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AQUACULTURE ASIA

Hatchery tech for short-necked clams, Vietnam

Homestead modular hatchery technology, West Bengal

Indigenous RAS, India

Lorcariid catfish invasion

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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COVID-19 rolls on

I am really looking forward to the day when I can read the news without seeing any mention of COVID-19, but that day looks to be a long way off yet.

We should all be encouraged that several countries in the region look like they may have eradicated the virus (please note I am not applying technical definitions in this column), whether nationally or at individual state / province level, while others have successfully suppressed it to very low levels.

There is no doubt now that eradication *is* possible, although perhaps not under every country's circumstances. However, I am sad to report that the notion that we should 'just let it burn itself out' is still disturbingly common. This idea needs to be thrown out.

Perhaps the more difficult question is how to restart economies without a catastrophic resurgence. As foreshadowed, early attempts to relax public health controls have had mixed results. This was expected. Countries that have eradicated the virus face few hurdles in reopening businesses and moving towards a more normal life, at least internally; while those that have suppressed but not eradicated it are moving forward, if slowly, hampered by the need to stamp out the inevitable spot fires as they learn what works and what doesn't.

However, those that are relaxing restrictions without having first brought the virus to heel are in a difficult position; slowing the spread and limiting the damage until a vaccine or treatment arrives may be the best they can do. If this is the only option that circumstance allows, it is still a goal worthy of pursuing.

The impact of COVID-19 on market chains has become a bit clearer. Last quarter we knew that the wholesale grounding of commercial airline fleets was going to create major problems for products relying on air freight. What we did not anticipate was the level of disruption to sea freight and surface logistics.

The global collapse in consumer demand has led to warehouse space filling up, causing knock on storage problems at cargo terminals and distribution centres, and exacerbating imbalances in container supply.

As global demand fell away, shipping companies cut back on sea freight, with service being withdrawn in some areas, while in others the spillover of air cargo into sea freight overloaded remaining capacity.

As factories began resuming production, many found that there was just no way to get their products to market, or that there are extensive backlogs and delays in shipping. This is not just a problem for aquaculture, it is a problem for everyone.

Anecdotally, the freight and storage situation has stabilised to some extent and shipping times have improved a little, although they are still slow.

The economic fallout is still flowing through the system. In many ways, I expect the next quarter to be much tougher than the last, but with a bit of luck it will bring us some good news on the vaccine front. See you in three months, and stay healthy!

Simon Wilkinson

AQUACULTURE ASIA

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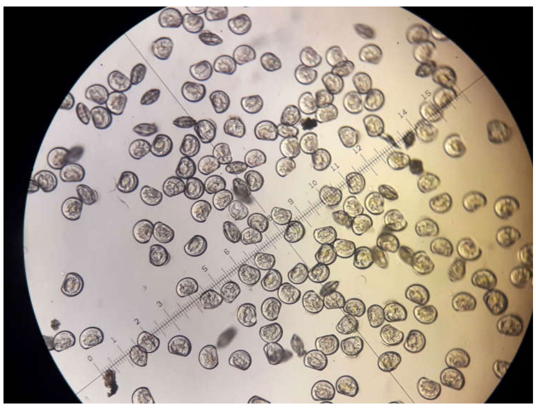

Hatchery techniques for the seed production of short-necked clams (*Paphia undulata*) in Nha Trang, Vietnam

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Induced spawning via a wet-stimulus thermal shock.

Aquaculture in Vietnam is of great importance due to its contribution to food security, employment, and economic value to the country. In fact, Vietnam is currently ranked as the fourth-largest seafood producer after China, India, and Indonesia, with an aquaculture production of 3.82 million tonnes in 2017 (FAO, 2018). With a long coastline of 3,260 kilometres and various islands and bays (FAO, 2019), Vietnam has great geographic potential for aquaculture growth.

Asia is the main producer of marine and coastal molluscs worldwide with an aquaculture production of 15.55 million tonnes, which is over 92% of the world's production in 2016 (FAO, 2018). One mollusc species, *Paphia undulata* (Born 1778), has become a popular food in most Asian countries, and its cultivation has been grown in popularity due to the depletion of its natural population and high economic value (Norte-Campos, 2010).

The short-necked clam *P. undulata* is a commercially important bivalve species with smooth and glossy, oval-shaped shells. They thrive in muddy (70%), sand or silt (30%) bottoms, with environmental conditions at a salinity of 30 to 35 ppt, dissolved oxygen greater than 4 milligrams per litre, and a pH range of 7.5 to 8.2.

Induced spawning via dry-stimulus thermal shock.

P. undulata hatchery history in Vietnam

Aquaculture of short-necked clam *P. undulata* in Vietnam started approximately ten years ago, but production has been very small due to the lack of seed supply from hatcheries. Famers either have to collect seed from natural sets (Helm, Bourne & Lovatelli, 2004) or import them from China, both of which result in extra production cost and unreliable supply to meet grow out culture requirements. As such, the potential of *P. undulata* as a new species for Vietnamese aquaculture remains unrealised, despite having started a long time ago. Novel seed production techniques are being researched and practiced at our mollusc hatchery in Nha Trang, Vietnam, to meet the market demand of *P. undulata*.

Despite having a large area for bivalve grow-out culture and being geographically close to the Chinese border to facilitate exports, Quang Ninh province, in Northern Vietnam, is not suitable for artificial seed production of aquatic species due to its high seasonal fluctuations in temperature. On the other hand, Khanh Hoa province, in Central Vietnam, has more stable environmental conditions and is better suited for seed production. Furthermore, our hatchery, being a part of the Institute of Aquaculture at Nha Trang University, is the first to conduct artificial seed production research on *P. undulata* and is, therefore, the first hatchery in Khanh Hoa province to produce seed of this species.

Broodstock preparation

Due to the close proximity of the hatchery to the sea (around one kilometre), water can be pumped directly from the marine environment to mimic natural conditions. Water is treated with chlorine at 10 ppm to reduce total suspended solids (TSS) in water for healthier seed production and is allowed to settle in tanks for three days before being pumped to spawning and rearing tanks.

P. undulata has a continuous breeding season, but its peak spawning is from July to December and is determined by food availability in the environment (Dai, 2019). Broodstock is selected directly from the wild population during spawning season with criteria for selection being over one year old (1+), having a minimum shell length of 5.5 centimetres, and weight 40 to 50 individuals per kilogram. Five kilograms, or around 200 individual broodstock, are kept in tanks with similar environmental parameters as previously described to acclimatise for at least three days and are fed 500,000 cells

Algal culture, Chaetoceros calcitrans.

per millilitre of *Chaetoceros calcitrans* @40 litres a day, which is 10 times higher than the amount of algae they will receive during rearing.

After acclimatisation, the clams are checked for maturity, as well as gonadal development stages. Sexual maturity of *P. undulata* can be determined by the size of the meat and the colour of the gonads. Mature individuals have gonads that are milky in colour. The clams can also be identified as male or female based on the viscosity of the gametes. When the gonads are gently cut open, sperm has a higher viscosity than eggs. If at least 70% of the broodstock is determined to be sexually mature, artificial spawning will be induced, otherwise they will continue to be fed with a high density of *C. calcitrans* and rechecked for sexual maturity every seven days.

Induced spawning

To induce spawning in *P. undulata*, the common practice is to inject spawning agents such as serotonin, potassium chloride, and other chemicals into the muscular foot of the clams (Salleh, 1989; Phongthana, 1993; Aguilar, 2001), but chemicals have adverse effects on both seed quality and viability (Helm, Bourne & Lovatelli, 2004). Therefore, instead of chemicals, the less invasive and stressful technique of thermal shock is used with the novel combination of dry and wet stimuli.

First, the broodstock is removed and drained from rearing tanks where the water temperature is maintained at 25 to 26 degrees Celsius. They are covered with wet sponges to avoid desiccation and are placed under the sun in their holding baskets for 30 minutes to raise their internal temperature to approximately 28 degrees Celsius. Next, water shock is induced by placing them in a container with 40 degrees Celsius water for 5 minutes. Finally, they will be hung over the spawning tanks, which are 10.5 cubic metres in volume (3.5 × 2.0 × 1.5 m), and allowed to spawn overnight.

The male clams will respond to the thermal shock first and release spermatozoa through their two siphons, which induces the female clams to release their eggs. The eggs are naturally fertilised in the spawning tanks. The number of gametes spawned using this method is dependent on the maturity level of the broodstock, but five kilograms of *P. undulata* can fill five spawning tanks at a density of five fertilised eggs per millilitre. Embryonic development will be completed and reach D-shaped larval stage after sixteen hours.

Larval rearing

D-shaped larvae spend approximately 10 to 14 days in the veliger stage dependent on temperature. When the larvae change into post-umbo larvae with hinge appearance and a size of approximately 200 to 300 micrometres in length, they are transferred, using mesh nets, to shorter tanks (8.5 × 2.0 × 0.6 m) at a density of six individuals per square centimetre to facilitate feeding. During rearing, the larvae are fed 20 litres of *C. calcitran* at 30,000 cells per millilitre twice a day. The tanks are aerated using air stones with two stones in the spawning tanks and eight stones in the short tanks.

Hatchery to open sea

The larvae will spend at least 50 days in the short tanks before reaching 2 to 3 millimetres in length, which is the suitable size for grow-out culture. At this point, the seed are sold to farmers in Quang Ninh province, in Northern Vietnam, due to its geographic advantages for bivalve aquaculture as previously mentioned.

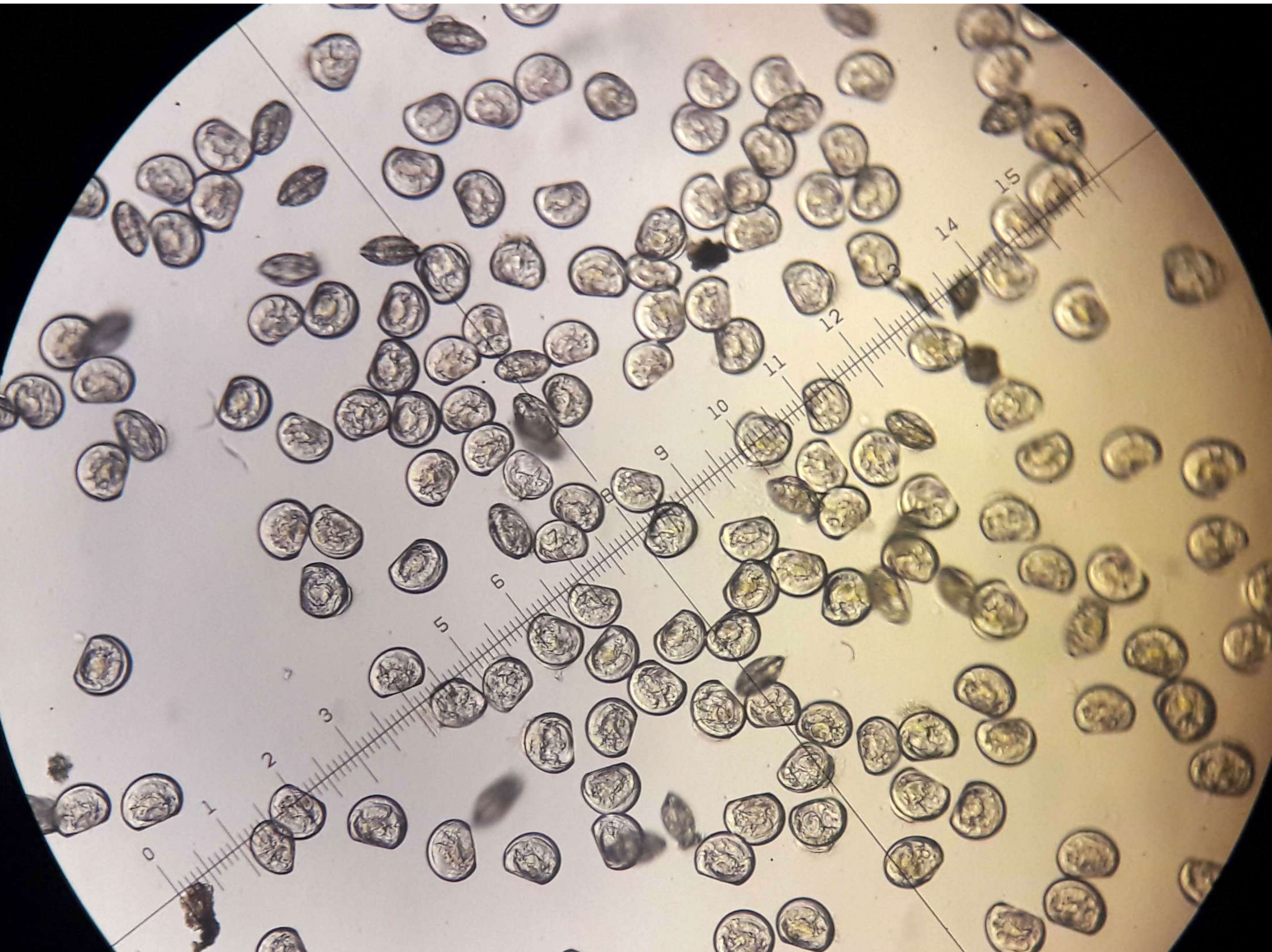
The seed are sent to the farmers in small plastic bags (40 × 20 cm), at a density of approximately 11,000 seed per bag, filled with clean seawater and pure oxygen. Seed are not fed for at least 24 hours before transfer to enhance their survival rates. The water temperature is lowered to 24 to 25 degrees Celsius to induce the juveniles into dormant states. The plastic bags are then placed into a large styrofoam box, which can hold sixteen plastic bags, with two bottles of ice to maintain a stable internal temperature of 24 to 25 degrees Celsius during the long transport from Nha Trang to Quang Ninh via air and land transfers, which can take up to 16 hours.

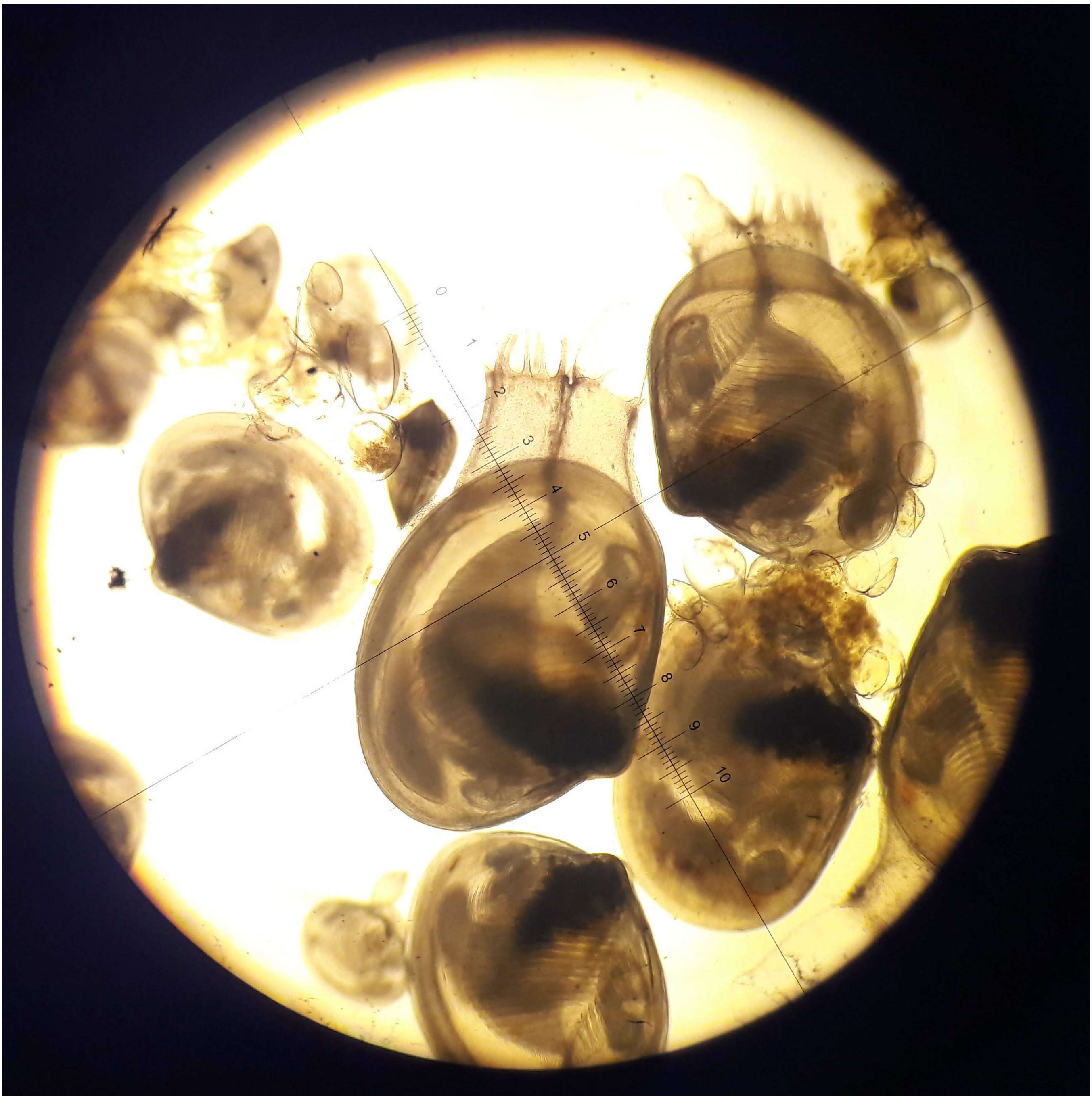
Before planting the clams, farmers have to apply for a license to allow for the cultivation of *P. undulata* in the sea. Then they will have to select and prepare a clean and suitable bottom with appropriate composition, as described above, which has to be at least 4 meters in depth, for planting. After these preparations, the seed can either be planted directly at the bottom of the sea at a density of 1,000 individuals per square metre or planted into baskets (60 × 45 × 25 cm) first, at a density of 2,000 individuals per basket, then planted on the seafloor. These *P. undulata* juveniles will reach a marketable size of 4.5 to 5.5 centimetres in length and are harvested after ten months.

Market value

The price of *P. undulata* seed is 20 Vietnamese dong per individual while the price of clams at marketable size of 70 to 80 individuals per kilogram can fetch approximately 120,000

D-shaped larvae.





Spat.

Vietnamese dong per kilogram, and are highly valued due to their delicious meat and low cost. Factoring in a survival rate of 40% from seed size of 3 millimetres to marketable size due to environmental fluctuations at sea throughout the year, *P. undulata* from seed to harvest presents farmers with an approximately 30 to 35 times return on their investment and effort.

Presently, China is the biggest importer of *P. undulata* from Vietnam, purchasing all yield from aquaculture in Quang Ninh province and 60% of total yield from fisheries in Central Vietnam. The remaining 40% of *P. undulata* caught from fisheries are being supplied to domestic markets such as restaurants.

Due to market demand and value, as well as low production cost, artificial production research on *P. undulata* is needed and should be continued in order to produce high-quality seeds to meet the market demand and to ease fisheries pressure on this species to allow the wild population to recover.

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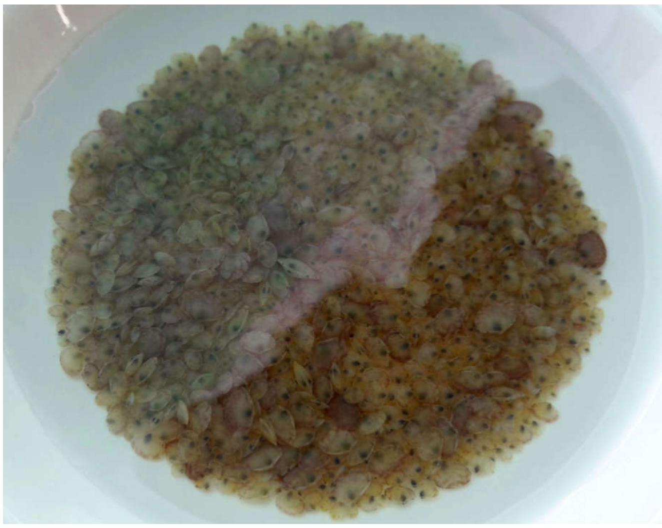

Phapia undulata seed.

Short tanks.

Long tanks.

Lovesome chum of the aquarium are wreaking havoc in East Kolkata Wetlands, India

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Pterygoplichthys sp.

Many of you might have seen a peculiar creature attached face-first to the glass of freshwater aquaria. These creatures are the suckermouth or armoured catfishes of the neotropical family Loricariidae. Originally native to South America, these catfishes are among the most popular freshwater fishes sold in the aquarium trade, where they are marketed as 'plecos' or 'algae eaters'. In Florida, there are currently about 170 farms where loricariids are cultured to supply the domestic demand for common varieties (e.g., *Ancistris* spp., *Hypostomus* spp., *Pterygoplichthys disjunctivus*, and *P. multiradiatus*). There is a report that in the year 2000, more than one billion wild-caught and captive-bred sailfin catfish were bought and sold in over 100 countries. Among these loricariids, *Pterygoplichthys* spp., commonly known as janitor fish, sailfin armoured catfish or in India as suckerfish, are amoung the most common plecos seen on sale, due to competitive prices and bulk exports from South-East Asia. Species such as *P. pardalis* and *P. multiradiatus* have been regularly bred and exported from Singapore. The problem is, when the plecos grow beyond aquarist hobbyist size, hobbyists find it difficult to accommodate them in the aquarium, and often release them into nearby freshwater sources where they can become abundant and change the way ecosystems look and function. Once introduced, *Pterygoplichthys* establish very rapidly because of their competitive advantages over existing fish fauna due to their hardiness, and ability to feed on algae from all submerged surfaces.

Loricariid establishment pathway

The Loricariidae, otherwise known as the "armored" or "suckermouth" catfishes, is the largest family of catfishes, with around 825 nominal species, 709 of which are considered valid to date. A distinguishing characteristic of this South American fish family is their bony plate armouring that extends along three rows across their entire upper surface. The body is flattened, with the lower surface of the fish wider than the height of the fish, such that in cross-section they appear somewhat triangular. All species possess a sub-terminal mouth that is developed for sucking organic matter and algae from the substrate; hence the term, "suckermouth" commonly used to name these fishes.

Sewage-fed pond of the East Kolkata Wetlands.

The aquarium trade pathway is the most significant source of loricariid introductions globally. The demand for these fishes in the aquarium trade is such that, in North America, Loricariids are considered to be a 'bread and butter' fish of the aquarium trade. There is a report that, in United States alone, more than 170 farms are currently involved with the culture and/or breeding of loricariids to supply the domestic demand for common varieties such as *Ancistris* spp., *Hypostomus* spp., *P. disjunctivus*, and *P. multiradiatus*). In many countries where wild populations of loricariids have become established, many people become involved in the collection of egg masses deposited in the wild, and the subsequent incubation and grow-out of fry from these egg masses to supply the aquarium trade. States such as Malaysia, Hong Kong SAR, USA (California. Florida, Michigan), Singapore, Sri Lanka, Colombia, Vietnam, Czech Republic, Taiwan Province of China, Cuba, Thailand, Trinidad and Tobago, Brazil, Peru, Venezuela and Ecuador are already actively engaged in the trade of loricariids to meet the demand of aquarists.

Indigenous switch-gate in the sewage feeder channel to regulate inflow to fish ponds.

Colonisation potential of loricariids

Loricariids have tolerance to a wide variety of water quality conditions and, therefore, have potential to invade both polluted and unpolluted waters. Though they prefer soft waters, in hard waters also they can adapt very quickly and thrive. They also can thrive in a range of acidic to alkaline waters (pH 5.5 to 8.0) and also a certain level of salinity. Modifications of the digestive tract function as an accessory respiratory organ, which allow these fishes to tolerate polluted environments through their air breathing ability. Loricariids,

Suckermouth catfish attached to glass of aquarium are a familiar sight to the hobbyist.

Uptake of sewage water from feeder channel into fish culture bheries through bamboo fencing.

particularly species that can grow to larger sizes, can be aggressive about defending territory and can compete for food. Most species within the family are generally nocturnal bottom feeders, mainly feeding on benthic detritus and algae along with worms, insect larvae, and various bottom-dwelling aquatic animals. Most loricariids are burrow spawners, exhibit male parental care for eggs and early fry and can withstand drought conditions in stagnant water or humid burrows, because of their capability of breathing air by swallowing it and extracting oxygen through the gut lining. Moreover, these catfishes possess large-sized blood cells and large amounts of DNA per cell, which allow these fishes to down regulate their metabolism as well as tolerate changes in body fluid composition, in adverse physiological conditions during periods of hypoxia or during drought periods. Collectively, these aspects of their physiology have provided loricariids with a physiological advantage over the other less tolerant native fishes, and paved the way for their colonisation worldwide.

Sewage-fed aquaculture in the East Kolkata Wetlands and invasion of loricariids

The East Kolkata Wetlands (EKW), a complex of natural and man-made wetlands with rich biodiversity, colloquially called the “kidneys of Kolkata”, is the only Ramsar site in West Bengal and largest among the 26 Ramsar sites in India. Previously known as the Waste Recycling Region (WRR), EKW is the world’s largest wastewater fed aquaculture system, where city sewage is utilised for traditional practices of aquaculture and agriculture. An estimated 30–50% of the sewage from central Kolkata is treated and reused by the fishponds of the EKW, prominently to culture Indian major carps and exotic carps. In general, large Indian major carp fingerlings and exotic carps of an average weight of 10–15 g are stocked @ 5-7 individuals/m^2. Supplementary feed is used by many farms, particularly during the monsoon season when the supply of wastewater is insufficient for the ponds[1]. Mustard oil cake and mohua cake are traditional supplementary feeds, but owing to their relatively high cost, leather milk - a waste product of the leather industry, and hotel dust consisting of organic waste from hotel kitchens were also being used by many farmers. Multiple stocking and multiple harvesting are carried out with 1 kg of seed stocked for each 5 kg of harvested fish[2]. Most farms yield from 3 to 5 t ha^{-1} $year^{-1}$. Currently the wetland system produces over 15,000 MT of fish per annum from its 264 functioning aquaculture ponds, locally called bheries.

Loricarid catfish species of the genus *Pterygoplichthys* have extensively invaded the East Kolkata Wetlands in West Bengal. These non-native fishes were introduced in EKW around 2002 or 2003 by an aquarist, who released three specimens of *Pterygoplichthys* in a sewage feeder channel. It is believed that from there these fishes proliferated and invaded the water bodies of EKW and are now found in enormous numbers. The first official reports of breeding populations of *P. disjunctivus* and *P. pardalis* (Family: Loricaridae) in Gomokpota beel under EKW were made in the DARE/ICAR Annual Report (2008–2009). Since then,

Fishermen after completing a haul.

Transport of captured fishes from far end of bheries.

Loricarrids captured during a seine net operation.

Harvested fishes from East Kolkata Wetland.

A seine of 0.6 ha yielded 86.2 kg of catfish (261 individuals).

Identification of loricariids based on external morphology.

Variations in ventral colouration, spot and pattern of the armoured catfish taken from East Kolkata Wetlands.

Adult male Pterygoplichthys 498, mm total length and 1.2 kg.

Berried female Pterygoplichthys with orange coloured eggs.

Algal mat in East Kolkata Wetlands pond - a major food for Pterygoplichthys.

because of the availability of a congenial environment for shelter and breeding in the form of water hyacinth and ample food in the form of detritus, loricariid catfishes, particularly of genus *Pterygoplichthys*, have invaded widely in the fish culture bheries of EKW, particularly through the sewage feeder channels, and proliferated profusely[3].

Ecological and economic impact of loricariids and EKW

Loricariids have capacity to alter the ecosystem and biodiversity of the invasion sites, by physically altering the invaded habitats and by competing with native animals for food and space. Being large and a bewilderingly resilient bottom feeder, these catfishes reduce the food availability for natives by grazing on benthic algae and detritus, and also incidentally ingest the substrate-attached eggs of native fishes while consuming the bottom periphyton. These catfishes also plow the bottoms of the water bodies while foraging, and thus can uproot or shear aquatic plants and reduce the abundance of beds of submersed aquatic vegetation used by many native fishes as refuge and/or breeding ground. These catfishes have the capacity to sequestrate nitrogen and phosphorus of the system through their body armour, which can result in depletion of fish food organism production. In EKW, the population of once abundant small indigenous *Puntius* sp. and *Chanda* sp. has reduced drastically after the establishment of loricariid catfish. In loricariid-invaded water bodies of EKW, farmers are compelled to use an average of an additional 500,000 litres of sewage per hectare per year to maintain plankton productivity, which comes to approximately Rs. 3,000 as calculated cost. Per unit productivity of commercially cultured fish has also declined by approximately 10 percent on average in EKW due to proliferation of these catfishes. Loricariids dig deep horizontal and branching nesting burrows in the banks or dykes of the water bodies, and sometimes form a large “spawning colony” in which several dozen occur in very close proximity. These colonies can compromise the stability of the banks or dykes and also can increase erosion and suspended sediment loads. Sometimes they even occupy the burrows of other aquatic animals such as crabs or tilapia. Moreover, these fishes cause direct economic losses to fishermen by damaging fishing nets. Bruises in cultured fishes such as the Indian major carps and exotic carps, due to the hard dorsal and pectoral spines of *Pterygoplichthys* are also damaging to the fishermen of EKW economically. Moreover, additional time and labour requirements to catch the same quantity of cultured fish in haul seine fisheries due to the huge biomass of loricariids, as well as additional costs from discard fees for loricariid catfish caught are impacting economics of EKW fishers and fisheries.

Management/utilisation of loricariid catfish and EKW

Once established it is very difficult or almost impossible to eradicate these fishes. In EKW, to prevent new introductions, farmers are sieving sewage water through multilayer screens before taking it into their ponds and are also practicing intensive netting to limit upsurge of the existing population. Though these fishes are harvested in bulk daily, very few fishermen of EKW claim to have tasted these loricariids, and those mainly

Redness due to abrasion with Pterygoplichthys during haul.

A portion of a small burrow colony in dykes of bheries. Pterygoplichthys burrow openings are often triangular.

Captured loricariids dispersed on pond embankment.

Skeletons of decomposed loricariids.

Above, below: Loricariids are boiled before descaling to collect flesh for consumption.

due to curiosity. Because of their very hard external armour, these fishes are boiled in water as a whole and then descaled by hand to obtain the flesh, which is either taken plain or cooked further using spices. But in general EKW farmers are avert of eating these fishes and there is no market for them elsewhere in India as food, both for reasons of taste and smell, and as a result farmers cull loricariids taken as by-catch during commercial fishing. Moreover, because of the very high ash content and lower flesh yield, as well as the difficulty of handling due to the hard spiny outer shell, their use as ingredients, for example as fish meal for animal feed preparation or other means through value addition has not yet made any progress.

Loricariids and human health issues

Invading organisms, such as loricariids, that alter nutrient dynamics have the potential to change food availability in a system and affect all of the other organisms that depend on those resources. As farmers are throwing loricariids on the shore of water bodies to decompose, the fish constitute a source of environmental pollution and potential public health problems. Also, fishermen often injure themselves while segregating these fishes from the haul of commercial fishes, mainly because of the spiny scales.

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Concept of indigenous recirculatory aquaculture system executed in West Bengal, India and other places

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In pursuit to modernise fish culture practices, instead of the conventional method of rearing fish in open earthen ponds in rural areas, novel recirculatory aquaculture systems (RAS) have been introduced in semi-urban areas in West Bengal and other parts of India. A feature of RAS 'clear water culture' is that materials normally considered essential in the pond environment such as plankton, fertile soil base, sunlight, fertilisers and nutrients, lime and common water treatments are not required.

Quite a few progressive fish farmers in India have adopted 'high profile' advanced-type, intensive and imported versions of RAS featuring huge plant, while other farmers adopted small and indigenous version of RAS, where the investment is comparatively low. This article upholds the design, principles, state-of-the-art and associated practical aspects of indigenous model, i.e., low-cost version of 'water-smart' RAS technology presently executed commercially by some RAS practitioners and experts in West Bengal and other places.

Basic features of recirculating aquaculture systems

Aquaculture technologies such as RAS, super-intensive raceways, aquaponics, and integrated multi-trophic aquaculture are likely to make a significant contribution to future global fish production and supply[1]. Countries such as Germany, Israel, Egypt, and others have adopted intensive aquaculture and one of the methods is to use fully closed water systems based on biofiltration units that can produce fish at over 100kg/cubic metre[2]. RAS are fully controlled systems and can limit water consumption, which is important in regions of water scarcity. With fresh water supplies increasingly under pressure in India, there is a growing requirement to produce higher volumes of fish from limited supplies[3]. Water leaving fish culture tanks from centrally positioned outlets is constantly filtered and cleaned for recycling back into the culture tanks for reuse. Treated water is saturated with dissolved oxygen to optimise fish growth; the concentration of carbon dioxide, ammonia (both its non-ionised and ionised forms), and nitrite are reduced to nil while that of nitrate remains within safe limits. High-valued edible indigenous freshwater fishes of West Bengal and tilapia are farmed; water quality in well run RAS tanks is of better quality when compared to earthen ponds.

Utility and merits of RAS

Since access to good quality water for aquaculture is becoming more limited, the adoption of high-tech fish farming systems becoming necessary to sustain fish productivity level[4]. Better food conversion ratios are achievable with RAS[5]. In circular tanks in RAS, fry-staged fish are stocked at a higher density in comparison to conventional and familiar earthen pond aquaculture systems. Problems such as slow growth, fish mortality and unhygienic bottom soil can be avoided in RAS.

According to progressive fish farmers in West Bengal, there are many issues impeding the development of both commercial and rural inland pond aquaculture. These include:

- Insufficient availability of quality water for fish culture in rural areas, and reduced pond water resources.

Indigenous RAS biofilter design.

Indigenous filter design.

- Deteriorating physico-chemical parameters of pond water and soil.
- Water discharged from ponds being mixed with natural open freshwater resources, which may be redrawn for supply.
- Shortages of suitable land and the cost of new pond excavation for fish culture, which often have low water retention capacity.
- The cost of periodically drain ponds to remove silt/ sediment deposits from farming operations.
- The high cost of repairs to dyke of earthen ponds, particularly in new ponds which may need repair every year.
- Escape (loss) of crop during heavy rain and flood events.
- Harvest size is falling despite stocking levels remaining the same.
- The cost of labour to seine and maintain the pond.
- The spread of pathogenic microorganisms.

Issues such as these are helping to make RAS a viable alternative, as it can overcome or avoid such impediments. More fish can be produced in less space, without fear of poaching. Normally in RAS, 1kg of fish can be produced from every 16-25 litres of water, which is much more efficient compared to the water required for an equivalent yield in a pond. Mortalities are generally lower, and less labour is required - only one or two employees to monitor an entire RAS system and check the water quality parameters. Market-sized fishes can be easily harvested at the proper time, quantity and even size, creating produce that is more acceptable to consumers as being antibiotic- and chemical-free. According to officers at the Indoor Fish Farming Project under BCSIR, Dhaka: From every 1,000 litres of water, 100 kg of fish may be produced from a typical RAS compared to 10 kg of fish from an earthen pond, or 20 kg in ponds when paddle-wheel aerators used.

Mechanical and biological filtration systems

Mechanical filtration

In RAS, used water is purified by a combination of mechanical and biological filter systems. The former removes suspended solid waste originating from uneaten fish feed, fish faeces and bacterial biofilms from continuously flowing used water. Firstly, water passes from the fish rearing tanks and enters into a drum filter, where water passes through a filter microscreen of 40-100 micron mesh size. Rotation of the drum causes solid wastes to be trapped on a filter screen, which are retained within, rejected and lifted to a backwash area which accumulates filtered particles into a sludge tray for disposal. Clear water, devoid of organic particles, ejects out of the filter screen.

Biological filtration

Primarily treated water passes into a biofilter or biological purification system; aiming to eliminate and convert toxic ammonia nitrogen and dissolved nitrates in an aerobic environment. This is effected by a community of beneficial nitrifying bacteria. Application of beneficial microorganisms to degrade waste materials of fish rearing tanks into less toxic forms is bioremediation; it can lead to a good harvest by increasing survival and growth rate of desired culture species[6]. Nitrifying bacteria grow on the surface of beads that provide a large substrate for formation of biofilms, while allowing water flow through the media bed. A moving bed filter (MBF) consists of a rectangular tank with an aeration device, filled with filter beads that are light in weight and have a high surface area. Hundreds of closely-packed plastic media, also termed moving bed biofilm reactor media, move around in the water due to air currents created by a pump inside the MBF tank. Microscopic organic material from used water is removed. Water flowing out of the biofilter is treated with antimicrobial UV-C light (having short wavelength 200-280 nm), to reduces potential pathogen load before water is recirculated back into the culture tanks[7].

Bacteriological nitrification, a practical method of removal of ammonia from closed aquaculture systems, is also commonly achieved by setting up sand and gravel biofilters, through which water circulates. Biofilters are readily designed and constructed in modular form, making them useful for water quality management in aquaculture[8].

Simple design of RAS

Structure of filter system

High-tech RAS involve high capital outlay and running cost. To reduce expenses and maintain production, simplified RAS have been designed for small-scale fish farmers, which require only small investment, using drum filters constructed from blue plastic water barrels (220-300 litre capacity) (courtesy: Sri Rajkumar Jha, Radio Madhubani, Mithila, Bihar). In each 10,000-litre fish rearing tank, 500 seed are stocked. Used water enters the first drum filter from below. After moving in a circular motion, water passes upwards through a sponge-type filter or fine-meshed net and thereafter via thick bed of gravel (separate beds of small- and large-sized gravel). As water moves into a second drum filter from above, it passes down through three layers; the first and third comprise thick beds of gravel and the middle layer is a bed of sand of equal thickness. The gravel reduces turbidity by trapping and removing particulate matter from suspension[9]. Purification of water occurs in outer few centimetres of the sand layer. Undesirable bacteria and other microorganisms are captured by the sand grains as water passes through the layer.

As water leaves the second drum filter it is treated with UV light before entering a third drum filter consisting of biomedia, i.e., small pieces of plastic that provide a large surface area to facilitate attachment and growth of nitrifying bacteria. Materials used to wash kitchen utensils (some utensil scrubbers, Scotch Brite), micro-sponge (sponge filter), bio-balls, pumice stone (*jhama pathar* in Bengali) and even-sized stones may be used while preparing the biofilter tank. Oxygen levels are maintained in this filter via an air blower/aerator. After passing through the biofiltration drum, water is returned to the fish culture tanks. In indigenous design, plastic black-coloured K-1 media in moving bed filters are used as media to grow nitrifying bacterial colonies; K-5, K-6 media and black bioballs also used in RAS biofilter tanks.

Sri Samar Mondal's RAS

Wise RAS practitioner and expert Sri Samar Mondal at Patikabari Village, Murshidabad District, West Bengal, has constructed an indigenous rotary automatic mechanical drum filter (RDF) using a plastic drum, shaft, iron frame and other accessories and installed it inside a rectangular cement cistern. Water is lifted into the RDF from fish culture tanks via a pipeline and motor. Screen printing mesh cloth (micron net) is used to construct the RDF to filter out uneaten feed particles and faeces. Wastewater is drained via a pipeline outside the RDF container. Filtered water is stored inside a cement cistern beneath the RDF and passed into sedimentation tank, and thereafter into a rectangular cement tank (first biofilter) consisting of moving and self-cleaning plastic media, ie. a moving bed filter. Sri S. Mondal uses small, home-cut pieces of corrugated black flexible pipe as media. K-1 media packed quite densely moves freely in the biofilter tank. The constant chaotic movement of air from the pump causes media to self-clean. In Sri S. Mondal's set-up, treated water from the first biofilter tank enters the second, which is occupied by a thick bed of activated charcoal and gravel placed within the water column. Fine impurities in the water, not screened by the RDF, are separated here.

Next, water is passed into a UV filter tank, where it is treated before being returned to fish tanks of around 1 metre depth. Initially the water level is maintained at 45-60 cm but is increased with advancement in fish growth. According to him, for each of 1,000 litre RAS fish tank, and indigenous biofilter of 300 litre capacity must be set up consisting of 150 litres each of water and biomedia. To enhance populations of nitrifying bacteria and to eliminate ammonia and nitrate, the product 'Bacteria-Push Microlife-S2' (liquid bacterial suspension) may be applied in the moving bed filter, seeding the bed. Bacteria become active within 3-8 hours and begin functioning. In this RAS, the air blower produces 21,000 litres of air every hour to maintain oxygen levels in the fish culture and moving bed filter tanks.

According to Sri S. Mondal, a RAS of 5,000 litre capacity will cost approximately Rs 55,000/-, with expenditure break-up as follows: Rs 30,000/- for single cement tank construction; Rs 10,000/- for RDF (self-made); Rs 5,000/- for biofilter; Rs 4,000-5,000/- for good quality air pumps suitable to treat 5,000 litres of water; Rs 2,000/- for UV light and Rs 3,000/- for a quality water pump. From the culture tanks, water first passes into the RDF; clear water thereafter successively passes through the moving bed filter tank (cement construction with air pump), normal bed biofilter tank (with small rocks and charcoal), UV tank (18 w UV light), before treated water recirculates back to the fish rearing tanks. Two biofilter tanks and the UV tank are made of cement, rectangular and almost equal in size. He has two cement fish tanks, each 2.44 m in diameter, height 1.2 m (water column: 1.05 m) and approximately 6,000 litres in capacity, where 3,000 advanced *H. fossilis* fry (7.6-8.9 cm) are stocked in every 3, 000 litres of water.

Second author's RAS filter design

According to second author, construction cost of an indigenous small backyard RAS costs around Rs 300,000-400,000/-. Two RAS tanks of 10,000 litre capacity each for *H. fossilis* culture, with 3,000 fish in each tank, are maintained with greenhouse netting as an overhead shade. Fish attain 8.9-11.4 cm in length 35 days after stocking and are sold within the next two to three months. Three diffuser-type aerators are used in each tank.

In another small-scale RAS set up, two circular brick-walled fish tanks 1.50-1.75 m in diameter (water level: 1.0-1.2 m) are constructed for rearing *O. pabda* and *M. vittatus*. Mild water flow is created in tanks with the force of water inlets positioned above the rim of tanks. Three blue plastic barrel-based drum filters are employed, including a biofilter. Used water from fish tanks is first lifted and filtered through stainless steel wire nets from above before entering the first filter tank. Here, water is sieved using two kinds (double filter) of high-quality sponge filter and plastic chubri (round rim flexible plastic baskets used in the kitchen). In the second filter, the bioflter tank, many plastic bioballs placed in the water and an activated carbon system set up with intensive oxygenation. Treated water finally enters the third filter tank, consisting many home-made K-1 media in a submerged and continuously moving state due to the action of bubbles. Treated water is finally lifted back to the fish culture tanks using a 0.5 HP motor. A home-made iron filter constructed in this RAS complex comprises gravel and sand beds, which are essential if ground water is used. Rainwater harvested from the roof top is used in fish tanks and recirculated. After three years of thorough experimentation, the second author became a pioneer in introduction of indigenous RAS technology in West Bengal in 2016.

Two RAS fish tanks under shade.

Water inlet generating circular flow in RAS cement fish tank.

Mystus vittatus

RAS set-up of Janab Malekh Sekh

Progressive fish farmer Janab Malekh Sekh at Gadisahebnagar Village, PS Sagardighi, Murshidabad District, has set up 5,000-10,000 litre concrete RAS fish tanks on a home terrace for *O. niloticus*, *O. pabda* and *M. cavasius*. He has found FCR to be in the range 1.5-2.0 and 0.7-1.0 (beneficial) in pond conditions and RAS tanks respectively. In a RAS tank of 3.65 m x 3.95 m (45-60 cm water depth) with oxygenation system, Janab Sekh stocked 10,000 advanced *C. batrachus* fry and will harvest 1,000 kg of fish after four months. Fishes grow from 5 g at stocking to 20 g in three weeks. He has constructed an indigenous water filter system that removes ammonia (Courtesy: Biofloc fish farming murshidabad com).

RAS at ICAR-CMFRI, Visakhapatnam

It is possible to reduce the initial investment in RAS if a rapid sand filter (RSF) of indigneous design is used as an alternative to expensive RDF in advanced-type RAS. 350kg of white sand with a 2 mm particle size is kept in each of two RSFs. In an indigenous biofilter model of 2,000 litre capacity and cement structure, dead oyster shells or those of freshwater mussels and bioballs (4,000 pieces) are used, providing substratum for growth of nitrifying bacteria biofilms. Oyster shells with sufficient surface area used for attachment of nitrifying bacteria and maximising contact with passing water for ammonia removal. The cost is around Rs 130,000/- and Rs 20,000/- to set up two RSF units and one biofilter tank respectively, with a total establishment cost of around Rs 1,403,000/-[10]. Water requirements are reduced, since recirculation aquaculture systems can be adopted in salinity varying from 0-30 ppt[11].

Indigenous RAS in Bangladesh

RAS systems are also in use in Bangladesh; some examples include:

- At Hobigonj Town in Sylhet District, Sri Uttam Bhai is running RAS in six fish tanks, each of 1,000 litre capacity with 2,000 *H. fossilis* fry stocked in each. Fish attain 15-20 individuals/kg (50-66 g) in four to five months and are harvested and sold in the market (Courtesy: Agro fish farming channel 'fishmarketbd', Bangladesh).

- A home-based RAS has been set up at Dighirchala Village in Gazipur District for farming *H. fossilis* where approximately 8,000 fish are reared in three well-oxygenated rectangular tanks of 800 litre capacity each.

- In Shimultoli Village in Gazipur District, RAS-based rectangular cement tanks for *H. fossilis* have been established with 5,000 fish stocked in each tank.

- At Manikganj, *H. fossilis* is reared in four circular RAS tanks (12,000 fish stocked in each 8,000 tank) with plastic barrel-based biofilter tanks positioned on the boundary wall of cement tanks (Courtesy: 'bd ras' fish farming video).

- At Gachirhata Village in Kishoreganj District, a RAS project has been established with four circular concrete tanks for *O. niloticus*. In some RAS, in addition to other filter elements, used water is treated in tanks containing masses of naturally-grown *Eichhornia crassipes* and *Ipomoea aquatica*, which help in ammonia removal.

- At Mauna town in Gazipur District, a cement tank (4.58 x 6.10) m^2 in area (1.5 m high) is functioning as RAS, where 11,000 *H. fossilis* are propagated.

Mystus cavasius.

Additional information on RAS

According to Sri Pawan Phogat at Wazirpur Village near Dehri in Bihar, the construction cost of a 10,000 litre tank (4 m diameter, 1.22 m deep) made of square iron mesh support frame and tarpaulin (650-700 GSM) is around Rs 18,000/-, including tarpaulin, air stone and other aeration devices. Circular fish tanks made of zinc-aluminium alloy sheets are used in intensive RAS. Due to their dual respiration habit, *H. fossilis* is ideally suited for RAS and will survive an electricity (aeration) failure. Air-breathing catfishes *Clarius batrachus* and *H. fossilis* grow faster than *O. pabda* and *M. cavasius*. Nutritionally balanced pellet-type floating supplementary feed (Rs 45-75/-/kg) is fed to growing fishes daily. Excess feeding and sinking-type pelleted feed should be avoided as it will hamper water recirculation and working of RAS. Fish tanks are saturated with dissolved oxygen (8-11ppm), and a proper dosage of feed maintained. Stable bioavailable vitamin C is sometimes added to feed before use; growth promoters, chemicals, and medicines (antibiotics) completely avoided.

Anabas testudineus.

Oxygen generators and air blower are important components in indigenous RAS models; dissolved oxygen content must be maintained throughout the whole system. An oxygen supply outage of more than four hours in the biofilter tank may kill nitrifying bacteria colonies formed over a moving bed filter. A constant and sufficient oxygen supply is required for proper functioning of nitrifying bacteria. Two to three bubble diffuser-type aerators are used in each fish tank (more in tanks containing larger fishes); adequate dissolved oxygen levels and correct pH encourages fast growth of fishes.

Under the initiative and advice of second author, four RAS tanks, each of 13,000 litre capacity and 2.14 m in height are under reconstruction in North 24 Parganas, West Bengal with provision of a K-1 media filter and mechanical filter. Another project has started at Ranaghat, District, Nadia, with four cement tanks of 10,000 litre capacity each. Concrete circular breeding pools (components of Chinese hatchery design used in induced breeding and spawn production of major carps), smaller in size, may function as RAS fish tanks but contact of water with cement layer on its inner walls and inherent chemical reactions must be prevented. RAS expert Sri Viswanadha Raju Bh. R. in Hyderabad, Telangana State constructed cement RAS tanks with a coat of epoxy paint.

Circular RAS fish tanks are most convenient as suspended solids move out rapidly via the central drain with a pipe diameter of around 10 cm. In RAS tanks made of cement exclusively, alkalinity increases, and water pH can become uncontrollable, although cement tanks have more longevity than tarpaulin tanks. The diameter of the former should be about 4.5 m with a slope of around 15 cm towards the centre and a wall thickness 15-25 cm.

End note

Besides commercially-important major carps, there are high-value freshwater (warm water) fishes in West Bengal such as *H. fossilis*, *C. batrachus*, *Puntius sarana*, *Labeo gonius*, *A. testudineus*, *M. vittatus*, *M. cavasius*, *O. pabda*, *O. niloticus* that are cultivable in confined systems under control. Diversification of freshwater fish culture in West Bengal and other places can be achieved by incorporating these species, which are mostly small and indigenous; are nutritious, and have higher commercial value and market price in comparison to major carps. Their propagation from fry/advanced fry up to marketable size is advantageous in RAS when compared to earthen pond conditions.

It is necessary to convert 10-15% of aquafarms in India to intensive aquaculture systems such as raceway culture, running water culture, and recirculatory aquaculture which, are feed-based systems (Courtesy: ICAR-CIFA Vision 2050). The average freshwater fish farmer in India are able to produce 2,000-3,000kg/ha/year while progressive farmers may achieve 8,000-10,000kg/ha/year. Contrary to this,

Ompak pabda.

RAS may be able to produce up to 60,000kg fish/year. It is expected that RAS will gain an increasingly strong foothold in Indian aquaculture production soon[12]. In the near future, both imported and indigenous versions of RAS will be promoted widely; more fish farmers in different parts of India are expected to adopt this modern technology.

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Homestead modular hatchery technology of brackishwater catfish, *Mystus gulio*: A potential alternate livelihood option for small and marginal farmers of Sunderban

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The long whiskers catfish, *Mystus gulio*, a member of the family Bagridae, is a euryhaline fish, commonly called *nona tengra* in Bangladesh and West Bengal, India (Kumar et al., 2019). *M. gulio* is usually found in canals, lakes, rivers, estuaries (Ganges-Brahmaputra estuary), and *bheri* (constructed impoundments in coastal wetlands/brackish-water tide-fed areas) of the Sunderban delta of Bangladesh and India (Kumar et al., 2019). It is a small indigenous fish species with a high nutritional value due to relatively high protein, micronutrient, vitamin, and mineral content (Ross et al., 2003). The domestic market price of this fish depends on size, which ranges from \$ 2.18-6.55 kg^{-1} (Kumar et al., 2019). Attributes such as its high nutritional value, market demand, hardy nature and fast growth make this species a desirable candidate for aquaculture in Southeast Asia (Ross et al. 2003). As a euryhaline species, it is suitable for culture in both fresh and brackishwater environments (Siddiky et al., 2015). It is co-cultured with other brackishwater fishes in paddy fields and *bheris* of the Sunderban. However, expansion of culture in pond systems has stumbled because of the unavailability of hatchery produced seed (Kumar et al., 2019). Wild seed availability is limited, unpredictable, time-consuming to collect and uneconomical. Seed production through induced breeding techniques is the only option to overcome such problems. In this connection, the Kakdwip Research Centre of the ICAR-Central Institute of Brackishwater Aquaculture, West Bengal, India has developed and popularised a cost effective, farmer-friendly Homestead Modular Hatchery and farming technology of *M. gulio*. We have also investigated the current status of farming and marketing of this species in the Sunderban of India.

Operation of the homestead modular hatchery

Broodstock maintenance

Smaller sized earthen ponds (500-1,000 m^2) are ideal for maintaining the broodstock of *M. gulio*. Broodstock need to be fed at the rate of 5% of body weight twice daily with supplementary feed (25% protein, 8% lipid). One month before the onset of spawning season (April-August), broodstock are fed once daily with chicken liver to satiation.

Adult Mystus gulio.

Water supply system

Water from the broodstock pond/canal is pumped to a reservoir tank (1,000 litres) and treated with bleaching powder (200 kg ha^{-1} or 20 ppm). After de-chlorination, water is pumped from the reservoir tank to the overhead tank (500 litres). During breeding, water is supplied to the breeding unit continuously from the overhead tank to maintain constant flow.

Breeding unit

Plastic containers (capacity 100 litres) are used as a breeding unit arranged in rows. In each tub, water is supplied from the overhead tank through a perforated PVC pipe. To create constant water flow in breeding tubs, each is perforated on top and covered with fine mesh to facilitate flow while retaining the eggs. In each breeding tub, three to four egg collectors are kept submerged with the help of a weight fixed at one end. The egg collectors are made from a bunch of nylon fibers, each consisting of around 500-600 strips of around 15 cm length.

Homestead modular hatchery breeding unit for Mystus gulio.

Maturity assessment and injection

Sexual dimorphism in *M. gulio* is distinct and prominent, a muscular papilla with reddish-pink tip is present in males, and it is absent in females. During the spawning season, mature *M. gulio* are collected from the broodstock ponds. An ovarian biopsy of the female is performed to assess maturity. However, without ovarian biopsy, maturity can be judged through morphological observation of vent; a swollen belly and swollen reddish vent indicates maturity. Mature males can be identified by the presence of an elongated papillae with a pinkish tip. Generally, females and males in the range of 75-150g and 25-75 g, respectively, are selected for breeding. The operational sex ratio of males and females is 2:1. A single intramuscular injection of either human chorionic gonadotropin (HCG), leutinizing releasing hormone (LhRHa) or a commercial hormone at the dose of 10 IU g^{-1}, 5 µg g^{-1} and 20 µl g^{-1} body weight of the female, respectively, induce the fish to spawn. Males are injected simultaneously with half the dose of females. After hormone administration, one set (one female and two males) is released in one tub. Aeration and water flow is maintained cround the clock after hormone injection.

Mystus gulio male (top) and female (bottom) with elongated genital papillae and round vent, respectively.

Egg collection and incubation

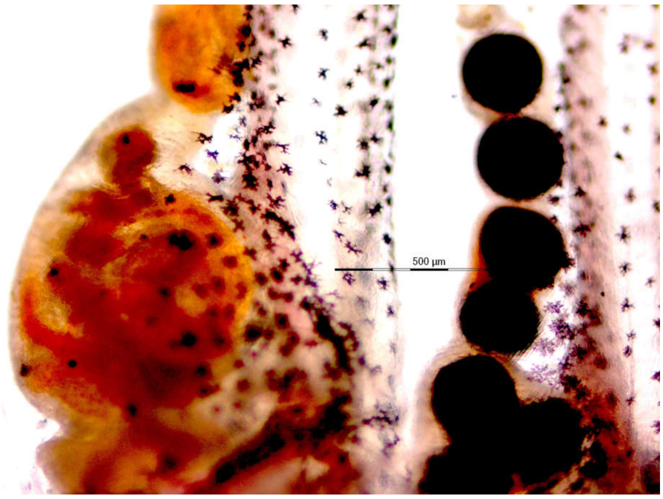
The latency period between injection and spawning ranges from 8-10 h, depending on the stage of maturation and water temperature. Fertilised eggs are round, demersal, and sticky, and demand provision of substrate in the form of the egg collector. Egg-bearing collectors are transferred to incubation units with provision for water flow to improve hatching and survival. Around the clock aeration is a must. Incubation period of *M. gulio* ranges from 16-18 hours.

Egg collector with eggs.

Larval rearing

One day before larval rearing begins, larval rearing tanks are filled with clean water and aerated. To avoid mortality and stress, the newly hatched larvae are gently transferred to larval rearing units as soon as possible. The newly hatched larvae start feeding two days post hatching, before the yolk sack is fully exhausted, which occurs on day three. Larvae

Newly hatched Mystus gulio larvae.



Gut of larvae filled with feed.

are stocked at a density of 25 per litre. They are fed from the second day onwards with freshly hatched *Artemia* nauplii at a density of 3,000 nauplii per litre, four times per day (Kumar et al., 2018). *Artemia* nauplii feeding continues until the seventh day. After that, larvae are fed twice daily with *Artemia* nauplii and twice with a 500 µ larval feed. After 30-35 days post hatching, larvae attain a size of 35-48 mm. During larval rearing, 0.5-1% of fast growing 'shooters' are typically seen in the first seven days, which are cannibalistic. Shooters must be manually removed for the first seven days to improve the survival of larvae.

Nursery rearing

Nursery rearing is essential to produce stockable sized seed for farming. Larval nursery is carried out either in net cage hapa, tanks or small ponds. Nursery rearing in hapa is easy to monitor and economical, and rearing for 60 days in hapa is a suitable system to produce fry for stocking. To carry out

Mystus gulio fry after nursery rearing.

nursery rearing, seven- to ten-day old larvae (0.01-0.02 g) are stocked in hapa (2 x 1 x 1) at an ideal density of 500 larvae/hapa. Larvae are fed four times daily with larval feed at the rate of 10% of total biomass. After 60 days of rearing, larvae attain around 1.30-1.50 g with an average survival of 45%.

Farming of *M. guilo*

Ponds are prepared following the standard procedure of drying (7-10 days), liming (agriculture lime at the rate of 200-250 kg ha^{-1}), filling (depth 1 m), bleaching (bleach powder @ 500 kg ha^{-1}) and fertilisation. Ponds are fertilised after dechlorination (5 to 7 days after bleaching) with organic

Pond preparation.

and inorganic fertilisers. Mustard oil cake, urea, and single super phosphate are applied at the rate of 250, 50, and 50 kg ha^{-1}, respectively. Farmers also practice the application of fermented 'juice' made up of molasses, 8-10 kg; probiotic, 50 g, wet yeast, 100 g; rice bran, 1 kg; mustard oil cake, 5 kg and water, 200 litres. This juice is kept for fermentation in a tank covered with polythene for seven days, and is sufficient to treat 1,300 m^2 of pond area. Nursery-reared fry of 30-35 days age are stocked at a density of 10 fry m^{-2}. Either floating or sinking feed having a protein content of 28-30% is fed at the rate of 5-8% of body weight. In six months of culture, fish attain an average marketable size of 50 to 60 g with the production of 1.2 to 2.4 tonnes ha^{-1}. The cost of production comes in around \$1.06-1.19 kg^{-1} and it has a ready market price of a minimum of \$3.31-3.97 kg^{-1}, which is economically lucrative. High-density farming (10-20 fish m^{-2}) in RAS and polythene-lined small backyard ponds (300 to 500 m^2) are suitable farming practices.

Paddy-cum-fish culture of *M. gulio* is common in the Sunderban area of West Bengal and India. In monsoon months along the coastline, high rain-fed regions are used for freshwater rice cultivation, which is mono cropped. After this crop, fields remain fallow due to highly saline soil, and are used for farming of salt tolerant rice varieties and brackishwater fish. In another system of farming, *M. gulio* along with other brackishwater fishes are farmed in low lying ponds with paddy on the upper area. Along with commercial feed, farmers also use low cost dried shrimp as feed for *M. gulio*. Dried shrimp soaked in water for a few minutes before fedding. Sampling and partial harvesting with cast net is practised, however, it is advisable to go for complete harvesting.

Physico-chemical parameters of water

To avoid stress, physico-chemical parameters such as temperature, pH, salinity, dissolved oxygen, and total ammonia of broodstock ponds, breeding tanks, incubation and larval rearing tanks must be uniform. In brackishwater systems, the ideal physico-chemical parameters of water such as salinity, temperature, dissolved oxygen and ammonia range from 7-18 ppt, 29-31°C, 4.5-5.0 ppm, and 0.02-0.05 ppm, respectively in the broodstock pond, hatchery, and larval rearing systems.

Popularisation and adoption homestead modular hatcheries

This homestead modular hatchery technology for growing *M. gulio* has been popularised among farmers of the Indian Sunderban through hands-on training and demonstration. More than one hundred farmers have received hands-on training at the Kakdwip Research Centre of CIBA. The technology has been demonstrated to farmers of the Sunderban

Paddy cum fish culture of Mystus gulio.

Table 1: Economic analysis of *Mystus gulio* homestead modular hatchery operation producing 50,000 30-day old fry in one cycle (16 females+32 males). Total production capacity is 200,000 fry in four months.

Fixed costs	Description and rate	Cost ($)
Water intake system	Electric water pump (2 HP), overhead tank (1,000 L) and PVC items	132.46
Air blower	Aeration, filter and accessories	39.74
Broodstock holding pond (500-1000 m^2) on lease	To maintain sub-adult and brood fishes	66.23
Breeding unit	Round plastic tub (100 L) x 15	132.46
Incubation cum hatching unit	Round plastic tub (100 L) x 15	132.46
Larval rearing unit	Rectangular or round cement tanks (500 L x 6)	397.39
False shed	Size: 50 X 50 m	198.69
Total fixed cost (A)		**1,099.43**
Operational costs		
Broodstock fish	Total broodstock required: 4 kg @ Rs. 700/-	37.09
Electricity / diesel	Operation of pump and blower for one cycle	13.25
Inducing agents and chemicals	Hormone, sanitiser and chemicals	9.27
Artemia cysts	~200 g	52.98
Larval feed	~250 g	1.32
Labour	For 35 days@Rs.500	231.81
Total operational cost (B)		**345.73**
Total cost of production (C) = A+B		**1,445.16**
Revenue / return		
Gross return (D) **Total fry ~50,000 are produced in one cycle (16 sets of breeding).** **Sale price @ $ 0.0099/fry (30 days old)**		**496.73**
Net return (E)= D-B		**151**
Operating ratio or benefit cost ratio (D/B)		**1.43**

Trainees and faculties in *Mystus gulio* hatchery yard.

Release of reading materials on *Mystus gulio* seed production and farming technology.

Demonstration of homestead modular hatchery to Sri Aniruddha Das, from Namakhana, West Bengal.

Demonstration of homestead modular hatchery technology to Sri Dipankar Bera, Pathatr Pratma, West Bengal.

Distribution of hatchery produced *Mystus gulio* seed to Mr Kamanashish Sarkar, West Bengal.

Marketable size of *Mystus gulio* in West Bengal.

Marketing of *Mystus gulio* in Namkhana, West Bengal.

Marketing of *Mystus gulio* in Nischintpur, West Bengal.

as an alternate livelihood option. Further, to popularise the technology, seed of *M. gulio* has been distributed among small and marginal farmers of the Indian Sunderban area.

Economic analysis of homestead modular hatcheries and marketing status

M. gulio has low fecundity, ranging from 12,000 to 25,000. We have observed that a mature female (70-100 g) after administration of hormone typically releases around 10,000-12,000 eggs. In homestead modular hatcheries, one female generates around 4,000-5,000 fry at thirty days of age. The price of thirty-day fry varies with a minimum of $0.0066 and average of $0.013. Economic analysis of the system is shown in table 1. The price of *M. gulio* depends on market fluctuations, month, season, freshness, size and consumer demand. Recently, we conducted a survey of *M. gulio* in a few markets (Namkhana, Nischitpur, Kakdwip) of the Sundarban area and found that this fish has a very high market demand with prices ranging from $2.18-6.55 kg^{-1}. The price of *M. gulio* is also influenced by size. Smaller (50-70 g), medium (50-70 g), and larger fish (more than 100 g) are sold at $2.18, 5.10 and 6.55 kg^{-1}, respectively by wholesalers to retailers who in turn sell to consumers with a mark-up of $ 0.44 to 0.73 kg^{-1} (CIBA, 2015).

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Paddy-cum-fish culture pond of Mystus gulio.

NACA Newsletter

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Vale Professor Sena De Silva

Prof. Sena De Silva presenting at the Global Conference on Aquaculture 2010.

It was with great sadness that we learned that our dear friend Professor Sena De Silva passed away on 6 May, 2020. On behalf of the Governing Council, the Chair Dr Yingjie Liu, and the NACA Secretariat, would like to express our sincere condolences to his family. The aquaculture community, and the region, has lost one of its true champions.

Prof. De Silva was a brilliant scientist working across multiple disciplines including nutrition, limnology, inland fisheries, fish breeding, biodiversity and environmental issues. He was a renowned teacher and mentor; he loved teaching and had a genuine interest in capacity building. His students may be found in nearly every country throughout the region. Many now occupy high-level roles in government, industry, academia, and international organisations. Many may also be found in rural villages, working their farms.

Prof. De Silva's association with NACA dates back to the beginnings of the organisation itself. He represented the International Development Research Centre at a meeting in 1989, where the Provisional Governing Council adopted the NACA Agreement and decided to make it an inter-governmental organisation. From that time on, Prof. De Silva frequently worked in conjunction with NACA, developing and deploying projects in collaboration with scientists across the region. These included regional initiatives on aquaculture education, managing conflicts between capture fisheries and aquaculture in reservoirs, limnology and fisheries studies, broodstock management of mahseer, tsunami relief work and many others. He also worked with NACA staff in the development of projects on biodiversity and conservation, the use of GIS as a tool in inland fisheries management, the fisheries and conservation of Philippine lakes, provided input into NACA's Governing Council and later served as a member of the Technical Advisory Committee.

He was a member of the Advisory Committee of the FAO/NACA Conference on Aquaculture in the Third Millennium, held in Bangkok in 2000, where he prepared the Global Synthesis, which was one of the main working papers. He was later appointed a member of the NACA Task Force 2000, whose recommendations were instrumental in the development of the 3rd Five Year Work Programme; he would again serve as a NACA Task Force member in 2015.

In 2006 Prof. De Silva was elected as Director General of NACA and served for five highly successful years, playing a key role in project development in areas including culture-based fisheries, the development of better management practices for Vietnamese catfish, management of reservoir fisheries, the use of remote sensing for inland fisheries management, reducing the dependence on trash fish in feeds for marine fish, and climate change. His term culminated in the highly successful FAO/NACA Global Conference in Aquaculture 2010, held in Phuket, Thailand, where he presented the regional synthesis paper on Aquaculture Development in the Asia-Pacific.

During his term NACA was selected to win the 2010-2011 Margarita Lizárraga Medal, conferred by FAO, with recognition of its significant contribution to sustainable aquaculture development in the Asia and Pacific Region, serving as a cohesive intergovernmental forum for the formulation of regional policies as well as cooperation and coordination in aquaculture research, development and training.

Prof. De Silva took a personal interest in improving the lot of the region's small-scale farmers and was at his happiest working on field projects, seeing the positive changes in the communities. He was also a powerful advocate for the interests of small-scale farmers at international meetings and fora; if he felt that the interests of small-scale farmers were being trampled, look out! He was never afraid to be the lone voice of dissent or to criticise injustices in the status quo.

After completing his term as Director General, Prof. De Silva returned to Deakin University, Australia, where he continued his research and collaboration on aquaculture development projects with NACA until this day. His most recent project with the network was to write the Asia-Pacific regional synthesis paper for the now postponed FAO/NACA Global Conference on Aquaculture 2020, which he was to present in Shanghai, China.

We, the staff of the NACA Secretariat, will miss Sena. He was not just a colleague, teacher and mentor, he was also our friend.

The State of World Fisheries and Aquaculture 2020

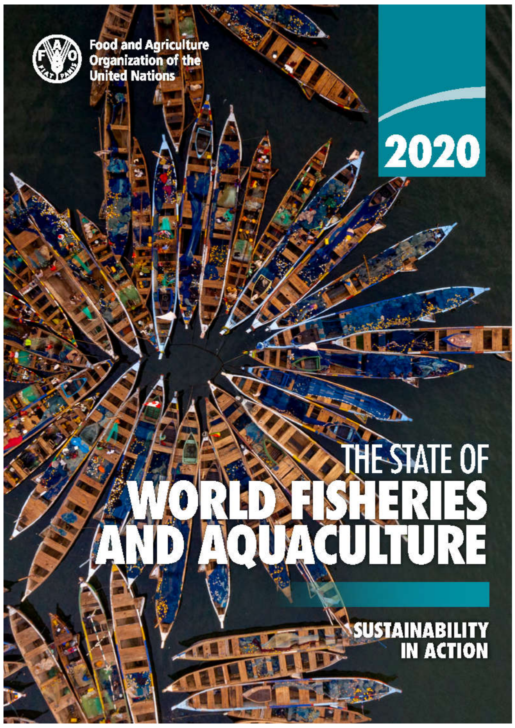
FAO has released the 2020 edition of The State of World Fisheries and Aquaculture, which has a particular focus on sustainability. This reflects a number of specific considerations. First, 2020 marks the twenty-fifth anniversary of the Code of Conduct for Responsible Fisheries (the Code). Second, several Sustainable Development Goal indicators mature in 2020. Third, FAO hosted the International Symposium on Fisheries Sustainability in late 2019, and fourth, 2020 sees the finalisation of specific FAO guidelines on sustainable aquaculture growth, and on social sustainability along value chains.

While Part 1 retains the format of previous editions, the structure of the rest of the publication has been revised. Part 2 opens with a special section marking the twenty fifth anniversary of the Code. It also focuses on issues coming to the fore, in particular, those related to Sustainable Development Goal 14 and its indicators for which FAO is the "custodian" agency. In addition, Part 2 covers various aspects of fisheries and aquaculture sustainability. The topics discussed range widely, from data and information systems to ocean pollution, product legality, user rights and climate change adaptation. Part 3 now forms the final part of the publication, covering projections and emerging issues such as new technologies and aquaculture biosecurity.

It concludes by outlining steps towards a new vision for capture fisheries. The State of World Fisheries and Aquaculture aims to provide objective, reliable and up-to-date information to a wide audience – policymakers, managers, scientists, stakeholders and indeed everyone interested in the fisheries and aquaculture sector.

Several resources are available from the FAO website. These are:

- The full report: http://www.fao.org/documents/card/en/c/ca9229en
- Brief version of the report: http://www.fao.org/documents/card/en/c/ca9231en
- Summary of the impacts of the COVID-19 pandemic on the fisheries and aquaculture sector: http://www.fao.org/documents/card/en/c/ca9349en



Viral covert mortality disease (VCMD): Disease card

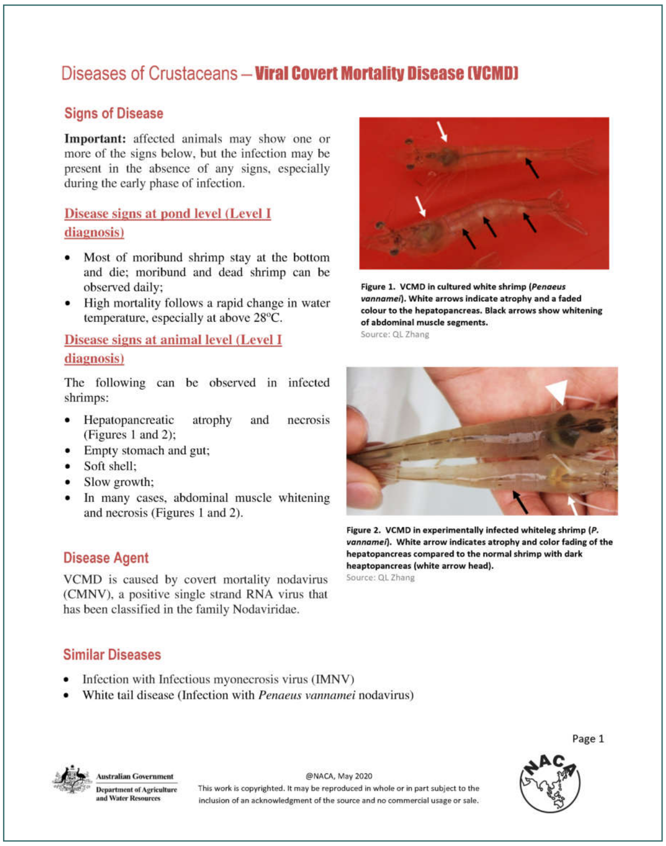
This disease advisory describes the history, known host range, clinical signs and PCR detection methods for viral covert mortality disease (VCMD). Crustaceans currently known to be susceptible to VCMD include *Penaeus vannamei*, *P. chinensis*, *P. japonicus*, *P. monodon*, *Macrobrachium rosenbergii*, *Procambarus clarkii*, *Exopalaemon carinicauda*, *Ocypode cordimanus*, *Diogenes edwardsii*, *Corophium sinense*, *Parathemisto gaudichaud* and *Tubuca arcuate*. Fish species including *Mugilogobius abei*, *Carassius auratus*, and *Paralichthys olivaceus* may also be susceptible to the virus.

At the pond level, most moribund shrimp stay at the bottom and die, and dead shrimp can be observed daily; high mortality follows a rapid change in water temperature, especially at above 28°C. At the animal level, clinical signs of infected shrimp include hepatopancreatic atrophy and necrosis; empty stomach and gut; soft shell; slow growth; and in many cases abdominal muscle whitening and necrosis.

Importantly, affected animals may show one or more of these signs but the infection may be present in the absence of any signs, especially during the early phase of infection.

The disease card is available for free download from:

https://enaca.org/?id=1108



Diseases of Crustaceans – **Viral Covert Mortality Disease (VCMD)**

Signs of Disease

Important: affected animals may show one or more of the signs below, but the infection may be present in the absence of any signs, especially during the early phase of infection.

Disease signs at pond level (Level I diagnosis)

- Most of moribund shrimp stay at the bottom and die; moribund and dead shrimp can be observed daily;
- High mortality follows a rapid change in water temperature, especially at above 28°C.

Disease signs at animal level (Level I diagnosis)

The following can be observed in infected shrimps:

- Hepatopancreatic atrophy and necrosis (Figures 1 and 2);
- Empty stomach and gut;
- Soft shell;
- Slow growth;
- In many cases, abdominal muscle whitening and necrosis (Figures 1 and 2).

Figure 1. VCMD in cultured white shrimp (*Penaeus vannamei*). White arrows indicate atrophy and a faded colour to the hepatopancreas. Black arrows show whitening of abdominal muscle segments.
Source: QL Zhang

Figure 2. VCMD in experimentally infected whiteleg shrimp (*P. vannamei*). White arrow indicates atrophy and color fading of the hepatopancreas compared to the normal shrimp with dark heaptopancreas (white arrow head).
Source: QL Zhang

Disease Agent

VCMD is caused by covert mortality nodavirus (CMNV), a positive single strand RNA virus that has been classified in the family Nodaviridae.

Similar Diseases

- Infection with Infectious myonecrosis virus (IMNV)
- White tail disease (Infection with *Penaeus vannamei* nodavirus)

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Australian Government Department of Agriculture and Water Resources

NACA

Disease advisory: Decapod iridescent virus 1 (DIV1): An emerging threat to the shrimp industry

This disease advisory describes the history, known host range, clinical signs and PCR detection methods for decapod iridescent virus 1 (DIV1). Preventative strategies are suggested. Currently known susceptible species of DIV1 include *Penaeus vannamei*, *Macrobrachium rosenbergii*, *Exopalaemon carinicauda*, *M. nipponense*, *Procambarus clarkii*, and *Cherax quadricarinatus*. Clinical signs of infected *P. vannamei* are not typical, including slightly reddish body, hepatopancreatic atrophy with colour fading, and empty stomach and guts. The full advisory may be downloaded from:

https://enaca.org/?id=1098

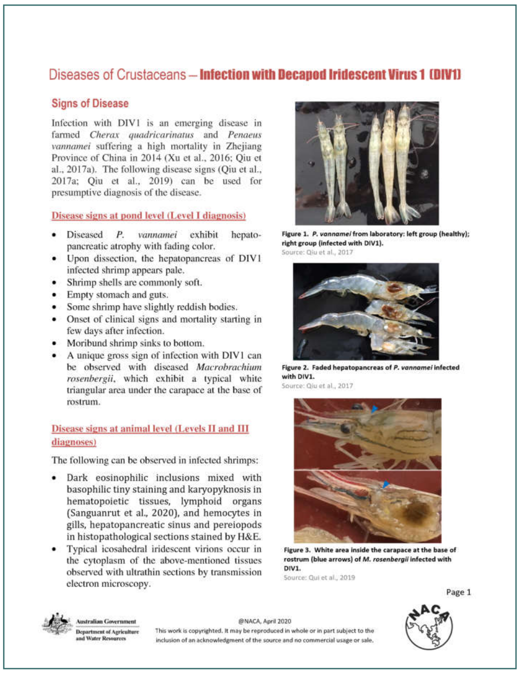
Infection with decapod iridescent virus 1 (DIV1): Disease card

Infection with DIV1 is an emerging disease in farmed *Cherax quadricarinatus* and *Penaeus vannamei* suffering a high mortality. This disease card provides information on:

- Signs of disease at pond land animal level (levels I - III diagnoses).
- The disease agent, known host range and distribution in the Asia-Pacific region.
- Molecular diagnostic methods and key expert contact points for further information.

The disease card is available for download from:

https://enaca.org/?id=1104



Diseases of Crustaceans – **Infection with Decapod Iridescent Virus 1 (DIV1)**

Signs of Disease

Infection with DIV1 is an emerging disease in farmed *Cherax quadricarinatus* and *Penaeus vannamei* suffering a high mortality in Zhejiang Province of China in 2014 (Xu et al., 2016; Qiu et al., 2017a). The following disease signs (Qiu et al., 2017a; Qiu et al., 2019) can be used for presumptive diagnosis of the disease.

Disease signs at pond level (Level I diagnosis)

- Diseased *P. vannamei* exhibit hepatopancreatic atrophy with fading color.
- Upon dissection, the hepatopancreas of DIV1 infected shrimp appears pale.
- Shrimp shells are commonly soft.
- Empty stomach and guts.
- Some shrimp have slightly reddish bodies.
- Onset of clinical signs and mortality starting in few days after infection.
- Moribund shrimp sinks to bottom.
- A unique gross sign of infection with DIV1 can be observed with diseased *Macrobrachium rosenbergii*, which exhibit a typical white triangular area under the carapace at the base of rostrum.

Disease signs at animal level (Levels II and III diagnoses)

The following can be observed in infected shrimps:

- Dark eosinophilic inclusions mixed with basophilic tiny staining and karyopyknosis in hematopoietic tissues, lymphoid organs (Sanguanrut et al., 2020), and hemocytes in gills, hepatopancreatic sinus and pereiopods in histopathological sections stained by H&E.
- Typical icosahedral iridescent virions occur in the cytoplasm of the above-mentioned tissues observed with ultrathin sections by transmission electron microscopy.

Figure 1. *P. vannamei* from laboratory: left group (healthy); right group (infected with DIV1).
Source: Qiu et al., 2017

Figure 2. Faded hepatopancreas of *P. vannamei* infected with DIV1.
Source: Qiu et al., 2017

Figure 3. White area inside the carapace at the base of rostrum (blue arrows) of *M. rosenbergii* infected with DIV1.
Source: Qui et al., 2019

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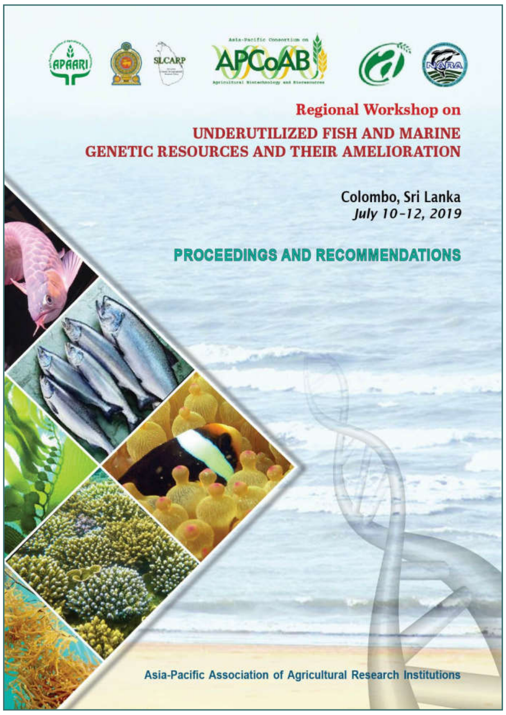
Australian Government Department of Agriculture and Water Resources

NACA

Regional Workshop on Underutilized Fish and Marine Genetic Resources and their Amelioration – Proceedings and Recommendations

The Regional Workshop on Underutilized Fish and Marine Genetic Resources (FMGR) and their Amelioration was held from 10-12 July 2019, at the National Aquatic Resources Research and Development Agency, Colombo, Sri Lanka. The workshop was organized by the Asia-Pacific Association of Agricultural Research Institutions (APAARI) under its programme on Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources, the Sri Lanka Council for Agricultural Research Policy and the National Aquatic Resources Research and Development Agency (NARA).



The key objectives of the workshop were to:

- Assess the status of underutilised FMGR at the regional level and to assess R&D status of priority species with potential for use in food and agriculture.
- Discuss knowledge gaps and the way forward in defining regional priorities concerning underutilised FMGR and create awareness on their role and potential for diversification of food supplies and livelihood generation.
- Formulate strategies for strengthening the institutional framework for FMGR management, and legal and policy framework to promote their conservation and sustainable use at the regional level.

These proceedings contain a summary of the thematic presentations, discussions, and recommendations of the workshop. They are redistributed here courtesy of APAARI. The proceedings are available for free download from:

https://enaca.org/?id=1111

Latest special issue of Gender, Technology & Development examines new learnings on women and fisheries

The latest Special Issue of Gender, Technology and Development (Vol. 24, 2020) contains seven papers and a guest editorial exploring gender issues in fisheries and aquaculture.

The papers address issues around technology, innovation and organisation, and the positive changes that occur when the contributions of women are made visible, they are empowered, and have a voice in decision making.

The special issue is drawn from papers presented at the 7th Global conference on gender in Aquaculture and Fisheries "*Expanding the Horizons of Women in Fisheries and Aquaculture*" in 2018.

The conference was co-organised by the Gender in Aquaculture and Fisheries (GAF) Section of the Asian fisheries Society, the Asian Institute of Technology and NACA.

For more information please visit the GAF Section website at:

https://www.genderaquafish.org/2020/05/26/latest-special-issue-of-gender-technology-development-examines-new-learnings-on-women-and-fisheries/

www.enaca.org

Development of a global information system for farmed types of aquatic genetic resources

FAO's recent report on The State of the World's Aquatic Genetic Resources for Food and Agriculture identified a number of important needs and challenges in the conservation, sustainable use and development of aquatic genetic resources. One of the key priorities identified was to "Establish and strengthen national and global characterisation, monitoring and information systems for AqGR", including through:

- Promotion of a globally standardised use of terminology, nomenclature and descriptions of AqGR.
- Improved and harmonised reporting procedures and expanded existing species-based information systems to cover unreported resources, including aquatic plants, ornamental species and microorganisms.
- The development, promotion and commercialisation/institutionalisation of national, regional and global standardised information systems for the collection, validation, monitoring and reporting on genetic resources below the level of species (i.e. farmed types and stocks).

FAO convened a virtual workshop from 8-12 June to discuss the development of an information system under a project Registry of Farmed Types of Aquatic Genetic Resources, funded by the German Government. The main goals of the project are to develop prototype registry system that documents the main 'farmed types' used in aquaculture, and to validate it through a series of regional workshops.

A farmed type is a genetic resource *below* the species level. Primary farmed types describe the status of a cultured organisms domestication and improvement, for example wild sourced seed from a distinct stock, captive bred animals from a given hatchery population, and strains selectively bred for improved production characteristics provide the basis for assigning a primary farmed type.

Cultured organisms may also be assigned a secondary farmed type, which denotes the application of value-adding genetic technologies and manipulations such as hybridisation, monosex technologies, polyploidy or genetic engineering.

The purpose of the information system is to document existing farmed types, focusing on those that exceed 10% of national production of a given species. This will facilitate policy development and decision making regarding aquatic genetic resources, including monitoring and reporting to support conservation objectives and sustainable development goals.

The consultation was also used to gather feedback on a proposed 'Global Plan of Action for Aquatic Genetic Resources', which is being developed in response to a request made by the Commission on Genetic Resources for Food and Agriculture at its 17th regular Session in February 2019.

The plan is at a very early stage of development and more details will be made available as it begins to take shape.

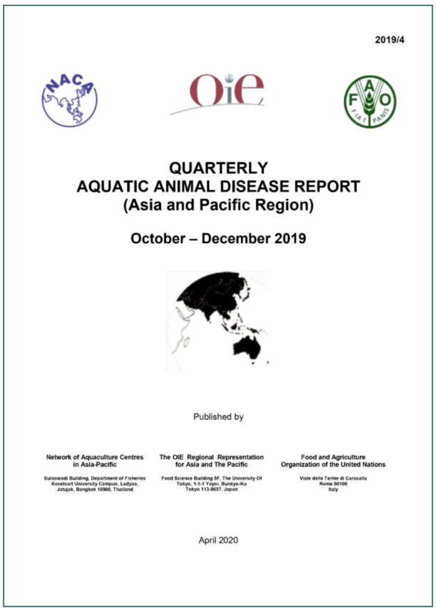
Quarterly Aquatic Animal Disease Report, October-December 2019

The 84th edition of the Quarterly Aquatic Animal Disease Report contains information from eleven governments.

The foreword discusses meetings of the ad hoc Steering Committee of the Regional Collaboration Framework on Aquatic Animal Health in Asia and the Pacific.

The report is available for free download from:

https://enaca.org/?id=1106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