of species, system diversification with high stocking, and external inputs in terms of balance feed are requirements in cage aquaculture. Indian major and minor carps, Chinese carps, catfishes, mahseers, freshwater prawns, and monosex Tilapia have all been cage tested[10]. With this background, the record of *T. spongillicola* infestation in a fish species could definitely be a concern for the fish health manager. Good fish health management practices are crucial to lower the risk of disease outbreaks and facilitate fish production in reservoirs to meet state and national targets.

Conclusions and way forward

Records of *T. spongillicola* prevalence show a progressive expansion of host range starting from invertebrates (sponges and crustaceans) to vertebrates. As we discussed in our publication, water flow could be one of the factors that provides a clue for its infestation. Thus, the present correspondence is a research brief that provides an insight on *T. spongillicola* infestation, which could be a strategic advantage for neighbouring southeast Asian countries for sustainable aquaculture production.

Acknowledgements

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Danei Reservoir, Odisha, India.

Aspects of air-breathing fish farming practiced at Mathurapur-II Block, West Bengal, India

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The small, shallow earthen water units of villages can be scientifically utilised initially as major carp nursery and rearing ponds until the post-monsoon months, and later for culture of air-breathing fishes such as *Clarias magur, Anabas testudineus* and *Heteropneustes fossilis*. Multiple use of water resources in this way provides scope for enhancing farmer incomes, rather than using them for carp fry and fingerling production alone.

Small, shallow, mosquito larvae-infested ponds that would otherwise remain fallow can be utilised for air-breathing fish culture after necessary pre-stocking management. These cultivable high-value fishes are 'migratory' under farm conditions and tend to escape from grow-out ponds to nearby low-lying paddy fields by climbing over the bunds (in absence of proper fencing) or passing through rat holes. This will not happen if their culture is practiced in concrete tanks, which typically have a lesser volume of water. In recent times quite a few youths and elderly small- to medium-scale fish farmers in villages of South 24 Parganas District, West Bengal have been involved in A*. testudineus* and *C. magur* farming in ponds and concrete tanks and cisterns, using normal, indigenous recirculation and semi-biofloc systems.

Native *A. testudineus* is a high-priced fish, nutritious and economically profitable for small- to medium-scale fish farmers. They avail of fry and advanced fry of indigenous *A. testudineus* in good quantity from local paddy fields and low-lying inundated areas in late summer, monsoon and post-monsoon periods.

The second author is an elderly fish farmer and biofloc practitioner in Mathurapur-II CD Block of South 24 Parganas District. He has initiated culture of these fishes in two concrete tanks applying biofloc technique since September 2019. The first author made a series of attempts to explore and document the rich practical knowledge of progressive elderly fish farmers in villages of West Bengal. This communication presents the underlying science, a few aspects of management practices in the fields of major carp pond culture and biofloc-based culture of *A. testudineus*, which the second author and Sri Shiblal Maity initiated in their tanks, in addition to cultivation in earthen ponds.

Mature female climbing perch.

Particulars of biofloc fish culture

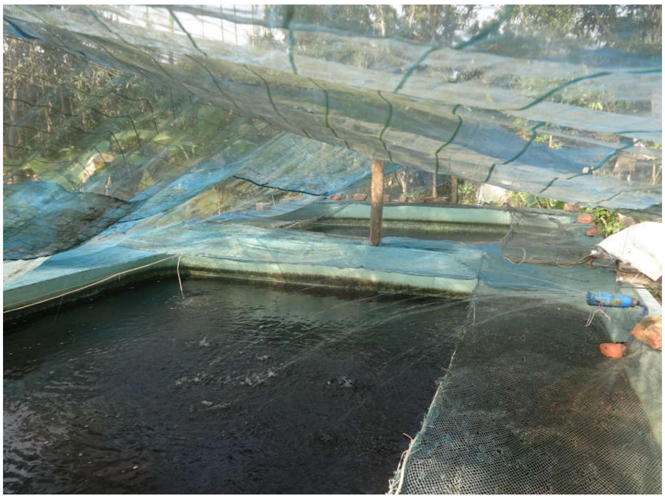
The second author's two fish tanks measure 3 m x 3 m x 0.75 m each. The total water volume maintained is about 14,000 litres and construction cost was INR 30,000. He also possesses four well managed earthen fish ponds with a total area of 4,200 m^2, where major carps, *Notopterus chitala* and the three air-breathing fishes are cultivated. Duckweed (*Azolla* sp.) is cultivated and maintained in an 18,000 litre cement tank and Napier grass on 60 m^2 of homestead land. Commercially available probiotics containing live bacteria such as five different species of *Bacillus*, *Yucca schidigera*, and *Pseudomonas denitrificans* are used in biofloc fish tanks. Sugarcane molasses is used as a carbon source. Heterotrophic bacteria *Bacillus* sp multiply very fast, around once in every 30 minutes in comparison to nitrifying bacteria which multiply once in 7-14 hours. Thus, the nitrifying bacterial population becomes outnumbered with the progress of time. In biofloc fish tanks, NH_3 is produced by denitrifying bacteria from fish faecal sludge containing undigested and unassimilated proteins (above 70%), which is utilised by both nitrifying and heterotrophic bacteria. NH_3 is inimical to the growth and well-being of fishes under culture above a certain concentration.

Heterotrophic bacteria are capable of synthesising essential components required for cellular multiplication by combining NH_3 and glucose/sucrose/starch derived from the carbon source added to biofloc fish tanks in a calculated manner with regards to the protein content of fish feed applied. Thus, hetertrophic bacteria effectively reduce the concentration of NH_3 in fish tanks and produce irregularly-shaped and porous 'biofloc', a heterogenous mixture of microorganisms, organic polymers and dead shells. biofloc contains about 55% protein and is nutritious for fish.

By the action of nitrifying bacteria, NH_3 is converted to NO_2- and then to NO_3- , which is another way of decreasing NH_3 concentration. NO_2- is harmful for fishes under culture especially in tanks, although less so than NH_3, and NO_3- is much less harmful than NO_2-. If it is felt that the amount of floc developed in tanks is low, faecal sludge matter shouldn't be released from tanks. Conversely, if a dense amount of floc is observed and estimated, then outlets can be opened for a few seconds to release a portion of the sludge.

It is good if semi-intensive to intensive culture of air-breathing fishes and small indigenous catfishes is done in biofloc tanks following a blend of 75% bottom-clean method and 25% biofloc system. The second author believes that cultivable small indigenous catfishes do not eat biofloc in great quantity, so it is not required to convert 100% of the NH_3 produced

Sri Purkait at his biofloc fish farm site.



Biofloc tanks of Sri Purkait.

A. testudineus 60-70 g.

Climbing perch fry are naturally found in paddy plot canals.

10 m tank built with state government support.

Induced-bred A. testudineus fry (pen cap for scale).

from the faecal sludge into biofloc-based food matter. At the same time, total bottom-cleaning with frequent exchange of water is not required. Small lumps of fish faecal matter are released in a controlled manner with discharge of water from the biofloc tanks, which are designed in such a manner that sediments accumulate at the centre of biofloc tanks. Floating semi-pelleted type home-made feed is used. Fish are harvested along with outflowing water after opening the valve of the bottom outlet pipe.

The three air-breathing fishes cultivated in biofloc tanks are the indigenous *A. testudineus* (4,000 pieces or 75-80% stocked in each tank) along with lesser numbers of *C. magur* and *H. fossilis*. Water volume in two tanks is increased up to 13,000 litres as growing *A. testudineus* attain 30-50 g in size. Its seed was stocked here in early August 2020 at 10-20 g size, and harvested at 100 g at the end of February 2021. Another crop has been raised and is being continued.

The use of $CaCO_3$ and dolomite acts as a buffering agent in biofloc tanks. The second author routinely uses a battery-operated total dissolved solids (TDS) meter, pH estimation meter and NH_3 (TAN) estimation kit with reagents to monitor water quality in. The addition of molasses increases TDS in tank water; raw salt (‘sandhok labon’ in Bengali) is added in a controlled and calculated manner with aeration in water to achieve TDS of tank water around 900-1,100 units before stocking fish seed. In conditions of increased TDS content, biofloc remains in a suspended condition in the tank water column, which is desirable, otherwise it will settle down. At pH ≤ 6.0, one tablespoon $CaCO_3$ /1,000 litres water is added during sunshine; subsequently a mixture of 20 g commercial probiotics and 40 g molasses per 1,000 litres water is added on the same night. Water is kept undisturbed with continuous aeration for 7-10 days and fish seed are stocked thereafter. The concentration of biofloc in the tank increases with time. The carbon source is added to tank water based on estimation of C:N ratio required to produce and maintain the biofloc.

Market-sized A. testudineus 50-60 g.

80-100 *A. testudineus* seeds weighing a total of around 1 kg should be stocked in biofloc tanks, which gives satisfactory growth; smaller ones (4,000 pieces/kg) reach 35-60 g in 4.0-4.5 months. The growth of small-sized seeds becomes slower if the culture period passes through winter. Beneficial bacteria should be cultured in biofloc tanks before stocking seed; and an advanced model of air pump set up for much-needed aeration in the tanks.

Major carp culture in ponds

The second author has experienced that semi-decomposed paddy straw in fish ponds can be a good food for *Labeo rohita*. Earth from the base of wild bamboo plants contains beneficial probiotic bacteria. Rice bran fermented with yeast and *Lactobacillus* sp. can be added regularly in fish culture ponds as feed. The proper application of organic matter such as paddy straw, Napier grass, and composted poultry droppings and cow dung in fishponds throughout the year is necessary for boosting phytoplankton and zooplankton growth to enhance natural food production in fish culture ponds and reduce feed cost. This system is sometimes now termed 'aquamimicry' fish farming, although the practice itself is very old.

Application of 1.25 kg organic matter/40 m^2 water area/week facilitates good growth of pond-reared fishes, which wouldn't be possible with floating supplementary pelleted feed alone. Application of Napier grass and duckweed *Azolla* sp in fishponds gives good results; cultivated Napier grass is eaten by *Ctenopharyngodon idella* and *Puntius sarana*, thereafter their excreta is fed upon by *Hypophthalmichthys molitrix* and *Aristichthys nobilis* (presently bighead carp is not cultivated by the second author). Carp spawn are obtained from fish hatcheries early in a season as seed from the first breeding are superior in quality and favoured for stocking in nurseries. Application of 30 g salt per kilogram of formulated fish feed enhances digestive capacity of farmed fishes. A mixture of 5 kg cow dung, 1 kg wheat flour and 200 g date palm jaggery ('*chitey gur*' in Bengali) is applied in every 640 m^2 pond, 24 hours after mixing and twice a month, leading to sufficient production of zooplankton. One can have successful fish production from ponds on the basis of 60-70% natural planktonic food (chironomid larvae, phytoplankton, zooplankton) and 30-40% supplementary feed, which may be farm-made or pelleted procured from market.

Before stocking air-breathing fish seeds into culture systems, bought in oxygenated packets, they should be treated and disinfected successively in potassium permanganate ($KMnO_4$) solution (0.5-1.0 g/10 litres) for 45-60 seconds, in salt solution (100 g/10 litres) for the same period, followed by freshwater, in separate buckets; the process is repeated 2-3 times. Even

Properly-fenced A. testudineus pond.

if bacterial or fungal infection occurs in some of these fishes under culture, the infection will be less likely to spread to other fishes.

Dry paddy straw @ 1 kg/40 m^2 once in every 20-25 days controls turbidity due to mud suspension. When straw starts decomposing in pond, the growth of chironomid larvae and periphyton occurs over it, both of which serve as natural food of major carps. Tiny aquatic worms also grow in the decomposed paddy straw at the bottom of ponds, which fish are fond of eating. A combination of fermented rice bran, mustard oil cake and minced Napier grass can be added in ponds regularly as fish feed. Napier grass contains a high percentage of protein and other nutrients and can be utilised for fish growth. Weekly application of 50-60 g of each of urea and single super phosphate and 10-20 g muriate of potash per 40 m^2 in pisciculture ponds is beneficial. Normally limestone powder is applied monthly @ 4.5 – 5 kg per 1,320 m^2 during culture period and its quantity should be increased in ponds that have a thick sediment load beneath. Fungal attack on cultured catfishes is prevented if salt is applied in ponds @ 1 kg / 40 m^2 (INR 7-8/kg) during the onset of winter.

Feed preparation for *A. testudineus*

For air-breathing fishes in ponds, the second author prepares mixture of 300 g rice bran, 400 g mustard oil cake, 100 g wheat flour, 120 g fish meal, 50 g broken rice and rest 30 g comprising yeast, probiotics, ‘chitey gur’, yoghurt and vitamin-mineral mix. The ingredients are mixed in a large stainless-steel bowl, fermented for 24 hours and fed to growing *A. testudineus* in ponds as dough balls placed over mosquito net cloth. This process improves the nutrient content in feed (25% protein content), which costs INR 22-25/kg for him and helps prevent pathogenic bacteria being able to colonise the gut of *A. testudineus* and other fishes. Such fermented feed can be given to *A. testudineus* in biofloc tanks four times per day. Additionally, a semi-pelleted form of floating farm-made fish feed is prepared using a meat grinder (mincer) supported with a pellet cutter.

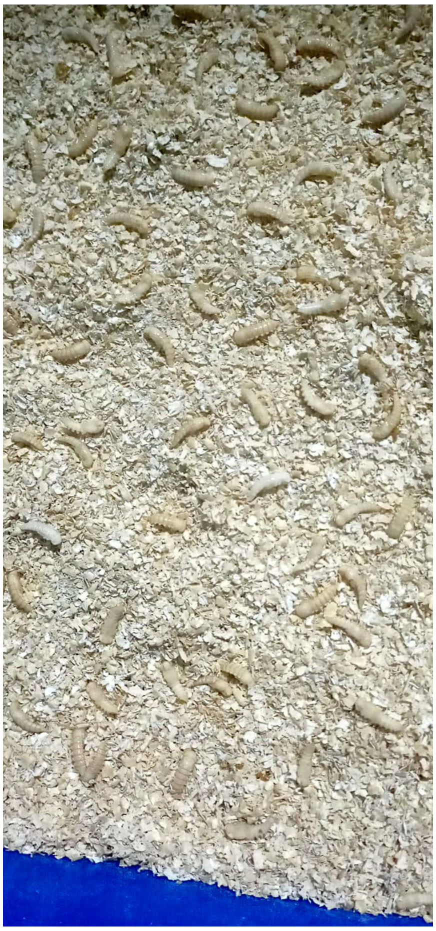
Pond-reared air-breathing fishes

Fingerlings of *A. testudineus* have a blackish spot on their caudal peduncle and greenish hue on the upper body surface. After stocking 25,000 *A. testudineus* of around 10 g each in a 1,320 m^2 pond, the second author harvested 100-120 g sized fish at end of eight months, with 3% mortality. Seeds and market-sized *A. testudineus* were counted at times of stocking and harvesting respectively, with around 9 kg of production from every 1 kg of seed stocked, and an income of INR 4,500 from INR 1,000 invested in *A. testudineus* farming. Seed of *A. testudineus* @4,000 pieces/kg were observed to grow up to 3.6-4.8 cm in a month. In another earthen pond, 4,000 *H. fossilis* seeds, 1,000 *C. batrachus* seed and 100 kg of *A. testudineus* seed (10 g size; INR 3/piece) were stocked and reared for eight months. It has been planned to culture Vietnamese shol (*Channa striatus*), *Ompak pabda* and *Mystus cavasius* in a biofloc system in pond conditions in 2021 and thereafter.

For both earthen ponds and biofloc tanks, the second author prefers to stock seed (2.4-4.8 cm) of *C. magur*, *A. testudineus* and *H. fossilis* collected from local natural sources. During June-August, adults spawn in water-logged rice fields, swamps and small village ponds. The resulting seed have high disease resistance and higher survivability in culture systems. While procuring seed of *C. magur* and *H. fossilis* from hatcheries or fish seed markets, farmers must be sure that the *C. magur* seeds bought are entirely of the desirable pure variety and are not hybrids or exotic magur species. Pure native *C. magur* has an entirely blackish body colour, all four pairs of barbels equal in size, and a ‘v’ shape observed on the posterior region of skull.

Maintaining mealworms to feed *A. testudineus*

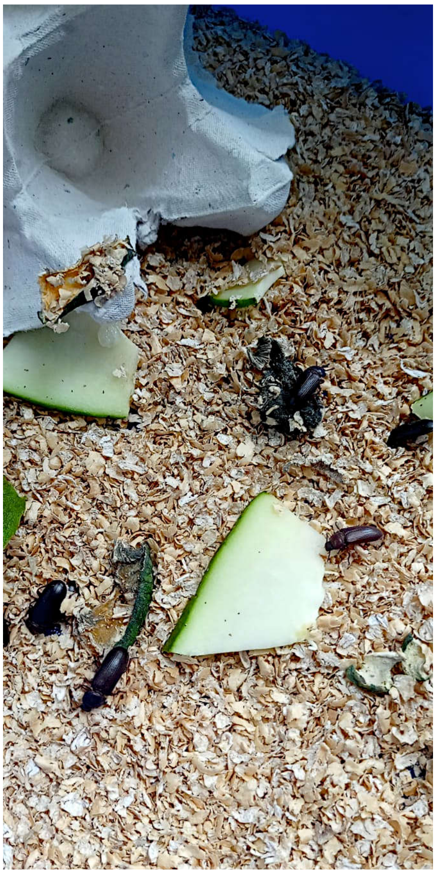
Mixed culture of murrels *Channa marulius*, *C. striatus* and *C. punctatus* gives a good yield with feed comprised of soaked dried marine trash fish and fresh silkworm pupae. Likewise did *A. testudineus* in net cages, when fed with rice bran, mustard oil cake and silkworm pupae. *C. magur* feeds on insect larvae and worms in natural water bodies. Commercial *A. testudineus* feed costs INR 55-60/kg. Live mealworm larvae (‘*beetol poka*’ in Bengali) are much preferred by growing *A. testudineus* as a food in culture systems, can be maintained by farmers at home, and partially replace dry commercial feed, lowering the cost of fish production. The second author procured 10-14 mm mealworm larvae @ INR 750 / 700 pieces and kept them in rectangular plastic trays (30 x 40 x 10) cm3, 1,000-1,200 larvae/tray) containing a 4.8 cm thick bed of a



Mealworm larvae advancing into pupa.

Mealworm larvae in small plastic cups.

Sri Purkait with a few of his mealworm beetle trays.



Mother mealworm beetle reared by Sri Purkait.

Proper condition for breeding and egg laying of mealworm beetle.

Mealworm beetle stock maintained by Sri Purkait.

wheat flour by-product ('*gomer bhusi*' in Bengali). Fine pieces of orange-red ripe papaya and sweet pumpkin are fed to growing larvae, which metamorphose into the brown-coloured pupae stage after 10-15 days in summer, monsoon and post-monsoon months.

Mealworm pupae are maintained in small, transparent, disposable 100 ml capacity plastic cups (INR 45/100 pieces) without food, one pupa in each cup. It takes 35-40 days for larvae to become an adult mealworm beetle, completely black in colour. Mother mealworm beetles are maintained in plastic trays (25-30 pieces/tray) containing 2.5-3.0 cm thick bed of wheat flour byproduct; ripe papaya fed to them. Matured male and females are allowed to mate underneath squarish pieces of brown cardboard carefully placed over trays. In next 7-8 days, eggs are laid over bed of wheat flour byproduct. Parent beetles are transferred to another tray. About 2 kg of mealworm larvae are obtained in each tray on the 25th day from laid eggs. A medium-scale set-up and population of adults and larvae of mealworm are maintained by second author, as a daily food supply for *A. testudineus*, which is an insectivorous fish.

Other observations

The authors have experienced that the carbon source that is used to control NH_3 in semi-biofloc fish tanks can cause natural fish body colour to become inferior, reducing the market price of such biofloc system-reared fishes accordingly. If this 10,000-12,000-litre circular tank is considered as a pond environment, then after filling with water cow dung may be applied at one corner and quicklime (CaO) applied after 3-4 days in combination with little salt; the pH should be between 7.5-8.5. A small amount of dried straw, the by-product of paddy grain crop, may be applied on the water surface in tanks. During sunshine, urea and single superphosphate are applied at the correct rate. Tank water will turn greenish over the next 3-4 days. Lime and common salt should be applied once a month; organic and inorganic manure once in every 7-8 days at correct rate. Floating weeds *Pistia* sp and/or *Ipomoea* sp should be kept in tanks. Such a process will help keep control over NH_3 formation in biofloc tanks, and at the same time the natural body colour of fishes under culture will remain intact.

Hybrid *A. testudineus* fry in nature – a concern

Native *A. testudineus* can be cultured in 320-1,200 m^2 earthen ponds. In West Bengal, fish farmers have also been farming it in cement cisterns using normal methods, ie. without biofloc or RAS, for nearly twenty years. Since 2015-2016, a few farmers started using semi-biofloc and RAS farming methods to culture air-breathing fishes. In ponds, the fish typically attain 50-70 g from 2.4

Growing hybrid fry of native x Vietnamese strain A. testudineus.

Vietnamese strain A. testudineus 125 g.

cm size in 135-150 days, 75-100 g in 9-10 months, producing fish with a blackish green/faint green colour, a 'v' shaped snout and terminal mouth.

A distinct strain of *A. testudineus* from Vietnam are also cultured in a few districts of West Bengal. These are fast-growing but not as good as the native strain, attaining 100-120 g in 90 days and 275 g in 7-8 months, with 15-20% fishes reaching 350 g. Vietnamese *A. testudineus* have a black circular blotch present near the caudal fin origin, a black mole on the operculum edge, a greenish red colour and a snout that is somewhat 'u' shaped rather than 'v'.

Both native and Vietnamese specimens exhibit 'climbing' behaviour in spawning season with onset of monsoon or after heavy shower (rain), native *A. testudineus* 50-90 g of both sexes migrate from one culture pond or normal pond to nearby seasonal ponds with submerged weeds, paddy fields (with embankments on all sides) with a minimum of 20-25 cm of rainwater stagnation or above, depressed temporary lowland, or shallow canals. Breeding season is during June-August. For native and Vietnamese *A. testudineus* monoculture ponds in villages, split bamboo-nylon net fences are erected on all sides up to 50-60 cm height to prevent escape, but accidental/unintentional release from some ponds often occurs during heavy rain through torn fence nets. This is problematic and poses a concern in the case of the Vietnamese strain, which is exotic. During August-October, native *A. testudineus* seed collectors conventionally place indigenous '*baanser ghuni*' (fish traps) at the mouth of outlets of those nursery grounds and capture 1-4 g fry (30-45 days old; 2.4-3.6 cm) produced through natural breeding. Grow-out farmers buy it for stocking from local collectors @ INR 2-3/ piece.

Farmers procure fry of Vietnamese *A. testudineus* from Naihati fish seed market and hatchery owners, which produce it locally using induced breeding methods. There was no report from farmers growing indigenous *A. testudineus* in pond and semi-biofloc systems in South 24 Parganas District about the occurrence of hybrid *A. testudineus* fry (crosses between native and Vietnamese strains) in nature in the same or nearby villages. On 11/2/2021, the first author was informed by Sri Shiblal Maity at Paschim Jota Village, Kankondighi Gram Panchayat, Mathurapur-II CD Block during an on-site conversation about hybrid fry produced in nature. Sri , aged 32, introduced a semi-biofloc system of indigenous *A. testudineus* culture in concrete tank in this Gram Panchayat at the end of 2019. He bought and stocked naturally bred fry at 1.0-1.5 g (20-25 mm size), and some fish reached 100-150 g in 3-4 months that didn't exhibit the true body features of native *A. testudineus* completely. He realised the occurrence of only 200 pieces of a pure (native) variety of *A. testudineus* in every 500 *A. testudineus* fry stocked, with the rest belonging to the hybrid variety.

There is increasing trend of pond farming of Vietnamese *A. testudineus* in this Gram Panchayat and is quite possible that some mature ones escaped through net screen and entered into water-logged paddy fields during heavy rain. Normally only gravid females of the Vietnamese strain move out from the pond. During this time, some mature males and females of indigenous *A. testudineus* escape from culture ponds, which also live in normal seasonal village ponds naturally. *A. testudineus* of one paddy field during monsoon and post-monsoon were mixed with another field in this Gram Panchayat, leading to mixing of mature adults of both native and Vietnamese strains and production of such hybrid seeds or fry, Sri Maity opined. Hybrid fry, trapped at 50% or above in the devices of seed collectors together with native *A. testudineus* fry, had black spots at the caudal peduncle and operculum. Their body colour resembled that of the Vietnamese variety and shape of the native variety. Sri Maity feels that it is an issue as the presence of Vietnamese *A. testudineus* in nature may lead to marked depletion of naturally occurring native seed in Kankondighi Gram Panchayat in future and increase the availability of hybrid seeds, which is strictly unwanted.

Floc production in tanks and remedy for bacterial infection

Sri Maity is doing *A. testudineus* culture in two cement cisterns (4.5 m x 3.5 m x 0.9 m) using a semi-biofloc system. A mixture of rice bran, mustard oil cake, wheat flour, uneaten rice from kitchen and a little trash shrimp meal/fish meal is fed to them as dough balls. He has experienced that red sugar produced from pure sugarcane jaggery (‘*aakher gur*’ in Bengali), with no added chemicals, serves as a good carbon source in biofloc tanks; 250 g sugarcane molasses and 200 g red sugar is added to every 1,000 litres of water. His home-made probiotic mixture comprises 100-200 g paddy grain, a little brackishwater, 18-20 g raw salt and 30 g red sugar in one litre water, which is shaken, aerated, sugarcane molasses added and further processed, and beneficial bacteria allowed to grow. The lid of the probiotic container is not tightly closed. One litre of mixture is diluted to 17-18 litre; 2 litres of inoculum is kept in airtight condition and applied after a week contributing to floc production in *A. testudineus* tanks at a good density. Cow milk @10 litres may be added to the mixture.

In a black 8,000 litre geo-membrane lined circular tank meant for *C. magur* farming, Sri Maity has successfully used a paste mixture of 7-8 g garlic and 50 g powdered turmeric in every 1,000 g supplementary feed of *C. magur* to treat low- to medium-level of external bacterial infection. Greenish extract

Sri Maity at his biofloc farm site.

Structure of Sri Maity's biofloc fish tank.

prepared out of boiled *Azadirachta indica* leaves (300-400 g dried leaves in every 5 litres of water) has also proved useful in treating small skin ulcers in growing *C. magur* both in small ponds and tanks during winter. Aeration continued in tanks, the carbon source added, and partial water exchange conducted to remove bitterness caused by the *A. indica* extract.

End note

Devoted and innovative fish farmers can disseminate knowledge and guide rural aqua-entrepreneurs and young progressive fish farmers for their betterment and success; their efforts will contribute to all-round development and expansion of air-breathing fish aquaculture in West Bengal. Back in year 1971, the All India Coordinated Research Project on air-breathing fish culture was launched in West Bengal and four other states to evolve appropriate farming technology and a complete package of practices, which were made known to rural fish farmers. With the passage of time, methods for captive breeding, large-scale seed production and culture of important air-breathing fishes and small- to medium-sized catfishes have been standardised in India. The late Dr Padmakar V. Dehadrai was the first Project Coordinator of this project, and to date the longest-serving Deputy Director General (Fisheries Science) of the Indian Council of Agricultural Research. Dr Dehadrai passed away ten years ago in June 2011. The authors dedicate this article to Dr Dehadrai to commemorate his contributions to the development of Indian inland fisheries and aquaculture.

A. testudineus 90-100 g.

Magical role of live foods in boosting spawn survival of climbing perch: A success in the farmer's field

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Human efforts continue to promote the aquaculture sector to meet the demand for protein rich foods from aquatic sources. The development of aquaculture emphasises the improvement of culture practices, diversification of aquaculture systems, and incorporation of more wild species into culture through their domestication. The climbing perch, *Anabas testudineus* (Bloch, 1792) is a preferred fish species with high market demand that was brought into culture practice in the recent past.

Climbing perch belongs to the family Anabantidae in the order Perciformes. It was treated as a monotypic genus *Anabas*, until another species *A. oligolepis* was known to us, which created a bit of confusion in regard to its distinctness from *Anabas testudineus*. *A. oligolepis* was later determined to have been first described as *A. cobojius* by Hamilton (1822) and is now accepted as a second species of the genus *Anabus*. The global population of *A. testudineus* is declining in many regions, but the substantial number of populations that exist assure the species remains unthreatened. Earlier, the species was treated as 'data deficient' on the IUCN Red List of Threatened Species, but later it was revised to 'least concern' on version 3.1 (Ahmed et al, 2020).

Habit, habitats and distribution

Habit

A. testudineus is an air breathing species which has an accessory air breathing organ situated above gills to facilitate the exchange of atmospheric air. This enables the species

Netting the broodstock.

A close view of harvested broodstock.

to withstand oxygen depleted conditions for a considerable period and enables the fish to migrate short distances overland to reach new habitats. The size and weight of adult males and females is usually in the range of 6.5-8.5 cm and 40-100 g, respectively. Adults may be 150 g in some cases. The species is migratory with movement usually taking place during the early monsoon months when showers start in June and July. *A. testudineus* prefers laying eggs in clean water and will search for preferred breeding ground in early rains so as to provide a suitable habitat for its progeny. Adults are omnivorous and will feed on large plankton, insects, invertebrates and small fish, but juveniles feed on plankton according to their capability at different ages. This species is a visual feeder and mainly feeds during the day; it prefers chasing prey, which seems to increase its appetite while feeding.

Above, below: Mature climbing perch.

Habitat

Climbing perch inhabit water bodies ranging from freshwater to brackish water, with diverse forms: Rivers, lakes, reservoirs, tanks, ponds, jheels, canals, karanjali, ditches, swamps, estuaries and low-lying water bodies. It also grows in paddy fields, flood plain lands and derelict water bodies, whether they be seasonal, annual or perennial. It can withstand sluggish flowing canals densely covered with aquatic plants, tolerate waters with high biological oxygen

Management of climbing perch broodstock in an earthen tank.

demand or polluted conditions, survive in turbid and stagnant water, and even remain alive buried in mud during the dry season. People commonly catch it from low-lying water bodies, swamps, and marshy lands which generally dry up during the summer months, but also catch this species during its migration at the eve of the rainy season.

Distribution

Climbing perch are dominant in the south Asia, comprising India, Bangladesh, Pakistan, Nepal, Sri Lanka and Bhutan. It also occurs in south-east Asia including Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Indonesia, Brunei, and Singapore. It is found in southern China, and has been introduced to the Philippines.

Medicinal importance and food value

Traditionally, people use *A. testudineus* as a food of medicinal importance. People who fall in sick due to stomach upset, intestinal disorder and repeated convulsions are advised to consume this species through traditional culinary preparation. Its muscle is soft and easily digestible and has a unique taste. It is a valuable source of docosahexaenoic acid (DHA), ecosapentaenoic acid (EPA) and several essential amino acids required for human brain development, and fat metabolism, essential for preventing diseases such as atherosclerosis, dementia, and Alzheimer's disease. Typical nutrient values of *A. testudineus* per 100 g are: Moisture, 70 g; protein (N × 6.25), 14.8 g; fat, 8.8 g; minerals, 2 g; carbohydrate, 4.4 g; energy, 156 kcal; calcium, 410 g; phosphorus, 390 g and vitamin c, 32 mg; vitamins A, D, E and K as 93.9, 43.12, 1.27 and 1.15 respectively. Climbing perch is highly valued for its unique flavour, and prolonged freshness.

Breeding

Broodstock management

Anabus broodstock are usually stocked from February onwards in selected ponds or in small tanks with suitable size ranges between 0.015- 0.02 ha, and water depth less than 0.7 m. They are conditioned under specific management strategies including daily feeding, water exchange, growth measurement, and disease surveillance. The broodstock are supplied with mixed plankton, along with high protein rich food purchased from the local market.

Broodstock are collected in a bamboo basket for selection of suitable fish.

Broodstock selection for breeding

As soon as broodstock develop a considerable size, they are examined through secondary sexual features to determine whether they are fully conditioned to take part in breeding. If they are found to be in suitable conditioned for breeding, the males and females are placed in separate tanks with slow showers falling into them for 3-4 hours. Then they are transferred to the breeding tray, and kept together in equal numbers.

Breeding in captivity

Selected broodstock are administered hormone injections: Females @1.0 ml/kg body weight and males @ 0.5 ml/kg body weight. Then both male and female broodstock were kept in the breeding tray with flowing water and aeration. After 7-8 hours, females release eggs. The fertilised eggs are put into a hatching chamber in which a running water flow is provided. Hatching occurs after 4 days. Then the difficult period of how to feed spawn begins.

Feeding spawn in captivity - critical to spawn survival

A farmer's struggle that urged in developing technology

Spawn survival of *A. testudineus* is a critical task. Not that everybody will succeed every time, but spawn mortality is a common phenomenon in captive culture. One has to know the secret of feeding spawn. What happened to farmer Saifulla Mandal of West Bengal is a learning point to others. Saifulla tried to breed fully conditioned and matured *A. testudineus* at captivity in his farm four or five times, but never succeeded in getting the spawn to survive. He is an expert farmer experienced in breeding and larval rearing of other fish species, but he never encountered such a difficult task, which left him feeling frustrated. In this juncture, he had interactions with Scientists of Regional Research centre, ICAR-CIFA, Rahara, West Bengal, India.

Development of 'fact query sheet' – a way to resolve the problems

Having listened to his difficulties, we suggested him to prepare a "fact query sheet' to note down all the facts related to spawn feeding.

Table 1: 'Fact Query Sheet' including facts and solutions.

Facts	Information
Fish species	*Anabus testudineus*
Character	Air breathing
Feeding behaviours	Carnivore
Sex	Male and female
Breeding time	Rainy season
Breeding behaviour	Fully migrant
Culture practice	Cultivable
Spawn age	4th -12th day
Spawn size	2,800 to 4,200µm*
Mouth aperture of spawn	290-623µm*
Probable prey	Plankton*
Suitable prey size	90-150µm*
Feeding condition	Visual feeder
Feeding behaviour	Chasing prey

**Information added by the Scientists, RRC, ICAR-CIFA, Rahara, Kolkata.*

With the prepared 'Fact Query Sheet', we understood that spawn would require those plankton which are less than 150µm and have motility to stimulate predation – a key point to emphasise. Prior to our suggestions, he had collected mixed plankton from his tanks/ponds prepared for plankton production, and supplied them to spawn from the 4th day onwards. When mixed planktons were supplied to spawn, the larger plankton with developed appendages could rupture the mouth of spawn – a probable incident might happen or larger planktons would feed on tiny spawn as prey. Both the facts might cause spawn mortality in despair. Having prepared the fact query sheet, he has been guided to carefully observe the following:

- Which size of plankton can enter into spawn mouth actively or passively, befitting with size of spawn mouth aperture through water movement?
- Whether spawn prefer to chase prey or wait for prey to move its nearby, then catch.
- Whether movement of prey stimulate spawn appetite to catch prey.

Having followed the suggestions, he observed the spawn behaviour and reported that spawn requires suitably sized plankton after 4 days in age. Simultaneously, we examined the length and mouth aperture of spawn aged in between from 4–12-day old samples which he supplied us. Length of spawn measured ranged from 2,800 to 4,200 µm, and mouth apertures corresponded to the range 290-623µm. With this range of mouth aperture, we suggested him to supply rotifer (*Brachionus calyciflorus*) – a zooplankton – suitable for spawn feeding. This suggestion brought a much-awaited success in achieving spawn survival and made him smile.

Acclimatisation of broodstock before breeding.

Collection of spawn from a rearing tank with a plankton net.

Spawn collected in an aluminimum plate.

Segregation of live foods – a technique easy to adopt

Saifulla methodically segregated a variety of plankton through plankton nets of different mesh sizes. He purchased a plankton net of around 150µm mesh size as a suitable one to sieve and collect desirable plankton to feed 4–12-day old spawn. After the 12th day, spawn were able to feed on mixed plankton of suitable size. In such practice, he collected a huge numbers of rotifer species with suitable size in the range of 90-150µm that could easily enter into the mouth of spawn. Further, the movement of rotifer stimulates spawn to chase them down and feed. Rotifer is also soft and easily digestible to spawn – the magical role it plays for spawn survival. Saifulla reported high spawn survival after following

Scientists of RRC, ICAR-CIFA, Rahara observing spawn maturity & survival with Saifulla Mandal, a progressive farmer.

our suggestions to feed spawn with rotifer. Scientists visited his farm to confirm the success of spawn survival that Saifulla achieved after implementing our technology.

Rotifer culture in outdoor tanks

In outdoor tanks, rotifer is cultured with green water that acts as a good source of food. Green water culture of rotifer with *Chlorella* is an ideal food for rotifer. *Chlorella*-fed rotifer supports spawn growth and development because *Chlorella* is an rich source of nutrients.

Scientists' advice to the farmer to achieve success

An essential intervention requires through interactions between scientists and farmers to establish technology that is viable in the farmers' field. What happened in Saifulla's farm is exemplary of exchange and coordination of ideas among aquaculture stakeholders and practitioners. Working together, farmers can improve their production using solutions that scientists have developed based on consultations with farmers concerning their conditions and difficulties. Success required farmers and scientists to exchange views and practical experiences from lab to land vis a vis land to lab.

Acknowledgement

Authors are grateful to the Director, ICAR-CIFA for his encouragement of farmers' interaction. Authors acknowledge Saifulla Mandal for his cordial invitation to visit his farm. We thank Mrs Bithilekha Mondal and Mr Knudal Pal for rotifer photography.

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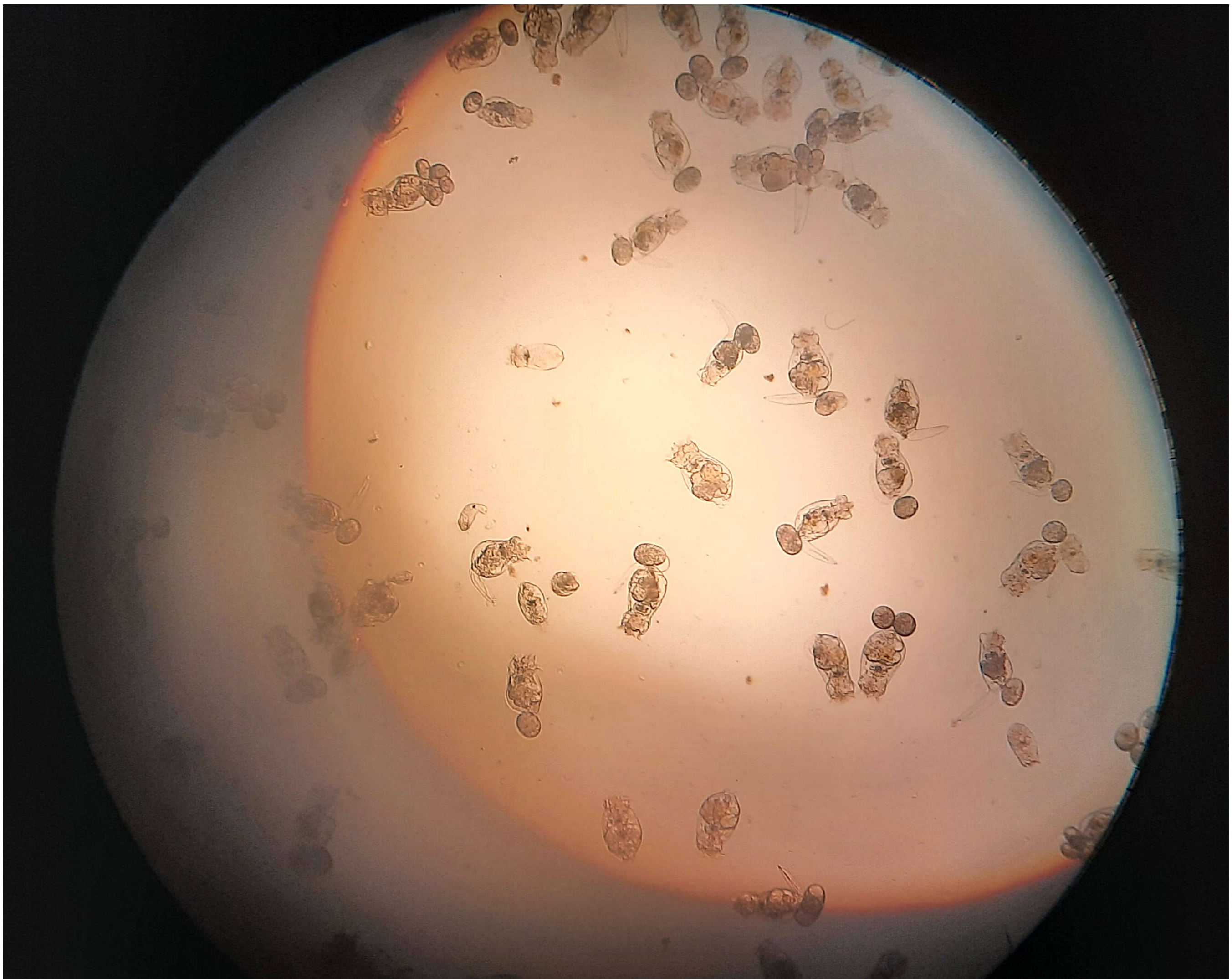
Microscopic view of rotifers (Brachionus calyciflorus) suitable for feeding spawn.



NACA Newsletter

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31st NACA Governing Council held online

The 31st Governing Council Meeting (GCM) of NACA was held from 29-30 November via video conference. The meeting was attended by 44 participants including the representatives of 16 member governments, the Regional Lead Centres for China, India, Iran and Thailand, the Food and Agriculture Organization of the United Nations (FAO), the Asia-Pacific Association of Agricultural Research Institutions (APAARI), the Network of Aquaculture Centres in Central and Eastern Europe (NACEE), the Pacific Community (SPC), the Bangladesh Shrimp and Fish Foundation (BSFF) and the Centre for Integrated Rural Development for Asia and the Pacific (CIRDAP). Hong Kong SAR was selected as Chair of the 31st Council and Thailand the Vice chair.

The main agenda item for the meeting was consideration of the new NACA Strategic Plan 2021-2024. The plan is a reworking and expansion of NACA's programmes to reflect the current operating environment, which has changed significantly in the advent of the pandemic, under the theme "Networking Regional Resources for Sustainable Aquaculture". The new programme structure is as follows:

- Productivity and Sustainability.
- Health and Biosecurity.
- Genetics and Biodiversity.
- Safety and Quality.
- Emerging Regional and Global Issues.
- Education and Training.
- Information and Networking.
- Strategy and Governance.
- One Community.

Implementation of the programmes will be via formation of subnetworks of experts or communities of practice, to share experience, resources, and opportunities, develop and take part in collaborative projects. The approach will initially be piloted on a few priority programmes and scaled up as resources permit.

The new strategic plan emphasises the use of virtual networking, with the majority of NACA workshops and events to be held online. This will continue the practice that has been proven over the past two years, as the pandemic has driven widespread adoption of virtual networking and normalised online collaboration. NACA's experience has been that a virtual event attracts from five to ten times as many participants, due to removal of travel and cost constraints, compared to an equivalent physical meeting and at a fraction of the cost. Video conferencing also eases the recording of presentations, which can then be shared via YouTube and similar platforms, further increasing reach of technical content.

The new strategic plan will be published on the NACA website in due course.

Of the issues raised by members, common issues included a renewed interest in the expansion of mariculture including in deep sea sites, the integration of "internet of things" technologies and automation in aquaculture systems, aquatic animal health and biosecurity and climate change impacts and mitigation.

The GCM considered a briefing on the outcomes of the Global Conference on Aquaculture Millennium +20, which had been the flagship event for 2021. FAO thanked the government of China for hosting the conference, which had been attended by 1,728 people from 113 countries, of which 1,228 attended virtually. Preparations for the conference included the development of a series of regional reviews on the status of aquaculture development and a series of thematic review papers, which were prepared by teams of expert authors commissioned by FAO and opened for public comment.

The main output of the conference, the Shanghai Declaration, was unanimously adopted by the participants and over 40 organisations had provided written statements of support, which are available on the conference website (https://aquaculture2020.org). It was noted that the Shanghai Declaration was a participant's declaration, outlined by an invited group of experts, informed by regional and thematic reviews and with input from many stakeholders of diverse interests.

SDG-aligned *Artemia* Aquaculture Workshop held in China / online

With the expansion of hatchery production, the demand for *Artemia* cysts has continued to increase. Annual consumption is now estimated at 3,500 – 4,000 tonnes, underpinning the production of over 900 billion crustacean post larvae and fish fry by a hatchery industry valued at more than USD 2 billion, and the final production of over 10 million tonnes of high-value aquaculture species. With approximately 90 percent of the current *Artemia* production harvested from inland salt lakes, the future of the hatchery industry could be at risk and requires urgent attention.

A new international interdisciplinary approach is needed to tackle these *Artemia* issues and opportunities, like the breakthrough in *Artemia* use in aquaculture following the 1976 FAO Kyoto conference. The purpose of the workshop was to explore needs and opportunities for a new international initiative to guarantee a more sustainable provision of *Artemia*, both from natural sources and from controlled extractive *Artemia* farming integrated with salt production and other fish/crustacean aquaculture.

The workshop was held on 22 September in conjunction with the Global Conference on Aquaculture Millennium +20 in Shanghai, China with international participation via video conference. The programme included technical presentations and a Q&A session with participants and an expert discussion panel. Over 400 people participated in the workshop, both locally in China and via video conference. The workshop was organised by:

- Food and Agriculture Organization of the United Nations.
- Laboratory of Aquaculture and Artemia Reference Center, Ghent University.
- Network of Aquaculture Centres in Asia-Pacific.
- Artemia Association of China.
- Asian Regional Artemia Reference Center.

Presentations

The presentations from the workshop are summarised below, but video recordings are also available for viewing via YouTube at:

- https://www.youtube.com/playlist?list=PLZxXgR0J17z0MeAdFe9P7qzc8PFRjlXyr

Patrick Sorgeloos (Ghent University) made a presentation "From Kyoto 1976 to Shanghai 2021: Brief history of *Artemia* use in Aquaculture". He described the key life cycle traits of *Artemia* and its crucial role in the commercial hatchery production of fish and crustacean species, beginning with the first commercial sources of *Artemia* cysts in the 1960s, and the first concerns about *Artemia* as a potential bottleneck at the FAO Technical Conference on Aquaculture in 1976. FAO had supported early work to verify the characteristics of *Artemia* and to investigate the feasibility of inoculating salt flats for integrated salt-*Artemia* production. In 1978 the Artemia Reference Center was established at Ghent University upon the suggestion of FAO. The International Study on Artemia was launched as an interdisciplinary study of *Artemia* strains, producing over 50 papers on aspects of the biology of *Artemia* and its application in aquaculture, culminating in the publication of the Manual for the Culture and Use of brine Shrimp Artemia in Aquaculture in 1986 (the "Artemia Manual"), and a chapter on *Artemia* in the FAO Manual on the Production and Use of Live Food for Aquaculture in 1996. Over time *Artemia* has come to underpin a significant fraction of commercial hatchery production for the aquaculture industry. Localised production provided security for local aquaculture industries. Concerns regarding the *Artemia* resource include sustainable harvesting, the protection of habitats, and preservation of the gene pool. The International Artemia Aquaculture Consortium has been established to address these concerns and to expand sustainable use of *Artemia* in aquaculture, involving 28 different countries.

Meezanur Rahman (WorldFish Centre) and Nguyen Van Hoa (Can Tho University) gave a Report of the 15 June 2021 webinar "International Workshop on *Artemia* Pond Production". The Artemia4Bangladesh project aimed to enhance food and nutrition security in Bangladesh through climate smart innovation, including introduction of integrated salt-*Artemia* systems and increased productivity in marine aquaculture in Cox's Bazar. The purpose of the workshop was to share information between public, private and academic stakeholders and to promote *Artemia* culture and research in different countries. More than 70 participants from 14 countries attended. Presentations gave an overview of farmed *Artemia* biomass and cyst production practices in different countries including Vietnam, India, Iran, Kenya, Cambodia, Myanmar, Bangladesh, China, Thailand, and Malaysia. Recommendations included integrating *Artemia* artisanal salt farming in Asia and Africa, desert/arid and salt-affected areas, conducting more work on species / strain selection and improvement for aquaculture applications, improving the resilience of *Artemia* pond culture to climate change events, and selecting suitable agricultural by-products as a food source for *Artemia*.

Simon Wilkinson (Network of Aquaculture Centres in Asia-Pacific) gave a report of the 2 September 2021 webinar "Status of the Use of *Artemia* Cysts in Fish and Crustacean Hatcheries Around the World", which was attended by 359 people from 53 countries and facilitated by the International Artemia Aquaculture Consortium.The workshop had featured presentations on contemporary hatchery practices from around the globe, which were described. The presentations revealed a wide diversity in hatchery practices, variations in efficiency and many deviations from the standardised protocols of the Artemia Manual. Allowing *Artemia* development to progress to instar II posed a biosecurity risk, as nauplii become contaminated by *Vibrio* and other potentially pathogenic bacteria once they begin to feed. The application of the umbrella stage of a particularly small *Artemia* strain (Vin Chau salt ponds) in mud crab hatchery production was highlighted. It was clear that there were significant opportunities to improve both *Artemia* utilisation and production. It was timely to reconsider publication of good aquaculture practices and standardised protocols for *Artemia* production and use in hatcheries, with a view to improving both the efficiency of cyst use and the biosecurity of *Artemia* as feed. The webinar recommended updating the FAO Artemia Manual and convening localised training courses for hatchery staff to facilitate uptake of good practices. The presentations from this workshop are available separately on YouTube at:

https://www.youtube.com/playlist?list=PLZxXgR0J17z3oahrQdjZw1S6602KifbUa

Thomas Bosteels (Great Salt Lake Brine Shrimp Cooperative) gave a presentation Sustainable harvesting of natural *Artemia* resource: the Great Salt Lake (Utah, USA) as model case. Around 90% of *Artemia* was still harvested from natural resources, highlighting the importance for sustainable management of wild *Artemia* and their salt lake habitats. Salt lakes were sensitive environments and vulnerable to anthropogenic influences. The progressive development of management measures for the Great Salt Lake and its *Artemia* resources was described. Salinity and nutrient management were the two main drivers for *Artemia* population health, with the optimum salinity range being 120-160 g/L to avoid predation and physiological issues, and adequate nutrient loading to support the population, as the lake is primarily nitrogen limited, with a co-limitation of phosphorus. A causeway allows adaptive management of the flow and salinity within the south arm of the lake which is the primary *Artemia* resource. Water inflows are regulated by government agencies at both State and Federal level, with input from the Great Salt Lake Advisory Council, a cooperative process involving stakeholders from many sectors.

Gonzalo Gajardo (Los Lagos University) gave a presentation "*Artemia* species and strains diversity: threats and potential". Wild genetic resources included six regional sexual species and asexual types. Genetic diversity in key traits were often harboured in locally adapted populations. Incipient farmed types with useful characteristics such as improved thermal tolerance had emerged following translocation of *Artemia* to new sites. There was a need for systematic monitoring of genetic diversity to assess impacts of climate change, habitat loss and other adverse factors. Loss of intraspecific genetic diversity was a hidden biodiversity crisis. *Artemia* provided an excellent model to study genotype-environment interactions for key aquaculture or adaptive traits.

Gilbert Van Stappen (Ghent University) gave a presentation "Availability of *Artemia* genome: R&D opportunities". The majority (90%) of the *Artemia* genome had recently been published and was now available through the ORCAE platform (for access contact Prof. Peter Bossier, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, peter.bossier@ugent.be). This data had considerable potential to assist with characterisation of *Artemia* strains and to inform selective breeding programmes. A gene for salt tolerance had been found (De Vos et al. 2021, The genome of the extremophile *Artemia* provides insights into strategies to cope with extreme environments, BMC Genomics Vol. 22, Art. 635), and *Artemia* was expected to provide a new model organism for gene discovery.

Q&A / panel discussion

A question-and-answer session was held with panellists providing feedback on questions from participants:

- Regarding biosecurity measures in *Artemia* production, biosecurity starts with protection of the resource, for example not allowing aquaculture within catchments used for natural cyst production. Hyper-saline conditions were beneficial in excluding potential hosts from the environment. With good disinfection procedures during processing, it was possible to produce cysts that did not contain human or aquaculture pathogens. However, pathogens could enter during the hatching process in the hatchery, if care was not taken to maintain good conditions.

- Many parthenogenetic *Artemia* strains occurred in China, it was likely that there would be some differences between them, but it was necessary to test different strains in order to document their characteristics.

- Africa had considerable potential for *Artemia* production, but wild populations were little studied and commercial developments were limited at present.

- *Artemia* availability was unlikely to become a constraint to future aquaculture development, assuming the ongoing trend of improving utilisation efficiency continued, and given the high potential for investments in *Artemia* research to deliver improved strains or farmed *Artemia* as a supplement to wild sources.

Conclusion and recommendations

The workshop made the following specific recommendations:

- Develop improved guidelines for bio-secure production and use of *Artemia* in hatcheries, including an update of the FAO Artemia manual and convene regional *Artemia* training courses for local hatcheries, to disseminate good practices and facilitate adoption of standardised protocols.

- In view of the large variety of species and strains of *Artemia* that are now available in the market their specific characteristics should be studied to identify their most suitable application for specific species of fish and crustaceans. This could relate to their nutritional composition, synchrony in hatching or enrichment characteristics.

- Initiate strain selection and selective breeding to develop improved *Artemia* strains for aquaculture applications, noting the availability of the *Artemia* genome.

- Investigate the use of umbrella *Artemia* as successfully applied in the Vietnamese crab hatcheries for wider application in aquaculture, as a new source of live food in earlier larval stages, be it for shrimp or in fish.

- Reconsider a wider use of *Artemia* enrichment techniques in hatcheries, as it is now restricted to applications in marine fish and crab production. This method not only allows enhancement of the nutritional value of the nauplii but can also be used as a vector to deliver, for example pre- or probiotics to the larvae.

- Investigate the impact of climate change on *Artemia* production in inland lakes and coastal saltworks.

- Develop science-based protocols to assure sustainable harvesting of wild *Artemia* sources, especially in central Asia.

- Conserve *Artemia* biodiversity through means such as a cyst banks, species identification, “wild” vs “farmed” species, genotyping and strain characterisation.

- Investigate integration of extractive *Artemia* farming with intensive fish/crustacean aquaculture.

- Investigate the use of *Artemia* biomass as high value protein ingredient in human diets.

- Consider integration of *Artemia* production in artisanal salt farming in Asia and Africa, desert/arid and salt-affected areas.

Closing remarks

The closing remarks were given by Matthias Halwart, FAO. He recounted the hypothesis of Patrick Sorgeloos at the 1976 FAO Technical Conference on Aquaculture in Kyoto, concerning the potential for Artemia to play a role in aquaculture, which FAO assisted in verifying, leading to Artemia becoming a widely accessible and suitable live food for fish and shrimp hatchery developments that were just taking off at that time. Over subsequent decades improvements in Artemia availability, sources and optimisations in utilisation had contributed to continued expansion of the fish and crustacean aquaculture. He noted that FAO had undertaken to prepare an updated Artemia manual to ensure more sustainable and bio secure use of this important food source. He noted the workshop’s advice to invest more in the study of Artemia biodiversity, sustainable exploitation, and management of salt lake resources in a changing climate, and the parallel need to explore farmed production of Artemia. He indicated that FAO’s Sub-Committee on Aquaculture would be informed of the progress highlighted by the workshop for member countries to consider further work on Artemia.

Policy brief on sustaining the future of the global seaweed industry

A policy brief on “Ensuring the Sustainable Future of the Rapidly Expanding Global Seaweed Aquaculture Industry – A Vision” authored by 37 experts from 30 organisations worldwide was published by the UNU Institute on Comparative Regional Integration Studies on 10 November 2021. The policy brief highlighted the key challenges that must be addressed for the long-term sustainability of the global seaweed industry, ensuring its role in providing nature-based solutions within the sustainable ocean economy agenda and contributing to the UN Decade of Ocean Science for Sustainable Development (2021 – 2030).

The policy brief acknowledges that seaweed production has increased 15 fold over the past 50 years. The industry produces an equivalent to about 35 million tonnes fresh weight, about 51% of the world’s mariculture production, with a total value estimated at USD 14.7 billion. The seaweed value chain supports the livelihoods of about 6 million small-scale farmers and processors. NACA member states such as China, Indonesia, the Philippines, and Malaysia produce the majority of farmed seaweeds in the world. Farmed seaweed is used in food, food supplements, feed, fertilisers, and biostimulants, as well as substitutes for fossil fuels and their derivatives. Moreover, seaweed farming benefits restore degraded environments, enriches biodiversity, and has potential to contribute to mitigation of the effects of climate change and coastal acidification. The seaweed industry has broad potential to address the UN SDGs.

The policy brief warns that the global seaweed industry faces significant challenges for future development. Socio-economically, a pest or disease outbreak can have devastating economic consequences on farmers, families, and their wider communities. The policy brief provided recommendations to balance economic profitability with the environment, human needs and health. The policy brief emphasised the sustainable seaweed industry requires effective biosecurity and genetic diversity from its analysis. It indicated that the introduction and spread of seaweed pests and disease poses a major and increasing threat to production. The movement of live seaweeds is acknowledged as a major vector. Introduced non-indigenous macroalgae can also alter ecosystem structure and function. As the global seaweed aquaculture industry grows and diversifies, the risk of introducing known and emerging pests and diseases to the new regions will escalate. National dependence on introduced seaweeds and their cultivars from other countries and regions, whenever possible, should be reduced.

The report makes policy recommendations for promoting wider environmental, gender-responsive and socially inclusive approaches to upscaling the seaweed industry, which includes:

- Developing clear international seaweed-related policies and regulations to improve biosecurity and genetic diversity.
- Developing global, regional, and national technology transfer and capacity building initiatives, focusing on biosecurity and genetic diversity.
- Developing regional and national seed stocks and biosecure nurseries.
- Maintaining the genetic diversity in wild stocks.
- Further developing assessment tools for balancing environmental and economic risks with the potential benefits of seaweed production.
- Incentivising the integration of seaweed production with other extractive and fed-aquaculture species and maritime activities.
- Channeling support for long-term investments to promote the beneficial aspects of the industry.
- Establishing international seaweed research networks to conduct further innovative, interdisciplinary research spanning the natural and social sciences.

The policy brief team was led by Prof. Elizabeth J. Cottier-Cook from Scottish Association for Marine Science, UNU Associated Institution, Scottish Marine Institute. Eight organisations from six NACA member states and the Secretariat were involved in the policy brief team.

The policy brief is available download from:

https://cris.unu.edu/gsstarpolicybrief


UNITED NATIONS UNIVERSITY
UNU-CRIS
Institute on Comparative Regional Integration Studies

SAMS
Scottish Association for Marine Science

POLICY BRIEF
#06 2021

Ensuring the Sustainable Future of the Rapidly Expanding Global Seaweed Aquaculture Industry – A Vision

Highlights

1. This policy brief highlights key challenges that must be addressed for the long-term sustainability of the global seaweed industry, ensuring its role in providing nature-based solutions within the sustainable ocean economy agenda and in contributing to the UN Decade of Ocean Science for Sustainable Development (2021 - 2030).

2. Seaweed production has grown rapidly over the past 50 years. It currently accounts for over 50 % of total global marine production, equating to ~35 million tonnes. In 2019, the industry's total value was estimated at USD 14.7 billion. The seaweed value chain supports the livelihoods of approximately 6 million small-scale farmers and processors, both men and women, many of whom live in coastal communities in low- and middle-income countries.

3. The aquaculture sector is increasingly interested in seaweed because of its potential for greater use in food, food supplements, animal feed, fertiliser and biostimulants, and in alternatives to fossil fuels and their derived products, such as plastics. Its cultivation can help restore degraded environments, increase ocean biodiversity and mitigate the effects of climate change and coastal acidification by capturing carbon and other nutrients. In low-, middle- and high-income countries, the seaweed industry has a wide-ranging potential to address the UN Sustainable Development Goals (SDGs) in particular, SDG 14 (life below water), SDG13 (climate action), SDG6 (decent work and economic growth) and SDG5 (gender equality).

4. The global seaweed industry, however, faces significant challenges. For future sustainability, improvements are urgently needed in biosecurity and traceability, pest and disease identification and outbreak reporting, risk analysis to prevent transboundary spread, the establishment of high quality, disease-free seed-banks and nurseries and the conservation of genetic diversity in wild stocks.

5. These improvements require technological innovation, capacity building and effective gender-responsive and co-ordinated policies, incentives and regulations. They will need to enhance occupational safety, whilst increasing the industry's resilience to the impacts of climate change and production hazards, such as pest and disease outbreaks. To align with the SDGs, particular attentions will need to be paid to small scale farmers and processors to ensure that the globalisation of seaweed aquaculture supports the development of sustainable, resilient and inclusive livelihoods.

Quarterly Aquatic Animal Disease Report

The Quarterly Aquatic Animal Disease report provides information about the status of aquatic animal disease in 21 participating states in the Asia-Pacific region. The diseases covered in the report are reviewed annually by the Asia Regional Advisory Group on Aquatic Animal Health.

The report was first published in the second quarter of 1998. It is a joint activity between NACA, the Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (OIE) Regional Representation in Tokyo.

The most recent reports are now being offered as Excel spreadsheets, rather than PDF, while an electronic reporting system is developed. The files may be downloaded from:

https://enaca.org/?id=8

Training Course on Mariculture Technology in Asia-Pacific

A free online training course on mariculture technologies was hosted by the Yellow Sea Fisheries Research Institute (YSFRI), from 18 October to 5 November, organised by the Department of International Cooperation, Ministry of Science and Technology, People's Republic of China.

The course was aimed towards officials, researchers and technician from fisheries and aquaculture departments, research institutions and enterprises, with priority given to personnel from developing countries.

308 people participated in the training from 28 countries, with those completing the training receiving a certificate from the Ministry.

The training was delivered by video conferencing, with the training covering subjects including:

- Genetics and breeding of mariculture species.
- Large-scale propagation techniques.
- Disease control and prevention.
- Nutrition research and feed development.
- Technology for different farming models.
- Equipment research, engineering and construction of farming facilities.
- Quality and safety inspection technology for aquatic projects.

Technical presentations from the course were recorded and will be shared on NACA's YouTube channel in due course. The link will be announced in a future edition of the newsletter.

YSFRI, founded in January 1947, is the oldest multidisciplinary research institute of marine fisheries in China. With an enduring dedication to the pursuit of academic excellence for nearly 70 years, YSFRI has made contributions in many fields of mariculture.

To date, the institute has established artificial propagation and culture techniques for more than 30 commercially important marine species, developed sixteen new varieties for mariculture, and set up and optimised several mariculture models such as integrated multi-trophic aquaculture for coastal aquaculture and pond culture, land-based industrialised mariculture, offshore net cage culture and sea ranching.

The institute has developed rapid on-field detection kits for over twenty aquatic pathogens, established and optimised several deep processing techniques for aquatic products and developed testing methods and inspection technologies for aquatic products safety and quality.

At present, YSFRI has ten research divisions, three experimental bases and four research vessels equipped with state of the art facilities to carry out fisheries research. The institute has over 400 faculty and staff members, including 160 senior scientists. Currently YSFRI's postdoctoral program offers research opportunities for more than 30 postdoctoral scholars.

This was the fourth online training course offered by YSFRI and the third mariculture training course. NACA would like to thank YSFRI and the Ministry of Science of Technology for their kind support in organising the training, and in making placements available to personnel from NACA member states and elsewhere.

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