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

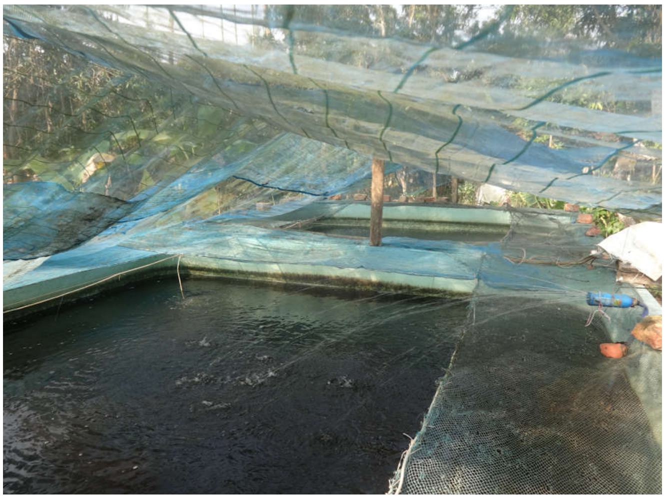
The second author's two fish tanks measure 3 m x 3 m x 0.75 m each. The total water volume maintained is about 14,000 litres and construction cost was INR 30,000. He also possesses four well managed earthen fish ponds with a total area of 4,200 m^2, where major carps, *Notopterus chitala* and the three 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.

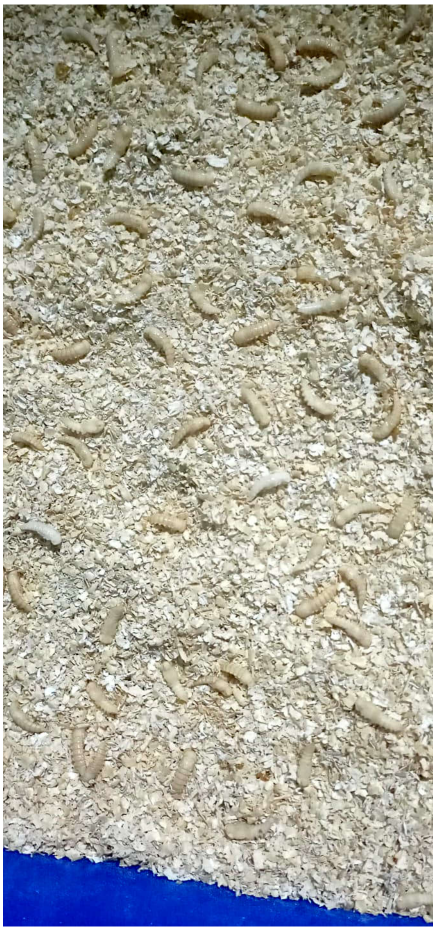
Pond-reared air-breathing fishes

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*

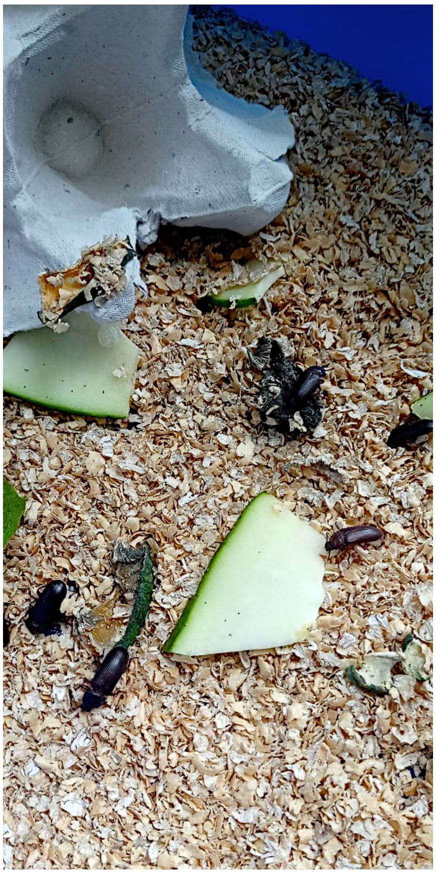
Mixed culture of murrels *Channa marulius*, *C. striatus* and *C. punctatus* gives a good yield with feed comprised of soaked dried marine trash fish and fresh silkworm pupae. Likewise did *A. testudineus* in net cages, when fed with rice bran, mustard oil cake and silkworm pupae. *C. magur* feeds on 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.