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Cost effective practices from West Bengal

Food and feeding habits of peninsular carps, India

Inland saline culture

Freshwater prawn farming

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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Have we underestimated the humble *Artemia*?

Artemia (brine shrimp) are a staple food in hatchery and nursery production, most notably for both marine shrimp and freshwater prawns, but are also widely used for marine and ornamental fish and many other species. For most people, their experience is of hatching cysts from a can on the shelf, and feeding the newly hatched nauplii to their larvae or juveniles.

But it seems the humble *Artemia* may have much more to offer. Small-scale farmers in Thailand, Vietnam and Bangladesh are producing adult *Artemia* biomass and sometimes cysts in ponds, or in salt pans associated with solar salt works.

Biomass in particular is spectacularly productive. We have seen intensive, yet small-scale, farms comfortably producing 100 kg of biomass per day from a 0.6 ha former shrimp pond, with capacity to at least double that, based on historical production. This is achieved using agricultural wastes to fertilise the pond and stimulate a bloom of phytoplankton and halophilic bacteria on which the *Artemia* feed, with only 2-3 hours of labour per day, and with zero effluent discharge.

The biomass has a ready market in shrimp and marine finfish hatcheries, which use it to condition broodstock and accelerate growth of fingerlings, respectively. But is also gaining traction as a human food and high-quality protein source. In Vietnam and Bangladesh, local communities have been incorporating *Artemia* into their diet for some time. *Artemia* biomass is used to make 'kebabs' in Cox's Bazar, and to make Artemia ommlettes in the Mekong delta. While I haven't had the opportunity to try it myself, the farmers I have spoken to had all tried it and said that it tastes similar to swimming crab, which is a highly favourable comparison.

Artemia is highly regarded as a live food and protein source within the aquaculture industry. At the recent International Artemia Aquaculture Consortium Conference in Belgium, two speakers (Robins McIntosh and Yattish Ramena) reported that the feeding larval shrimp with Artemia affected subsequent survival and growout performance. Videos of these presentations are available at:

https://artemia.info/news/?id=112

As yet unexplored is the potential for *Artemia* biomass as a protein source or partial fishmeal replacement in animal feeds. Not just for aquaculture, but also for terrestrial livestock. Insects have received considerable attention in recent years, but require considerable infrastrcture to produce at scale.

It is apparent that *Artemia* biomass can be produced at scale with a bare minimum of equipment and at a remarkably low cost. Farmers in Thailand are producing 1 kg of *Artemia* for around US$0.15 per kg, wet weight. All that is needed is a high-salinity pond, a nutrient (waste) source for fertilisation, and a net.

Maybe, *Artemia* are worth another look and some careful thought.

Simon Wilkinson

AQUACULTURE ASIA

Some practices and techniques in cost-effective small and medium-scale aquaculture in West Bengal

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Fish-cum-poultry integrated farming system.

Twenty-two years ago, I attended a presentation by the late Dr S.D. Tripathi on 'Small-Scale Farming Systems for Rural Development' at the Sixth Indian Fisheries and Aquaculture Forum, held at ICAR-CIFE, Mumbai, in December 2002. He discussed low-input, low-cost aquaculture technologies. These included bio-gas slurry-based and manure-based major carp culture, aquatic weed-based aquaculture, catfish farming in small and shallow ponds, low-density monoculture of giant freshwater prawns, and fish farming in paddy fields.

Dr Dilip Kumar, in his article Making Fisheries and Aquaculture More Relevant to Rural Development, argued that integrating aquaculture into agriculture and rural development would have a multiplier effect, including reducing input costs. Dr Radheyshyam noted that nearly 40% of global aquaculture production comes from small-scale extensive systems. In India, most fish production also comes from fish farming in remote rural areas[1].

Padma Shri Dr M. Vijay Gupta stated that development must be sustainable and should not compromise environmental integrity. To achieve this, the survival of smallholder farmers must be ensured, as much of aquaculture is smallholder-based[2]. Dr N. Sarangi and Dr J. K. Jena highlighted that freshwater aquaculture in India is mostly practiced by small and medium-scale farmers. It relies on low to moderate inputs, particularly organic-based feed and fertilisers. They emphasised the use of biofertilisers and processed organic materials, which should be encouraged in aquaculture systems[3].

Over the past decade, several fish farmers have reported that profit margins are gradually declining due to rising input costs. This article discusses various freshwater and brackish water aquaculture practices relevant to small and medium-scale fish farmers in both nearby and remote villages of West Bengal. It focuses on the use of non-conventional feed additives such as date palm molasses, yeast, and the disinfectant and oxidiser potassium permanganate ($KMnO_4$) in fish culture ponds. These approaches follow organic principles in both agriculture and aquaculture.

These farmer-friendly techniques avoid expensive commercial fish feed, aquaculture products, and high-cost inputs. The farmers use $KMnO_4$ judiciously and do not engage in intensive or industrial aquaculture. The information presented here is based on data collected over the past ten years from fish and shrimp farmers across different districts of West Bengal.

Methods to increase plankton production as food for farmed fish

In villages across West Bengal, many fish farmers use yeast and date palm molasses to enhance zooplankton production in aquaculture ponds. Date palm molasses is a non-crystalline, unrefined, and non-distilled sugar derived from the sap or juice of date palm plants. It contains a high amount of sugar and appears as a thick, sticky, dark syrup. The by-product of commercially produced date palm jaggery is also considered a form of date palm molasses.

Dr B.K. Mahapatra has recommended a formulation to promote phytoplankton growth in fish ponds. For every 40 m^2 of pond area, farmers should apply:

- 100 g mustard oil cake (soaked in pond water for 3–4 days)
- Small amounts of water-soaked diammonium phosphate (DAP) and urea

For increasing zooplankton production in the same area, the following mixture should be used:

- 100–150 g mustard or groundnut oil cake
- 120 g rice polish or rice dust
- 200 g wheat flour
- 100 g date palm molasses
- 10 g Aqua-Yeast

The mixture should be placed in a closed, drum-like container, with pond water added at a ratio of 6–7 times the mixture volume. It should be left to ferment for 4–5 days. To ensure proper fermentation, the liquefied mixture should be stirred daily with a wooden stick after opening the lid.

On the 5th or 6th day, half of the fermented mixture should be diluted with pond water and applied to the pond surface. The remaining half should be applied in the same way the following day.

For every 40 m^2 of fish pond area, a mixture should be prepared in a large plastic bucket using:

- 5 litres of lukewarm water
- 5 g dry yeast

Mixture of GNOC, date palm molasses and yeast.

Mixture of date palm molasses, mustard oil cake and yeast.

Settled fermented mixture for zooplankton growth in pond.

- 50 g date palm molasses
- 200 g wheat flour or rice bran

The mixture should be thoroughly stirred, covered with a polythene sheet, and left for 24 hours. After this, it should be diluted with pond water and applied to the water surface. On the 12th day, half of this mixture is prepared and applied.

The full mixture is applied again on the 25th day, and this process continues throughout the culture period to maintain sufficient zooplankton production (Courtesy: Shakib Agrotech Ltd.).

Good-quality yeast from a reputable brand can be activated on-site by dissolving it in lukewarm water for 5–10 minutes, along with a small amount of sugarcane jaggery, date palm molasses, or sugar.

Instead of costly, feed-intensive aquaculture used in high-tech systems by resource-rich entrepreneurs, many small-scale farmers focus on maintaining natural plankton populations in culture ponds. This approach reduces reliance on expensive commercial feeds while ensuring a steady supply of planktonic organisms for fish growth.

As a post-stocking grow-out pond management measure, a mixture of urea and triple superphosphate is applied at the correct dosage every 15 days to sustain phytoplankton productivity. For sustained zooplankton production, a mixture can be prepared for every 40 m² of water area using:

- 100 g mustard oil cake
- 150 g rice bran
- 50 g date palm molasses
- 5 g yeast

This mixture should be fermented for 72 hours in a drum and applied in major carp ponds every 12–15 days after dilution (Courtesy: Fish and Fisheries, J. Banik, Upa-Zilla Fisheries Officer, Kumilla, Bangladesh).

Several indigenous formulations used successfully by farmers in West Bengal to enhance plankton production are described below.

Indigenous formulations for plankton enhancement

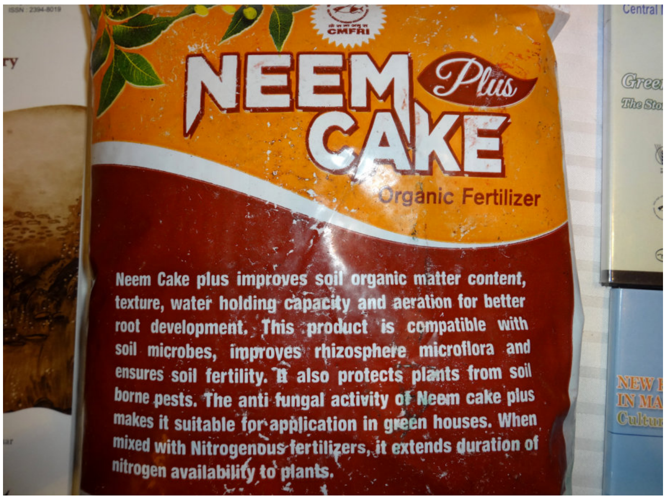
1. Zooplankton enhancement in grow-out carp culture: For every 1,320 m^2 pond, mix:

- 4 kg date palm molasses
- 7 kg mustard oil cake
- 150 g yeast

Prepare the mixture in a polythene-lined earthen pit (1.8 m × 1.2 m × 0.3 m) on the pond embankment and add water. Leave undisturbed for five hours, then apply the supernatant fluid to the pond. This significantly enhances zooplankton populations in grow-out carp ponds.

2. Fermented feed application in indian major carp culture: For every 3,840 m^2 pond, prepare a mixture of:

- 100 kg groundnut oil cake
- 10 kg sugarcane or date palm molasses



Neem cake as organic fertiliser (Courtesy ICAR-CMFRI).

Bags of sundried poultry manure for pond application.

Hygienic poultry litter for application in fish pond.

- 500 g yeast

Allow to ferment and apply in six portions over the first six days after stocking carp fingerlings. Repeat the process on the 13th–18th day in the same manner.

3. Enhancing beneficial bacteria and phytoplankton in *Macrobrachium rosenbergii* farming:

For every 1,000 m^2 pond, mix:

- 250 g yeast
- 3 kg rice polish or rice dust
- 1.5 kg date palm molasses
- 2 kg fish meal

Add 1 litre of water and leave undisturbed in a dark room for three days. Apply one-third of the liquid on the first day of juvenile stocking and the remaining two-thirds on the second day. Repeat every 15–21 days throughout the culture period. This reduces feed and medicine costs in fish, prawn, and shrimp culture.

4. Plankton enhancement in composite fish culture: In a small concrete cistern, ferment a mixture of:

- 25 kg rice bran
- 10 kg date palm molasses
- 250 g yeast

Apply this mixture to 10,000 m^2 of water, repeating three times at one-month intervals for sustained plankton production.

5. "Organic juice" for *Clarias batrachus* broodstock ponds: For every 1320 m^2 pond, prepare:

- 7 kg pulverised whole paddy grains
- 4 kg date palm molasses
- 500 g yeast

Add 4–5 litres of water and ferment for three days. Broadcast the concentrated liquid once every 15–20 days to significantly increase zooplankton populations.

6. Plankton enhancement and ammonia reduction in fish ponds: For every 40 m^2 fish pond with a water depth of 0.9–1.5 m, apply:

- 70–100 g date palm molasses diluted with water
- Apply for two days each week throughout the culture period.

This improves pond productivity, enhances plankton populations, promotes fish growth, and helps reduce ammonia levels.

7. Plankton production in *Penaeus vannamei* culture ponds: For every 1,000 m^2 pond, apply a mixture of:

- 250 g yeast
- 3 kg rice bran
- 1.5 kg date palm molasses
- 2 kg fish meal

Liquefied mixture of GNOC and soyabean dust as feed for carp spawn.

Dust-type home-made feed for major carp spawn.

Fermented fish feed containing GNOC, mustard oil cake, yeast and other ingredients.

Apply every 15 days to maintain plankton levels.

8. Fermented organic slurry for *Macrobrachium rosenbergii* culture: To prepare a slurry for every 1,320 m^2 pond:

- 5 kg date palm molasses
- 10 kg rice bran
- 250 g yeast
- 150 g commercial probiotic bacteria

Add 200 litres of water, artificially oxygenate, and allow partial decomposition for 12–18 hours. Apply before stocking prawn juveniles (3–5 cm size).

9. Fermented feed for *P. vannamei* post-larvae: For every 1,000 m^2 pond, prepare a mixture of:

- 750 g rice polish
- 350 g wheat flour byproduct
- 500 g date palm molasses
- 100 g limestone powder
- 15 ml soy sauce
- 200 g baking soda ($NaHCO_3$)
- 100 g commercially available probiotic

After controlled fermentation, the juice portion is fed to 20-day-old *P. vannamei* post-larvae.

10. Fermented nutrient mixture for major carp culture: For every 1,000 m^2 pond, mix:

- 3 kg groundnut oil cake
- 2.5 kg rice bran or rice dust
- 3 kg date palm molasses
- 500 g yeast powder

Add sufficient water, dilute, cover, and ferment for three days before applying in major carp ponds.

11. Organic juice for plankton bloom in brackishwater shrimp ponds: For every 10,000 m^2 pond during the pre-stocking phase, prepare an organic juice mixture with:

- 60 kg paddy flour
- 20 kg date palm molasses
- 3 kg yeast
- 200 litres of freshwater

Incubate the mixture in an airtight container for 48 hours Apply on the 6th day after bleaching powder application and on the 2nd day after dolomite application to stimulate plankton bloom. Repeat the process three times, at three-day intervals[4].

12. Zooplankton enhancement in composite fish culture ponds: In some composite fish culture ponds, *Cirrhinus mrigala* consumes large amounts of zooplankton, reducing availability for *Catla catla*.

To boost zooplankton production, prepare a mixture of:

- 250–500 g yeast
- 250–500 g sugar
- A small amount of finely pulverised wheat flour
- 15–20 litres of lukewarm water

Let the mixture sit undisturbed for 12 hours, then apply to the pond.

13: Organic juice for *P. vannamei* productivity improvement: Shrimp farmers M. Karuna Raju and Krishnam Raju from Bapatla, Guntur, Andhra Pradesh, use fermented rice bran and soya in *P. vannamei* culture. This practice improves water quality, phytoplankton, and zooplankton production, increasing *P. vannamei* survivability by 20%.

14: Soap and mustard oil treatment in *Pangasianodon hypophthalmus* nursery ponds. A mixture of LifeBuoy soap and mustard oil is used in nursery ponds. The fat content in mustard oil enriches zooplankton populations while the soap kills predatory aquatic insects. Preparation method:

- Soap is first boiled in a large iron vessel over a furnace.
- Mustard oil is then added.
- For every 1,320 m pond, apply a mixture of:
- 5 kg soap
- 15 kg mustard oil
- Apply 48 hours before spawn stocking.

These low-cost, farmer-friendly formulations help improve zooplankton production, pond productivity, and shrimp survival rates, reducing reliance on expensive commercial inputs.

Preparation of farm-made fish feed using yeast and/or molasses

Yeast are microscopic single-celled fungi widely used in aquaculture. Studies suggest that 5% brewer's yeast supplementation serves as a useful protein source for carp aquaculture[5]. It also acts as an immunostimulant and enhances probiotic development in feed. Yeast-based formulated fish feed is highly digestible and is sold in 500–1000 g packets in its dormant state.

Farmed air-breathing catfish (*Clarias batrachus*) are typically fed a mix of animal- and plant-based ingredients. Common animal-based ingredients include fish meal, small trash shrimp meal, semi-boiled chicken entrails, mussel meat, and dried silkworm pupae. Plant-based ingredients include rice bran, soybean dust, and groundnut oil cake. These ingredients are combined in different ratios depending on the stage of culture: a 1:3 animal-to-plant ratio in the first month, 1:1 in the second month, and 3:1 from the third to the sixth month.

An improved *C. batrachus* feed formulation has been developed that includes 60% fish meal, 15% roasted soybean meal, 10% groundnut oil cake, 3% baker's yeast, 2.5% sunflower oil, 2.5% cod liver oil, 4.5% starch, 2.5% vitamin-mineral mix, and 0.5% feed attractants such as methi (*Trigonella foenum-graecum*) and root dust of Ekangi herb (*Hedychium spicatum*). This mixture is partially decomposed under controlled conditions before being applied in ponds.

Fermentation enhances the nutritional value of feed ingredients. Instead of using dry formulated feed, some farmers prefer to mix yeast into feed to facilitate controlled fermentation, which improves digestibility and enhances probiotic activity. Dr Dilip Kumar has identified the development of cost-effective and efficient fish feed with minimal reliance on fish meal as a priority for aquaculture. He also emphasised the need for detritus- and primary productivity-based low-cost aquaculture systems for rainfed, undrainable ponds[6].

For pond applications, fish farmers may use 500–1000 g of high-quality yeast along with molasses or jaggery. For direct feed application, yeast can be used at a rate of 2–3 g per kilogram of fish feed (Courtesy: R. Kumar, PVR Aqua Farm). Fermented feed should not be applied daily or weekly to major carps and other fish in culture ponds. Instead, it should be used once or twice a month.

To prepare a fermented feed supplement for a pond where 10 kg of supplementary fish feed is scheduled for daily application, farmers add 1,000–1,500 g of date palm molasses and 100–150 g of yeast to the feed. The yeast, purchased in its dormant form, is first mixed with lukewarm water and left undisturbed for 30 minutes to activate. Once activated, an equal amount of pond water is added, and the mixture is stirred thoroughly. It is then left uncovered for 48 hours to allow fermentation before being applied over the pond surface (Courtesy: AM Aqua Farm).

Sample farm-made pelleted feed for major carps.

Fish farmer applying fish feed as moist dough ball.

Farmers in West Bengal have developed various low-cost, farm-made feed formulations that have been successfully used in major carp and finfish culture. These formulations enhance fish nutrition while reducing dependence on expensive commercial feeds.

1. Feed for *Pangasianodon hypophthalmus* seed rearing

A mixture of 50 kg groundnut oil cake, 40 kg finely pulverised shrimp feed, and 40 kg Agri-Min feed supplement is partially composted in cement cisterns. It is applied at 7–8 kg per 2,600 m^2 nursery pond.

2. Indian major carp feed

The feed contains 8–10% powdered green leaves of *Leucaena leucocephala*, *Terminalia arjuna*, blackberry, and *Heritiera fomes* (dried under shade), along with 15% paddy dust, 15% wheat flour or rice dust, and 30–35% oilcake (from coconut, sunflower, linseed, flaxseed, or mustard).

15–20% fish meal, 5–10% husk of *Lathyrus sativus* or moong pulses, 2% turmeric powder, 2% neem (*Azadirachta indica*) leaf powder, and 1% common salt are also added.

Rice bran, mustard oil cake, date palm molasses, and baker's yeast powder are mixed, pulverised to 100-micron particle size, and fed to growing spawn and fry.

3. Supplementary feed for *Penaeus monodon* in brackish-water ponds

The formulation includes 325 g molluscan meat, 325 g trash shrimp meal, 1,335 g maize dust residue, 1335 g wheat starch (gluten protein), and 20 g each of date palm molasses, palm oil, cod liver oil, and vitamin-mineral mix.

4. Fermented feed for Indian major carps

For every 10,000 m^2 water body, a feed mixture of 20 kg mustard oil cake and rice bran (combined), 10 kg date palm molasses, and 500 g baker's yeast is partially fermented for three days and applied once every 15 days.

A low-cost major carp feed is also prepared using black gram pulses, rice bran, wheat bran, pulverised mustard oil cake, flaxseed oil cake, vitamin-mineral mix, and date palm molasses.

5. Farm-made feed for *Pangasianodon hypophthalmus* in grow-out ponds

This formulation consists of partially insect-affected gram and peas, deoiled rice bran, broken rice, broken wheat grains, maize dust, inferior-quality pulses, sugarcane jaggery, and fat-eliminated pulverised silkworm pupae, all boiled before application.

6. Indian major carp feed with date palm molasses

This feed includes 25% wheat bran, 30% rice bran, 25% pulverised mustard oil cake, 10% fish meal, and 10% date palm molasses.

7. Alternative feed for major carps

Another method, prepared using deoiled rice bran, pulverised groundnut oil cake, maize dust, soybean dust, and date palm molasses in a 20:4:2:1:0.5 ratio, with a small amount of vitamin-mineral mix.

8. Partially decomposed feed for composite fish culture ponds

For every 1320 m^2 pond, a mixture of 15 kg wheat flour byproduct, 5 kg groundnut oil cake, 10 kg mustard oil cake, 2 kg inferior-quality soybean dust, and 50 g yeast is used.

The mixture is liquefied in earthen cylindrical containers (0.6 m diameter) by adding four bucketfuls of water and left to decompose for 7–8 days before application. This method has been reported as beneficial by a fish farmer.

Compost manure, vermicomposting, and integrated fish farming

Padma Shri Dr S. Ayyappan, in his article Fish for All Forever, highlighted the integration of freshwater aquaculture with other farming systems and the recycling of organic matter as key potential areas. In many villages across West Bengal, fish farmers prepare compost mixtures to enhance pond fertility. A standard 100 kg compost pile consists of 25 kg cow dung, 5 kg mustard oil cake, 20 kg water hyacinth ash, 25 kg agricultural lime, 10 kg submerged aquatic weeds, and 15 kg thick pond bottom sediment (silt). The materials are placed in a rectangular pit on the pond embankment under anaerobic conditions, ensuring that sunlight does not enter. After 30 days, water is added, and the pit is covered for another 3–4 days before the compost is liquefied and applied to fish ponds at a rate of 600–800 kg per 10,000 m^2 per month.

This method improves pond bottom soil fertility by supplying organic carbon, nitrogen, phosphorus, and potassium. The decomposition process eliminates harmful microorganisms, making nutrients readily available. Application of water hyacinth ash has also been observed to increase populations of *Moina* sp. zooplankton in ponds.

Pit for compost preparation on pond embankment.

Good quality compost fertiliser for pond application.

A view of poultry house built partially over pond.

In some cases, compost is prepared in small pits (1.5–1.8 m deep) dug on the pond slope. Over a 20-day period, a mixture of finely chopped green grass, leaves, vegetable peel-offs, fresh water hyacinth, submerged aquatic weeds, and raw cow dung (in equal proportion to water hyacinth) is used. A small amount of mustard oil cake is added, while common salt is included to kill fungus and lime to neutralise acidity. Water is added every 2–3 days to maintain proper moisture levels.

Composted water hyacinth has shown good results in newly excavated deep ponds created using JCBs and dredgers. The water becomes greenish due to increased plankton abundance. Before stocking carp fingerlings, 60–70 kg sun-dried water hyacinth (dried for 6–7 days), 10–20 kg cow dung or mustard oil cake, and 2–3 kg urea are layered in a rectangular pit under anaerobic conditions for 15–25 days. This process yields high-quality compost, which is then applied to the pond.

In grow-out major carp culture, *Labeo rohita* and *Cirrhinus mrigala* feed on partially decomposed plant-based organic matter, decomposing algae, detritus, and high-quality compost fertiliser from the pond. Compost should be provided in controlled amounts to promote proper fish growth.

Scientific discussions on integrated fish farming have extensively covered livestock-fish integration, vermicomposting, paddy-cum-fish culture, and treated domestic wastewater-based fish farming. These methods form the livelihood base for small- and medium-scale fish farmers in West Bengal. Many farmers have successfully adopted economically viable, scientifically validated, and refined techniques suited to their conditions.

Fish farmers possess strong indigenous technological knowledge, which, when combined with modern aquaculture principles, has proven to be highly effective. Elderly fish

Small poultry house on the bank of fish pond.

farmers engaged in small- and medium-scale aquaculture have developed innovative stocking, pre-stocking, and post-stocking methods, often leading to new, productive practices.

As a low-cost input, vermicompost has been used for fertilisation in shrimp culture ponds. It is prepared using hay, leaves of mangrove plants, kitchen waste, neem (*Azadirachta indic*a) leaves, pre-composted (aged) manure, and the earthworm species *Eisenia foetida*. It is applied at 200–500 kg per 10,000 m^2, with additional doses if necessary[7].

Approximately one million earthworms of selected varieties can convert 120,000 kg of organic matter into high-quality manure within 25 days. Typically, 1 m^3 of waste weighs around 500 kg and requires 4,000–5,000 epigeic earthworms for composting. The role of earthworms in sustaining soil productivity through organic waste recycling as vermicompost has been extensively studied[8].

Integrated farming systems involving fish and other livestock provide optimal resource use while generating continuous and increased income. Demonstrations and practical experiences indicate that farmers adopting integrated systems have seen income increases of 4–6 times[9]. Recycling by-products from farmed animals, including poultry and ducks, reduces costs and improves fish production efficiency.

In a fish-cum-poultry integrated farming system, 100 poultry birds consume 9 kg of dry *Azolla* daily, reducing poultry feed costs by 25%. From an initial 5 kg *Azolla* seed stock, up to 2,500 kg can be harvested in one month from every 1,320 m^2 pond. *Azolla* functions as both green manure and a nutritious feed for birds and fish.

In every 1,320 m^2 composite fish culture pond, 25 grass carp (*Ctenopharyngodon idella*) weighing 250–500 g are stocked to supply organic manure. These fish are fed 10–20 kg of green leaves or submerged soft aquatic weeds daily. Their faeces enhance pond fertility and serve as direct food for common carp (*Cyprinus carpio*) and *Labeo bata*, supporting nutrient recycling within the pond ecosystem.

Poutry-cum-fishery integrated farming system.

Small house for ducks on pond embankment.

Vermicompost chambers at ICAR-CIFA, Bhubaneswar.

Vermicast produced with epigeic earthworms.

Major carp and giant prawn polyculture for increased income

Giant freshwater prawn (*Macrobrachium rosenbergii*) has been successfully integrated into major carp grow-out culture systems in the Indian Sundarbans region, particularly in South 24 Parganas district. This polyculture system is practiced in ponds and canals in village areas. Post-larvae and juvenile prawns, used as stocking material, are readily available in tidal rivers across Kakdwip, Canning, and Diamond Harbour sub-divisions. These natural populations are harvested sustainably.

The introduction of *M. rosenbergii* into carp culture improves production, as the prawns, being bottom-dwelling, help clear unwanted residues from the pond bottom. This keeps pond conditions more favourable for carp growth. Market demand and pricing for *M. rosenbergii* in local markets are significantly higher than for *Cirrhinus mrigala* and *Cyprinus carpio*, which are not included in these polyculture ponds. Farmers reported that income from this system was more than double that obtained from major carp culture alone (Courtesy: Ramkrishna Ashram KVK, Nimpith). Prawns can be fed home-made feed prepared using green coconut flesh and other locally available ingredients.

Relevance of potassium permanganate to inland aquaculture

The severe cyclonic storms Amphan (May 19–20, 2020), Bulbul (November 9–10, 2019), and Yaas (May 25–26, 2021) caused significant damage to aquaculture in the coastal districts of West Bengal, including South 24 Parganas. Many freshwater and brackishwater ponds were affected due to tree branches falling into the water, fish deaths, and organic matter decomposition, leading to severe water quality deterioration.

As an immediate remedial measure, the District Magistrate of South 24 Parganas and the West Bengal Department of Fisheries distributed potassium permanganate and lime to affected fish farmers in brackishwater and marine zones.

Apart from controlling harmful microorganisms in pond water, potassium permanganate can also destroy phytoplankton and zooplankton populations, a phenomenon known as “plankton crush.” Due to this effect, it should be applied carefully in recommended doses over pond water, particularly in grow-out fish ponds during winter. Application is done in highly diluted form as a disinfectant or microbicidal treatment, typically in the early morning or late evening after sunset. The general dosage is 0.8–1 mg/litre or 8–10 kg per 10,000 m^2 as a prophylactic treatment.

The different uses of potassium permanganate in aquaculture are presented in the adjacent table.

A probiotic formulation enriched with effective microorganisms has been developed for use in major carp culture ponds. It helps eliminate ammonia buildup, reduces toxic gas accumulation at the pond bottom, and prevents oxygen depletion. The formulation also promotes fish growth and stabilises pH levels during both summer and winter months.

Application of duckweed in pond as fish feed.

To prepare the probiotic mixture, a 50-litre water drum is filled with 3 kg ripe papaya, 3 kg ripe pumpkin, 3 kg ripe banana, 1 kg date palm molasses, and one poultry egg. After thorough mixing, 10 litres of water is added, and the drum is sealed airtight. It is left undisturbed for 22 days, with the lid briefly opened for five minutes daily to release accumulated gases and allow beneficial bacteria to grow. This preparation is intended for every 4,000 m^2 water body.

After 22 days, the fermented mixture is diluted with 100 litres of water and 3–5 kg of date palm molasses, then applied to the pond surface during the daytime (Courtesy: Dr S. Bala, Iti Katha Research Centre).

For a 400 m^2 pond, a separate probiotic mix can be prepared using 3 kg mustard oil cake, 1 kg urea, 1 kg single super phosphate (soaked overnight), 1 kg wheat flour, 2 kg wheat flour byproduct, 500 g sodium chloride, and date palm molasses. After 24 hours of fermentation and dilution, it can be applied in freshwater finfish culture ponds. This is a low-cost and effective method for producing natural fish food organisms (Courtesy: Bala Fisheries, Jessore, Bangladesh).

End Note

On 16 August 2024, the Government of India announced the launch of Kisan ki Baat, a monthly radio programme aimed at disseminating scientific knowledge to farmers. The initiative is designed to modernise agricultural practices and equip farmers with the latest scientific information. Since the Indian farming community largely consists of small and marginal farmers, participatory research can help them generate and adapt appropriate technologies on-farm[10].

To ensure long-term sustainability, aquaculture must follow extensive or semi-intensive farming methods. These approaches are low-cost, sustainable, and economically viable[11]. Rural fish farming in West Bengal relies heavily on natural plankton production and home-made feed, reducing dependence on expensive commercial products. Farmers have transitioned towards modified-extensive, environment-friendly fish and prawn farming, which provides satisfactory to highly satisfactory returns.

Table 1. Applications of potassium permanganate in aquaculture.

Aim of Use	Dosage of $KMnO_4$	Duration of Treatment	Method
Cure ulcer-type bacterial disease in major carps	1 ppm or 10 kg per 10,000 m^2	-	Applied in pond water (depth: 1.0–1.2 m)
Kill crustacean ectoparasites *Argulus* sp. and *Lernaea* sp. in pond	4 ppm or 40 kg per 10,000 m^2	-	Applied in pond water
Cure dropsy disease in carps at its initial stage	5 ppm or 5 mg/litre	Dip treatment for 1–2 minutes	Used in a 1,000-litre cement tank
Cure ichthyophthiriasis and kill protozoan parasite *Ichthyophthirius multifiliis* in carps	10 ppm or 10 mg/litre	Bath treatment for 5 minutes	Used in a 1,000-litre cement tank
Kill crustacean ectoparasites *Argulus* sp. and *Lernaea* sp. on fish body	10 ppm or 10 mg/litre	Dip treatment for 40 seconds	Used in a 1,000-litre cement tank
Kill fungus *Saprolegnia* sp. and cure fungal disease in carps	10 ppm or 10 mg/litre	Bath treatment for 15 minutes	Used in a 1,000-litre cement tank
Quick increase in dissolved oxygen content in pond	15–20 g $KMnO_4$ + 5–7 kg soil + 50–100 g common salt	Every 1,000–1,320 m^2 pond (depth: 1.0–1.2 m)	Applied at 3–4 places in the pond
Treatment of unhygienic pond bottom soil	Sand + 700–750 g $KMnO_4$ + 5 kg limestone powder	Every 1,000 m^2 pond	-
In conditions of dissolved oxygen scarcity	175–200 g	Every 1,320 m^2 pond	Solution prepared and applied over the water surface
Eradicate smell of rotten eggs from pond bottom	250–350 g	Every 1,320 m^2 pond	-
Cure ulcer-type bacterial disease in major carps	20 g $KMnO_4$ + 20 g copper sulphate + 2 kg garlic + 2 kg common salt	For diseased fish in every 1,320 m^2 pond	Paste prepared, 35–45 litres of water added, spread in all parts of the pond
Prophylactic treatment of apparently healthy major carps	250–300 g	For fish in every 1,320 m^2 composite fish culture pond, once in 30–45 days	Fish drag-netted to one side, $KMnO_4$ solution poured over fish, released after 2–4 minutes

Fish farming is no longer considered a subsistence-level activity but a profitable small- to medium-scale venture. While some elderly villagers continue using backyard ponds for secondary income or household nutrition, most small- and medium-scale fish farmers in West Bengal have moved away from traditional, non-scientific methods. Over the past 10–12 years, they have adopted improved aquaculture techniques, actively seeking technical guidance from trainers and experts.

Young entrepreneurs and new entrant farmers, as termed by Peter Edwards, are increasingly interested in farming high-value freshwater and brackishwater fish in both indoor and outdoor systems. Their preference for major carps is decreasing, and when they do stock them, they prefer stunted fingerlings of 100–200 g instead of the traditional 15–40 g fingerlings.

Experienced fish farmers aged 45–70 years, either independently or as part of primary fishermen cooperative societies, strictly follow scientific, hygienic, and improved grow-out farming methods. They focus on reducing production costs by supplementing plankton-rich pond environments with farm-made formulated feed. Unlike older practices that relied solely on natural plankton, they now use moist dough balls and pelletised farm-made feed, avoiding the need for expensive factory-manufactured pelleted feed.

A cost-saving practice in village aquaculture involves allowing cooked rice to ferment overnight in water stored in aluminium vessels. A slightly sour aroma develops by morning, and cone-shaped dumplings obtained from local Santhal tribal households are added to the soaked feed as a feed attractant. The mixture is fed to major carps within 24–36 hours. Since profit margins in small-scale aquaculture are narrow, such cost-cutting measures significantly improve economic viability, as observed across Asia.

Regardless of scale, fish farmers must adhere to Good Aquaculture Practices to ensure that only healthy, unadulterated fish reach consumers. Whether farming Indian major carps, all-male tilapia, *Pangasianodon hypophthalmus*, or air-breathing catfish, fish must be grown, harvested, transported, and marketed in a safe and hygienic manner.

Consumers today are well-informed and highly conscious of food safety. They expect to purchase pure, high-quality fish from trusted local markets. Maintaining consumer confidence is essential to ensuring continued demand and profitability in the sector.

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Small-scale feed production unit at home of fish farmer.

Food and feeding habits of some peninsular carps

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Carps contribute significantly to global freshwater fish production. In India, the main aquaculture species include catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), and silver carp (*Hypophthalmichthys molitrix*). Several indigenous carps are also in high regional demand. These include fringe-lipped carp (*Labeo fimbriatus*), calbasu (*Labeo calbasu*), kuria labeo (*Labeo gonius*), bata (*Labeo bata*), reba (*Labeo ariza*), pig-mouth carp (*Labeo kontius*), pulchellus (*Hypselobarbus pulchellus*), kolus (*Hypselobarbus kolus*), and Carnatic carp (*Barbodes carnaticus*). Studies have shown that some of these species are compatible with major carps in polyculture systems. Integrating them into polyculture with Indian major carps could enhance productivity and increase farmers' income.

Small-scale farmers manage limited resources carefully to minimise risk. Using indigenous fish species can lower input costs and reduce financial risk in aquaculture. These species grow more slowly than commercial carps, making them more suitable for household consumption rather than large-scale retail. Their use could also help conserve biodiversity. Peninsular carps have high potential due to their ability to utilise natural productivity, reducing the need for additional feed. Suitable species for small-scale water bodies include *Hypselobarbus pulchellus*, *Barbodes carnaticus*, *Labeo fimbriatus*, *Labeo calbasu*, and *Labeo kontius*. Research (DFID, 1998) has identified *Labeo* species as the best candidates for low-input culture in small water bodies.

Studies on the food and feeding habits of animals are essential for understanding growth, migration, reproduction, and seasonal changes in body condition. Assessing the diet of fish helps determine their habitat and preferred food sources. Observing feeding habits alongside species composition also provides insights into competition for food among different populations.

Basic knowledge of a species' diet and feeding behaviour is crucial for assessing its suitability for aquaculture. It helps identify compatible species for culture systems, minimising interspecies competition for natural food (Anon, 2001). This information is also useful for developing supplementary feeds. This study compiles and summarises existing literature on the feeding habits of some peninsular carps, whose breeding technology has already been standardised.

Hypselobarbus pulchellus (Day, 1870)

Hypselobarbus pulchellus, a member of the family Cyprinidae, was once an important fishery species in peninsular India. However, it has been classified as 'Critically Endangered' (possibly Extinct) on the IUCN Red List of Threatened Species. Previously known as *Puntius pulchellus*, *Barbus pulchellus*, or *Barbodes pulchellus*, it was later reassigned to the genus *Hypselobarbus*.

This bentho-pelagic species inhabits the deeper sections of large streams and rivers along the base of the Western Ghats. It can grow up to 8 kg, making it a suitable candidate for composite fish culture. Including *H. pulchellus* in aquaculture could help diversify production while supporting conservation efforts. Juveniles and adults feed on filamentous

Hypselobarbus pulchellus

algae, aquatic weeds, grass, and water hyacinth roots, making them a potential alternative to grass carp. Although primarily herbivorous, *H. pulchellus* adapts its diet based on food availability.

David and Rajagopal (1975) studied the food and feeding habits of *Hypselobarbus pulchellus* using gut samples from 123 specimens ranging from 250 mm to 745 mm in length. They observed that the fish is primarily herbivorous, consuming a high proportion of vascular plants such as *Chara*, *Vallisneria*, *Hydrilla*, and *Ceratophyllum* species. *Chara* was the dominant food source, accounting for 18.8% to 66.25% of the diet. *Vallisneria* made up 35% of the diet in April and 12.55% in January and November. *Hydrilla* was present in January (35%), February (22.7%), March (16.2%), and November (9.2%).

Decayed tissues of aquatic plants and grass blades were more abundant in the diet during the post-monsoon period, peaking in August (62.5%), September (30%), and October (45.65%), with lower quantities in other months. Among animal components, *Paramecium* species were found in all months except January and May. Gastropods (*Vivipara* and *Pila* species) were more common when water levels were low, making up 21% of the diet in April and 45% in May. Insects and worms were nearly absent. *H. pulchellus* showed no significant correlation between its diet and plankton availability.

David and Rahman (1975) further studied the diet at different growth stages. Fry measuring 18 mm to 22 mm fed on zooplankton, diatoms, protozoa, and insect remains. Fish between 30 mm and 50 mm consumed decaying leaves, filamentous algae, and diatoms. As the fish grew, the proportion of higher plants in the diet increased. Adult specimens from tanks were found to consume aquatic plants along with small molluscs.

Gut length analysis from fry (18 mm, 34 mg) to adults (665 mm, 5.50 kg) indicated a gradual increase in gut length proportional to body size. The diet shifted from soft algae in early stages to tougher vegetation in adulthood. As an exclusive feeder on vascular plants, *Vallisneria*, *Hydrilla*, and *Chara* dominated its diet in the region of capture. Epiphytic diatoms were consumed incidentally, while small gastropods were an obligatory food source during low water levels in summer.

Basavaraja (2014) observed that captive *Hypselobarbus pulchellus* in farm conditions accepted Napier grass in addition to artificial floating feed. Studies by Barlaya et al. (2022) showed that dried meal of *Azolla* species and *Vallisneria* species could be incorporated into the diet at levels of up to 60% and 30%, respectively, for fingerling rearing.

***Barbodes carnaticus* (Jerdon, 1849)**

Barbodes carnaticus (syn. *Puntius carnaticus*, *Barbus carnaticus*), commonly known as Cauvery or Carnatic carp, is an endemic and threatened species of the Western Ghats. It has been reported from rivers in Kerala, Tamil Nadu, and Karnataka. This species has an elongated, stocky body and grows larger than other members of its genus. In natural waters, it can reach a maximum weight of 12 kg and a length of 60 cm.

The species exhibits rapid growth in its first year, making it a strong candidate for freshwater aquaculture. It is also valued as a sport fish. *B. carnaticus* prefers large pools in rivers and streams, where adults tend to hide under bedrock, boulders, and inside caves. The species feeds on fruits and seeds that fall from the canopy. Its sub-terminal mouth is adapted for column feeding (Gupta et al., 1999).

Manojkumar (2008) studied the food and feeding habits of this species. The study examined 904 specimens, including 262 males (232–430 mm total length), 150 females (270–472 mm total length), and 480 indeterminate individuals (52–227 mm total length). The species has a relatively long gut, with a relative gut length ranging from 2.1 to 4. Junger et al. (1989) classified cyprinids with a relative gut length of 2 or more as herbivores. However, in *B. carnaticus*, the intestine is elongated and coiled, indicating an omnivorous diet with a preference for plant matter.

Barbodes carnaticus

Gut content analysis showed that *Barbodes carnaticus* consumed semi-digested plant matter (30–32%), filamentous algae (17–19%), diatoms (12–16%), semi-digested animal matter (18–26%), and seeds (3–12%). Miscellaneous material, including sand, accounted for 5–8% of the diet. Manojkumar (2008) classified the species as a herbi-omnivore, as plant material made up more than 50% but less than 80% of its diet. The species exhibited a voracious feeding habit, with a full gut recorded in most months of the study.

Semi-digested plant matter included leaves, roots, and stem fragments. Seeds were found in specimens from riparian zones. Filamentous algae regularly present in the gut included *Spirogyra*, *Ulothrix*, *Schizogonium*, *Calothrix*, *Bulbochaete*, and *Hormidium*. Molluscs such as *Pleurodiscus* and the unicellular ciliate *Uronema* were also recorded. Diatoms identified in the gut included *Dinophysis*, *Navicula*, *Closterium*, *Pinnularia*, *Fragilaria*, *Nitzschia*, and *Rhizosolenia*.

Semi-digested animal matter consisted mainly of insects (50–60%), including *Chironomus* larvae and pupae, *Tanypus* and *Ablabesmyia* larvae (Diptera), *Corixa* and *Micronecta* (Hemiptera), mayfly nymphs (Ephemeroptera), *Hydrophilus* larvae (Coleoptera), and dragonfly nymphs (Odonata). Remains of small fish and crustaceans were also found in the gut. Some samples contained sand.

Hypselobarbus kolus (Sykes, 1839)

The peninsular carp *Hypselobarbus kolus* (syn. *Barbus kolus*, *Gonoproktopterus kolus*, *Puntius kolus*), commonly known as the Shooting barb or Kolus barb, is endemic to the Western Ghats. It has been reported from Kerala, Karnataka, Tamil Nadu, and Maharashtra. The species is classified as 'Vulnerable' on the IUCN Red List of Threatened Species. It can reach a maximum length of 30 cm and is considered a good candidate for species diversification in composite fish culture.

H. kolus has a protrusible mouth and is euryphagic, consuming a wide variety of food. Its diet includes molluscs, insects, copepods, ostracods, diatoms, *Chlorophyceae*, grass seeds, and decaying plant matter. Studies have shown a correlation between feeding habits and food availability in the environment.

David and Rajagopal (1974) studied the food and feeding habits of *H. kolus* and found that it is not a major plankton consumer. The phytoplankton component in gut contents included Bacillariophyceae diatoms (3.5%), such as *Navicula*, *Pleurosigma*, *Diatoma*, *Synedra*, *Fragilaria*, *Surirella*, *Cocconeis*, *Gomphonema*, and *Cymbella*. *Chlorophyceae* species included *Spirogyra*, *Zygnema*, *Oedogonium*, *Mougeotia*, and *Cosmarium*. Plant matter, including decaying aquatic vegetation, grass blades, and grass seeds (35–40%), was more abundant in post-monsoon months (September and October).

The animal components in the diet of *Hypselobarbus kolus* included copepods, ostracods, insects, gastropods, and bivalves. Copepod remains consisted of appendages and crushed forms of *Cyclops*, *Diaptomus*, and nauplii stages. *Cypris* species (ostracods) were recorded in all months but in low numbers. The frequent presence of ostracods suggests that the fish browses on the gradually sloping shallow margins of reservoirs while feeding (David et al., 1969).

Insect components included chironomids, mayfly nymphs, corixid bug exoskeletons and appendages, and trichopteran larvae. Gastropods such as *Vivipara*, *Melanoides*, and *Gyraulus* (2–6 mm in size) were found in the gut. Bivalves, including *Corbicula* and *Unio* species, were also recorded.

Decayed organic matter, sand, mud, and semi-digested animal and plant tissue were present in the gut. Sand and mud were likely consumed while feeding near the bottom.

Plankton components included *Cyanophyceae* (*Oscillatoria*, *Anabaena*, *Merismopedia*, *Microcystis*), *Chlorophyceae* (*Pediastrum*, *Scenedesmus*), and *Conjugatophyceae* (*Closterium*, *Cosmarium*). Ostracod eggs, cladoceran remains, and annelid setae were also observed.

Hypselobarbus kolus

Labeo fimbriatus

Labeo fimbriatus **(Bloch, 1795)**

The fringed-lipped peninsular carp, *Labeo fimbriatus*, is widely distributed across India, Pakistan, Nepal, Bangladesh, and Myanmar. In the wild, it grows slowly, reaching a maximum length of 91 cm and a weight of approximately 3.5 kg (David et al., 1974). It is primarily herbivorous, grazing on algae, protozoa, rotifers, and diatoms that grow on submerged rocks and twigs (Talwar and Jhingran, 1991). Its ventrally positioned mouth and fimbriated horny lips make it well-adapted for bottom browsing. As a stenophagic feeder, it primarily consumes sessile epiphytic diatoms, indicating a selective feeding habit.

David and Rajagopal (1975) examined the gut contents of 190 specimens ranging from 203 mm to 636 mm in length. The diet consisted mainly of plankton. Diatoms were the dominant food source, followed by green algae such as *Spirogyra*, *Mougeotia*, and *Hormidium*. Blue-green algae, including *Oscillatoria*, *Anabaena*, and *Microcystis*, were present in very small quantities. Plant tissue was rarely observed.

Animal components made up a small fraction of the diet (0.4–3.1%), consisting mainly of copepods. Insect remains, primarily chironomid appendages, were also found in the gut contents.

The largest food component in *Labeo fimbriatus* was semi-decayed and decayed organic matter, which accounted for 37.5% of the diet. Sand and mud were also common, making up an average of 26.8% of gut contents. Miscellaneous items included lower crustacean eggs, annelid setae, and other unidentifiable material. The structure and position of the mouth, along with the presence of significant amounts of sand and mud in the gut, confirm its bottom-feeding behaviour.

Rajanna et al. (2015) conducted a study on *L. fimbriatus* in Vanivilas Sagar Reservoir, Karnataka, using 537 male and 589 female specimens. They found that gut contents consisted of 46.54% mud and sand, 20.54% diatoms, 17.13% decayed organic matter, 11.48% other algae, 3.32% semi-digested matter, and 0.98% miscellaneous material. Analysis of different size groups showed that larger fish had higher proportions of diatoms and semi-digested matter, followed by other food items.

Labeo kontius

Earlier studies (Keshavanath et al., 2002; Gangadhar et al., 2015, 2016) demonstrated that *L. fimbriatus* efficiently utilises periphyton during fry and fingerling rearing, as well as in grow-out culture.

Labeo kontius (Jerdon, 1849)

The peninsular carp *Labeo kontius*, commonly known as the pig mouth carp or Cauvery carp, is endemic to the Western Ghats. It has been recorded in rivers of Karnataka, Tamil Nadu, and Kerala. This species can be domesticated for pond culture, making it a valuable addition to aquaculture. It grows to a maximum length of 61 cm and is predominantly herbivorous. Its feeding habits vary by life stage, with adults and fingerlings feeding at the bottom and midwater levels, while spawn and fry feed near the surface (Mohanta et al., 2008).

Alikunhi and Rao (1952) analysed the stomach contents of 42 specimens ranging from 112 mm to 495 mm, collected from Hogenakkal, Mettur, Bhavani, Tanjore, and Chetput Fish Farm. Like most species in its genus, *L. kontius* is primarily a plant feeder, with animal matter making up only about 5% of its diet.

Filamentous algae and aquatic plant leaves accounted for 32.3% of gut contents. *Spirogyra* was present in 70% of specimens and constituted 10–80% of the gut contents, making up more than half of the filamentous algae consumed. *Oscillatoria* was found in 50% of specimens, contributing 3–70% of the diet. Diatoms made up 27% of the diet, with *Navicula* species alone contributing about 20%. Diatoms were almost always present, ranging from 10–60% of stomach contents.

Sand and mud were found in 80% of specimens, making up 30.5% of the average diet, though individual specimens contained between 10% and 80%. The animal component, consisting of insect parts, earthworm remains, copepods, and rotifers, accounted for only 5% of the diet. In half of the specimens, stomach contents were entirely plant-based.

The stomach contents of *Labeo kontius* indicate bottom-feeding behaviour and browsing on stones and other objects in shallow marginal areas. When consuming large quantities of filamentous algae, the fish also ingests epiphytic and embedded diatoms. Several *Navicula* species diatoms, present as both frustules and fresh cells, are found in the surface layers of bottom mud and are likely consumed during feeding.

Observations suggest that habitat influences feeding habits. Specimens from freshwater ponds had a higher proportion of planktonic algae and lower amounts of sand and mud in their gut compared to those from riverine environments. This suggests that the species adapts its diet to the available food when transitioning from lotic (flowing water) to lentic (still water) environments.

Post-larval specimens and early fingerlings reared in laboratory aquaria fed voraciously on zooplankton, including rotifers, cladocerans, and copepods. When available, they also consumed large amounts of phytoplankton, particularly *Microcystis*.

Tor khudree (Sykes, 1849)

The historic range of *Tor khudree*, the Deccan Mahseer, was restricted to the northern and central Western Ghats of India, specifically in the eastward-flowing Krishna River system and its tributaries in present-day Maharashtra, Telangana, and Karnataka. However, large-scale introductions of artificially bred fish have expanded its distribution across peninsular India, including the westward-flowing river systems originating from the southern Western Ghats (Jayaram, 2005). The species can grow up to 1.2 m in length and reach a weight of 50 kg in the wild (Froese and Pauley, 2019). It is valued for both recreational fishing and aquaculture. The ICAR-National Bureau of Fish Genetic Resources (ICAR-NBFGR) has identified *T. khudree* as a potential species for cultivation.

Biju (2003) conducted a gut content analysis of *T. khudree* using 30 specimens from the Bharathapuzha River, ranging in length from 12 cm to 31 cm and in weight from 104 g to 410 g. The study found that semi-digested animal matter (mutilated flesh from various animals) was the dominant

Tor khudree

component, making up 52.3% of the diet. Other animal components included insect larvae, fish remains (bones and scales), and crustacean remains (appendages), with respective contributions of 5.2%, 3.2%, and 0.74%. Semi-digested plant matter, consisting of broken roots, leaves, and stems, accounted for 24.95% of the diet. Other components included diatoms (7.4%), filamentous algae (1.24%), sand (0.75%), detritus (2.99%), and miscellaneous substances (1.24%).

The study classified *T. khudree* as an omnivore with a strong preference for carnivorous food. The presence of sand and detritus in the gut supports its bottom-feeding habits. According to Kulkarni (1980), although *T. khudree* consumes small fish in certain months, it primarily depends on plant material, insect larvae, and molluscs.

Tor khudree is known to be a periphyton grazer. Juvenile fish feed on materials found on the substrate, including attached algae, aufwuchs (surface growths), insect larvae, snails, and occasionally shrimps and crabs. As a result, the stomach contents of smaller individuals primarily reflect benthic organisms. Larger fish (>25 cm) also feed on the bottom layer and aufwuchs attached to rocks and boulders. They consume aquatic vegetation along with leaves, flowers, fruits, and seeds from riparian vegetation when these plant materials settle on the substrate.

Keshavanath et al. (2002) reported that *T. khudree* efficiently utilises periphyton in grow-out culture. The relative gut length increases from 1.74 to 2.55 as the fish grows up to 30 cm in total length, after which it remains nearly constant. This range indicates an omnivorous feeding habit (De Silva & Somarathna, 1994).

The Sri Lankan *Tor khudree* (yellow mahseer) has been reported to feed on a variety of food sources. Willey (1903) documented its diet, which included crabs, molluscs, and small fish. Deraniyagala (1952) observed that it also consumed algal material, freshwater molluscs, and plant matter such as leaves and flowers that fell into the water. Fernando (1965) further noted the presence of insects and higher plants in its diet.

De Silva and Amerasinghe (1995) studied the feeding habits of Yellow Mahseer using specimens ranging from 5 cm to 60 cm in length. The fish was found to consume both animal and plant matter, leading to its classification as an omnivore. However, since its diet consisted mainly of aquatic insects and their larvae, the researchers further categorized it as an insecti-herbivore. As the fish grew, its diet shifted from predominantly animal matter to a higher proportion of plant material.

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Inland saline aquaculture: Prospects and challenges

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Salinity is a major problem in many regions and is expected to worsen over the next 30 to 50 years. Most research has focused on its impact on land, particularly the loss of agriculturally productive areas. However, increased salinity can also cause significant changes in aquatic ecosystems, including rivers, streams, and wetlands.

Globally, about 953 million hectares of fertile land have reduced productivity due to high salt concentrations in the root zone. Australia has the largest area affected by salinity and sodicity, followed by Asia. Salt-affected soils and brackish groundwater are mainly found in arid and semi-arid regions, where they contribute to freshwater depletion. In India, over 273 million hectares of land have been affected by salinity and sodicity. Secondary salinisation caused by irrigation in dry areas has also increased salt levels in groundwater, further degrading freshwater resources.

In coastal Andhra Pradesh and other areas, large-scale shrimp farming with seawater has rendered approximately 0.85 million hectares of land unsuitable for agriculture. Similarly, in north-western India, 30 to 84% of groundwater is saline or brackish, making it unfit for irrigation. The use of poor-quality irrigation water has left thousands of hectares of productive land barren.

Salinity-induced land degradation is a major challenge to food and nutritional security in developing nations. A growing population is increasing the demand for water, making efficient resource use essential. Pressure is mounting to utilise all available resources responsibly to produce protein-rich food and combat malnutrition. One underutilised resource is inland saline areas, which have not been fully exploited for food production.

According to the FAO/UNESCO soil map, sodicity affects 953 million hectares, about 8% of the world's land surface. Salt-affected soils cover 42.3% of Australia's land, 21.0% of Asia's, 7.6% of South America's, 4.6% of Europe's, 3.5% of Africa's, 0.9% of North America's, and 0.7% of Central America's. Australia has the largest saline-affected area, covering nearly one-third of the continent. In India, 2.73 million hectares of land are affected by soil salinity and alkalinity. Additionally, around 25% of India's groundwater is becoming sodic. Long-term use of these water sources for irrigation has led to large-scale salinisation, further degrading freshwater supplies.

Increased irrigation in dry and semi-arid areas without proper drainage has worsened salinity problems. Many canal-irrigated regions are already waterlogged and salinised. In several irrigation districts across India, the water table is rising at a rate of 30 to 100 cm per year. The severity of this issue varies by region, depending on topography, hydrology, climate, drainage, land use, and agricultural practices.

Given the scarcity of arable land and the presence of saline groundwater, inland saline aquaculture offers a promising solution. Water management experts suggest that increasing the efficiency of existing water resources is the best long-term strategy for addressing water scarcity. Using salinised water for aquaculture in low-salinity areas could be a viable approach for sustainable food production. Low-salinity aquaculture for freshwater fish can help reduce pressure on freshwater supplies while enabling fish farming in dry and semi-arid regions.

This article examines land degradation in inland saline areas, characteristics of these environments, species' salt tolerance and its physiological effects, global salinity challenges and opportunities, and mitigation strategies.

Characteristics of inland saline water

Salt-affected soils in India are classified into two main types: alkali (sodic) soils and saline soils. In some cases, saline-sodic soils also occur. These are generally grouped with sodic soils since their treatment is similar, except that they require additional water to leach soluble salts before amendments can be applied.

Sodic soils contain high concentrations of sodium in the soil solution and on the exchange complex. High pH levels, often exceeding 10.0 in severe cases, and an exchangeable sodium percentage of up to 90% negatively affect crop growth. These conditions disrupt nutrient availability, damage soil structure, and suppress biological activity. Sodium carbonates and bicarbonates undergo alkaline hydrolysis, further increasing sodium levels in the soil. Alkali soils are deficient in nitrogen, calcium, zinc, and organic matter, while some micronutrients cause toxicity or deficiency issues.

Alkali soils mainly form due to irrigation with groundwater high in carbonate and bicarbonate ions, rising groundwater levels from canal irrigation, and salt-laden runoff from undrained basins. Inland saline plains are common in arid and semi-arid canal-irrigated regions. These soils contain neutral soluble salts such as sodium, calcium, and magnesium chlorides and sulphates, with sodium chloride being dominant.

High soil salinity is often linked to shallow groundwater, typically within 2 metres of the surface. Since subsoil water is usually saline, irrigation worsens soil degradation and reduces crop yields. While saline soils often have good physical properties, poor drainage is a major problem. The formation of saline soils is mainly due to rising water tables caused by irrigation and inadequate drainage.

These degraded lands, which are unsuitable for agriculture, could be used for inland saline aquaculture. This approach could help increase fish production while ensuring environmental sustainability.

Scope of inland saline aquaculture

Inland saline aquaculture includes various species, production systems, and water conditions. These systems offer significant potential for increasing aquaculture output. Using or reusing inland saline water can help produce high-quality seafood while making use of underutilised resources in salt-affected areas. This is particularly important as demand for freshwater and coastal marine areas continues to rise.

The integration of aquaculture with traditional farming systems, halophytic crops, or seaweed farming could further enhance efficiency and sustainability. Ongoing research is providing the knowledge needed to develop these systems into viable commercial operations. Key research areas include the use of aquaculture effluents for crop production and the physiological challenges of rearing high-value species in inland saline conditions.

With increasing global competition for limited resources, future challenges will include water scarcity, climate change impacts on conventional crops, and fertiliser shortages. Inland saline aquaculture offers a sustainable way to increase seafood production and address these growing concerns.

Use of poor-quality water for aquaculture

India holds 42% of the world's freshwater resources and supports 17% of the global population. Agriculture consumes about 85% of India's freshwater, while domestic and industrial sectors use the remaining 15%. Groundwater quantity and quality are critical for high productivity. However, regions with water scarcity often rely on low-quality groundwater.

The dry and semi-arid states of Rajasthan, Haryana, Delhi, Punjab, and Uttar Pradesh have the highest concentrations of saline and brackish groundwater. Due to freshwater shortages and rising pumping costs, brackish groundwater is increasingly used for irrigation. Over-extraction of groundwater has led to contamination of once high-quality aquifers, making them unsuitable for agriculture.

The indiscriminate use of poor-quality water, without effective soil, water, crop, and livestock management, poses serious risks to soil health, livestock, human health, and the environment. Prolonged use leads to sodicity and toxicity buildup in soils, reducing crop yields and often rendering land unsuitable for farming. However, the aquaculture sector can utilise these salt-affected water resources to boost fish production in degraded areas.

Species tolerance to inland saline water

The key criteria for selecting fish species for large-scale inland saline aquaculture are similar to those in other aquaculture sectors. Suitable species must have established hatchery protocols, strong market demand, disease resistance, robustness, salt tolerance, fast growth, and consumer popularity. Additionally, the water quality requirements of a species must align with the available water conditions to ensure optimal performance. This is particularly important for fish farming in inland saline environments.

Various species have been studied for their suitability in inland saline conditions, including marine, estuarine, diadromous, and freshwater euryhaline species. The following species are currently being tested for commercial production in inland saline water (refer Table 1).

Salinity is a key environmental factor influencing the growth, development, and reproduction of marine fish. Teleosts regulate plasma ion balance through their osmoregulatory organs, including gills, kidneys, and intestines. The Na^+, K^+-ATPase (NKA) pump plays a critical role in ion transport by creating the electrochemical gradient needed for ion and water exchange across cell membranes.

Research on salinity stress has focused on physiological and biochemical responses. Blood biochemical parameters are commonly used to assess fish health and diagnose diseases. Studies show that salinity levels influence blood ion composition, which is monitored to evaluate fish osmoregulatory capacity. In euryhaline teleosts, salinity stress affects protein synthesis, enzyme activity (such as Na^+, K^+-ATPase), and the development of specialised cells like pavement cells, ionocytes, and mitochondria-rich cells, which adapt to either seawater or freshwater conditions.

Table 1. Species being tested for commercial production in inland saline water.

Species	Tolerable salinity ‰	Species	Tolerable salinity (‰)
Labeo rohita	12	*Macrobrachium rosenbergii*	12-15
Ctenopharyngodon idella	25	*Penaeus monodon*	23-25
Hypophthalmichthys molitrix	10	*Penaeus japonicus*	35
Cyprinus carpio	12	*Scylla serrata*	28-34
Oreochromis niloticus	20	*Artemia*	>200
Channa punctata	13	*Dunaliella salina*	>200
Heteropneustes fossilis	9	*Isochrysis*, *Tetraselmis*, *Chaetoceras*	30
Clarias magur	8	*Spirulina platensis*	30
Pangasius hypophthalmus	15	*Gracilaria* spp.	30
Carassius auratus	10	*Ulva* spp.	30
Crayfish	6-8	*Caulerpa* spp.	30

Salinity fluctuations are also linked to immune responses and oxidative stress. Increased reactive oxygen species (ROS) production can weaken immune function, making fish more vulnerable to diseases. In addition to digestion, the intestines play a role in osmotic and ionic regulation by absorbing water. Salinity changes may also impact intestinal microbiota, which is essential for metabolism, growth, and overall health.

Intestinal microbial communities are gaining attention in both human and animal research due to their role in various biological processes. In aquaculture, gut microbiota activity has been linked to the growth of euryhaline species such as Oreochromis niloticus and Litopenaeus vannamei. However, there is limited understanding of how fish intestinal microbiota respond to salinity changes in aquaculture conditions. Further research is needed to explore these interactions and their implications for fish health and growth.

Despite differences in local soil chemistry, certain patterns in sodicity management are observed globally. In the Wakool region of Australia, saline groundwater contained the lowest potassium levels, with only 5% of the concentration found in seawater of equivalent salinity. Calcium levels in saline groundwater varied widely, ranging from 1.4 to 130 times higher than in seawater. Sulphate levels were generally in excess, except in Alabama and Haryana, India. Magnesium deficiencies were noted in some areas, particularly in Australia.

Extensive research has focused on correcting water chemistry imbalances. Various mineral sources have been identified as potential supplements for major cations, addressing deficiencies in different water sources used for shrimp farming worldwide. Among these ions, potassium has received significant attention due to its physiological importance.

Red sea bream (*Pagrus auratus*) lost balance and became dormant within three days of exposure to saline groundwater. However, when potassium was supplemented, survival and growth matched those observed in coastal seawater. Other species farmed in saline groundwater, such as *Argyrosomus japonicus*, *Sciaenops ocellatus*, and *Litopenaeus vannamei*, have also benefited from potassium supplementation.

Inland saline water often has irregular calcium levels. Research has shown that adding calcium chloride to low-salinity groundwater improves survival, growth, and feed efficiency in red drum (*Sciaenops ocellatus*). While lowering pH can also help, it is often too costly and impractical. Most inland saline groundwater sources contain excessive calcium compared to seawater.

In Haryana, groundwater has higher calcium and magnesium concentrations than seawater, which affects *Macrobrachium rosenbergii* larval production. A filtration system containing 0.5 m^3 of ion exchange resin can treat 2,500 litres per day of saline groundwater, supporting a *Macrobrachium* hatchery producing 1.5 million post-larvae (PLs) annually.

Ions are lost from aquaculture ponds due to rainfall overflow, soil adsorption, and water exchange. Remediating these losses can be expensive. Potassium, in particular, is strongly adsorbed by pond sediments due to clay minerals that fix it between tetrahedral layers.

Attempts to correct potassium deficiencies in saline groundwater through dietary modifications have not been effective for finfish. However, *Litopenaeus vannamei* raised in low-salinity groundwater showed improved osmoregulatory function when their diet was supplemented with magnesium, potassium, phospholipids, and cholesterol.

Saline groundwater often contains various ionic imbalances and potential pollutants, requiring site-specific investigations. Most research has focused on major variations in individual ions, but as aquaculture using saline groundwater expands, chronic effects may become more evident. Studying the physiological responses of aquaculture species in low-salinity water and developing artificial mixed-salt environments can help address these challenges.

In addition to ionic composition, suboptimal pH negatively impacts aquaculture potential. Acidic conditions can arise from acid-forming fertilisers, acid sulphate soils, ferrolysis, and high levels of dissolved carbon dioxide. To improve water quality and boost primary productivity, biochar can be applied to both sediment and water. Research suggests that applying biochar in lower doses to water is more effective than using larger amounts in sediment.

Biochar use in inland saline pond water (ISPW) can also help replenish potassium, which is essential for fish and crustacean osmoregulation. This approach could enhance productivity in degraded soil and water systems. Producing biochar from agricultural crop waste could support aquaculture development in degraded land areas, making better use of saline groundwater resources.

Advantages of inland saline aquaculture

- Inland saline aquaculture enhances the conjunctive use of freshwater in salt-affected areas worldwide.
- There are abundant water resources, promising early results with temperate fish, and successful commercial operations using saline groundwater.
- Research is ongoing into using saline water for fish culture in evaporation ponds, indoor systems, and intensive fish-farming facilities.
- Inland saline aquaculture requires water to be treated, contained, and possibly recycled on-site.
- It supports the development of national environmental management policies for sustainable aquaculture.
- It helps reduce the release of untreated nutrients into aquatic ecosystems.
- When cultivating algae for food and feed, saline groundwater may offer advantages over seawater.
- Several molluscan species, including Pacific oysters, Sydney rock oysters, tropical oysters, flat oysters, pearl oysters, silver-lipped oysters, black-lipped oysters, and winged oysters, may be suitable for culture in inland saline waters.

- It enables the creation of a database documenting inland saline water source characteristics.

Conclusion

Freshwater supplies are declining globally, while land and groundwater salinisation are increasing. In the coming decades, saline water will become a primary resource for both agriculture and aquaculture. In India, inland saline water lacks potassium ions, requiring fortification with K^+ in the culture medium or mineral supplementation through feed before use in aquaculture.

Rising salinity levels threaten aquatic species by causing oxidative stress, disrupting metabolism, and weakening immune function. Shrimp farming is widely practised in India's inland saline regions. However, given the high population density and environmental concerns, cultivating low-salinity-tolerant species may be a more sustainable approach than shrimp farming in low-saline conditions. This would allow better utilisation of underused water resources in inland saline areas.

Inland saline water can also be used for freshwater fish culture if appropriate production methods are applied to prevent environmental damage. Research indicates that aquatic organisms adapt better to salinity stress when given a longer acclimatisation period, improving survival rates in aquaculture systems.

A success story of freshwater prawn farming as an alternative livelihood for self-help and user groups in Mayurbanja District, Odisha, India

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Fisheries play a crucial role in livelihoods and provide food for over one billion people worldwide. In India, the population has grown rapidly over the past five decades. This has widened the gap between supply and demand for essential commodities such as food, clothing, shelter, and fuel.

Fisheries contribute significantly to the country's economy by providing food, employment, and foreign exchange. In India, 60–70% of the population lives in rural areas. Many do not have sufficient land or alternative job opportunities. Over 85% of rural income comes from agriculture and related activities.

A large number of people rely on subsistence fishing and fisheries-related activities. In India, fishing is one of the oldest subsistence practices. The country's economy and social development depend heavily on fisheries. This sector provides employment to many, supplies affordable protein-rich food, and contributes to foreign exchange earnings.

Fisheries and aquaculture are among the fastest-growing industries globally. They play a key role in economic development by supporting food and nutrition security, national income, and employment. The sector also generates significant foreign exchange, contributing about 10% of total export earnings. Most of these earnings come from shrimp and prawn, making fisheries the third most important export sector after garments and leather.

Odisha is one of India's leading fish-producing states, ranking fourth in total fish production after Andhra Pradesh, West Bengal, and Gujarat. In the fisheries sector, freshwater fish and giant freshwater prawn (*Macrobrachium rosenbergii*) are among the most important species in aquaculture. However, the earning potential of this sector remains underutilised.

Due to the relatively simple techniques involved, freshwater prawn farming has the potential to create significant employment opportunities in rural areas for both men and women. It can also generate additional income with minimal risk and requires less time.

The Odisha Integrated Irrigation Project for Climate Resilient Agriculture (OIIPCRA) was launched in 2020–21 across 15 districts in Odisha. This World Bank-assisted project, with funding of $22 million, is a minor irrigation project (MIP)-based initiative. It aims to promote climate-smart agriculture in irrigation command areas covering about 56,400 hectares under 107 minor irrigation projects and approximately 70,000 hectares of rain-fed land influenced by these projects. The goal is to enhance farmers' capacity and income in the project area.

Farmers are catching freshwater prawn.

Under the OIIPCRA project in Mayurbanja district, Odisha, genetically improved freshwater fish and freshwater prawn farming were introduced. The project provided initial investment by supplying fingerlings, post-larval scampi, and other inputs.

User groups (UGs) and women-led self-help groups (SHGs) received training and participated in exposure visits organised by the Department of Fisheries, Government of Odisha. These efforts aimed to establish fish farming in minor irrigation projects MIPs.

This study examines the role of tribal men and women in promoting fish farming across different villages in Mayurbanja district. SHGs have played a key role in managing and expanding fish and prawn farming, as well as marketing, to improve livelihood security for rural tribal communities.

Capacity-building programs and field demonstrations have helped many men and women in Mayurbanja adopt improved pisciculture techniques, enhancing their knowledge and income opportunities.

Even in coastal and saline areas, freshwater prawn farming is becoming increasingly popular due to its low risk and low cost. The technology is simple and relies on freshwater, which can be sourced from rivers, canals, ponds, reservoirs, or MIPs.

The farming of giant freshwater prawn, commonly known as scampi, is gaining momentum in the global market. It is in high demand both domestically and internationally and is now considered an exportable commodity. However, production remains inadequate due to the limited availability of quality seed, feed, and technical knowledge.

Scampi farming is expanding rapidly due to advancements in culture techniques and its relatively high environmental sustainability compared to other crustaceans. The species is favored for its large size, tolerance to changing water conditions, resistance to handling stress, and ability to feed on unconventional diets (El-Sayed, 1997).

This case study focuses on freshwater prawn farming in villages of Karanjia under the Shyamakhunta block in Mayurbanja district, Odisha.

Approach

The impact of the OIIPCRA (IRDMS) project is evident in the significant increase in fish and prawn production, particularly in Karanjia village, Paikbasa Gram Panchayat (GP), under Shyamakhunta block (MIP1), and in Tato village, Tato GP, under Karanjia block (MIP2).

MIP1 was stocked with 30 kg of fish and 800 post-larvae (PL25) prawns. Similarly, MIP2 was stocked with 10,000 PL25 prawns and 100 kg (3,000 fingerlings) of genetically improved Indian major carps weighing over 50 g each.

Programme overview

The experimental farming case study showed good growth and survival rates in both MIP1 and MIP2 despite challenges such as erratic rainfall, cyclonic weather, and disruptions in the feeding system. Factors like feed consumption, light, and temperature fluctuations affected the farming process. However, the overall results were promising.

MIP2, with a water area of 1.25 hectares, performed better than MIP1 in both yield and quality. It produced higher-grade prawns with uniform size and greater mean weight, even though both MIPs followed a polyculture system. Among Indian major carps, catla dominated in both size and weight compared to rohu and mrigal in both sites. MIP2 achieved better fish and prawn production due to its biculture system, a perennial water source, and proximity to the main market in Baripada.

Economic analysis is essential to assess the feasibility of aquaculture investments. This study considered the cost of seed, feed, operations, and infrastructure in relation to marketable yield. Both MIP1 and MIP2 met the necessary cultural norms and proved to be economically viable.

The study confirmed that freshwater prawn farming, when combined with modern technology, is profitable and sustainable. The future of scampi farming looks promising due to its palatable taste, high nutritional value, and strong export potential. To prevent inbreeding, genetically improved seed from wild broodstock should be sourced from RGCA, Chennai, as Odisha currently lacks this facility.

Scampi has a strong position in the international market due to its quality and demand, comparable to tiger and white-leg shrimp.

Breeding and culture

During the monsoon, healthy wild berried females and males were collected from rivers, canals, culture ponds, and MIPs for hatchery breeding. After acclimatisation, they were disinfected with 25–30 ppm formalin for 10–15 minutes before being transferred to maturation tanks. They were fed at 5% of their body weight with snail meat, clam meat, crab meat, pelletised feed, and *Artemia* nauplii. These feeds provided protein, carbohydrates, ash, moisture, and fat essential for broodstock and larvae.

Males and females were kept together at a 1:4 ratio for mating. Segregation was based on color changes from pink to grey and then deep grey. Mating occurred within 8–10 hours, followed by spawning. The fertilised eggs were deposited on the ventral side of the female's abdomen and were held firmly by the pleopods. In captivity, females mature 2–3 times per season, with an interval of 20–30 days between successive puberty molts. A 50–60 g female prawn can lay 20,000–30,000 eggs, though fecundity decreases with each cycle.

In fibre-reinforced plastic tanks, 3–4 berried females were stocked at a water temperature of 26–28°C and salinity of 5–6 ppt to optimise hatching. The incubation period lasted 18–20 days, during which the female ventilated the eggs using pleopod movements. Prawns carrying grey eggs were transferred to separate tanks, one per tank. Hatching occurred on the second night and continued for 2–3 days from a single mother prawn. The female dispersed the newly hatched larvae using pleopods.

Spent females were moved to separate tanks to prevent them from consuming unhatched eggs and larvae. Scampi larvae undergo 11 distinct stages before metamorphosing into post-larvae, each with unique morphological traits. Larval rearing is a critical phase, highly susceptible to disease, requiring continuous monitoring of water quality, temperature, feed, and climatic conditions. Under optimal conditions, it takes 35–40 days for the larvae to develop into juveniles ready for sale to entrepreneurs.

Feeding

In this experiment, both MIPs were fed pelletised feed of different grades based on growth stages—starter, grower, and finisher. Additional feed sources included rice bran and groundnut oil cake. Since scampi are cannibalistic and scavenging by nature, they also consumed natural feed such as aquatic insects, algal blooms, mollusks, crustaceans, and small larvae.

Water quality monitoring

Water quality parameters, including pH, dissolved oxygen (DO), biological oxygen demand (BOD), hardness, alkalinity, nitrate (NO_3), and nitrite (NO_2), were monitored at least twice a month in both MIPs. Testing was conducted by the Fishery Facilitator (Assistant Fishery Officer or Fishery Technician) using a testing kit provided by OIIPCRA through the District Fisheries Officer (DFO).

Morphometric study and health monitoring

Fish and prawn samples from both MIPs were analysed for length and weight, and their health was assessed at the district laboratory under a zoom microscope. Common diseases observed during the experiment included fungal, bacterial, and protozoan infections. Medications such as Cifax, nitrite treatments, formalin, Butox or Lysetik, and fluconazole were used for disease management.

Marketing & economics

The culture period lasted six months (180 days), with a single harvest conducted in both MIPs. However, some fish and prawns remained, particularly in MIP2. Growth variation was observed among species, with prawns reaching 250–300 g and carp species growing as follows:

Above, below: Length and weight measurement.

- Catla: ~1 kg
- Rohu: ~600 g
- Mrigal: ~700 g
- Grass Carp: ~2 kg
- Jayanti Rohu: ~1.5 kg
- Amur Carp: ~1.5 kg

Since this was an experimental single-batch culture, harvesting was carried out using drag nets, cast nets, and hand-picking after draining the ponds. Both MIPs recorded good harvests.

To support fishers, OIIPCRA is providing three-wheelers and four-wheelers equipped with ice boxes. This initiative helps stakeholders transport larger harvests and sell their stock at better prices in nearby markets.

Needs of user groups and self-help groups

To successfully establish fish and prawn farming, self-help groups require:

- Training in fish and prawn breeding techniques.
- More on-field training and demonstrations.

- Exposure visits.
- Technical support from authorities for efficient production and propagation.
- Improved marketing facilities.

Factors contributing to success

- Technical support and cooperation from government departments.
- Timely supply of inputs and regular guidance and motivation.
- Strong coordination and commitment among UG/SHG members.
- Availability of suitable water sources.
- Increasing demand for aquaculture products in urban areas.

Lessons learned

The fish and prawn farming initiative has provided a vital livelihood opportunity for economically disadvantaged tribal communities. It has contributed to capacity building and income generation for marginalised groups, including women's self-help groups, producer groups, and water user groups within the irrigated areas of MIPs. The skills gained ensure self-employment and financial security for these communities.

Future strategies and way forward

Efforts are underway to build farmers' capacity for technological improvements in seed production. Successful farmers are receiving technical support to scale up fish and freshwater prawn seed production by establishing prawn nursery rearing systems. New farmers are also being encouraged to adopt these technologies through horizontal expansion under the OIIPCRA programme.

To enhance sustainability, farmers are being linked to existing government schemes and institutions such as State and Central Fisheries, ATMA, KVK, OCTMC, and IRDMS. These partnerships provide improved support and increased income opportunities. Additionally, better market linkages with aquashops in both local and distant towns are being developed. A buyback trade system with local traders has already proven profitable. Furthermore, a fish feed production training programme has been introduced to help farmers generate additional income.

Moving forward, sustainable and eco-friendly utilisation of aquatic resources will be prioritised. The introduction and upgrading of genetically improved freshwater species such as pangasius, tilapia, Jayanti rohu, and grass carp will support aquaculture development. Rainwater harvesting for pisciculture is also being explored to maximise water resource utilisation.

Community involvement will play a key role, integrating local people into three livelihood tiers—eco-friendly aquaculture practices, fish feed production, and marketing. This approach is expected to improve the economic conditions of the villagers. Scientific methods will be applied to ensure sustainable fish farming, with a focus on improving aquatic health through monitoring of physicochemical parameters and fish health management. New technologies suited to local conditions will be introduced, ultimately contributing to better livelihoods for the local population.

Conclusion

Aquaculture has the potential to be adopted across Odisha as a means of enhancing livelihood opportunities. The state has already established itself as a major fish producer in India. Freshwater prawn farming, in particular, offers a viable option for commercial small-scale operations. It can be carried out in limited space under varying environmental conditions, including extreme temperatures, with relatively low investment. However, further efforts are needed to maximise its potential.

To increase fish production, underutilised water bodies must be explored and managed sustainably. Both the central and state governments are prioritising prawn farming through various user groups and self-help groups as an alternative livelihood strategy. This study highlights the role of self-help groups as a process-driven initiative that organises rural communities, builds capacity, and facilitates exposure visits, enabling them to become self-managed entities.

More opportunities should be created, particularly for women, through better information sharing and technology transfer across different districts and states. Addressing the socio-economic challenges faced by farmers, improving aquaculture infrastructure, and adopting modern, robust management systems are essential for sustainable development.

Although freshwater prawn farming offers significant social and economic benefits, concerns remain about its long-term sustainability. High production costs, limited financial resources, scarcity and high cost of post-larvae, lack of technical knowledge, weak institutional support, and inadequate extension services pose challenges to expansion. If more areas were brought under prawn culture, Odisha could significantly increase its foreign exchange earnings through exports.

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Training Programme on Safeguarding *Artemia* Resources for Aquaculture held in Rome

Participants in the training course during the field trip to Tarquinia Salt Works.

The Training Programme on Safeguarding Salt Lake Brine Shrimp (*Artemia*) Resources for Aquaculture was held in Rome from 2-6 September, as foreshadowed in the previous issue. The training was attended by 37 participants from 15 countries, namely: Belgium, Bolivia, Chile, China, Georgia, Iran, Italy, Kazakhstan, Russia, Saudi Arabia, Sweden, Thailand, USA, Uzbekistan, and Vietnam. 23 organisations were represented, including three government agencies, seven private sector, ten academic and one NGO.

The proceedings were opened by Xinhua Yuan, Deputy Director, Fisheries and Aquaculture Division, Food and Agriculture Organization of the United Nations (FAO).

Welcome remarks were delivered by Philippe De Maeyer, Permanent Secretary, Royal Academy of Overseas Sciences (RAOS); by Simon Wilkinson, Network of Aquaculture Centres in Asia-Pacific (NACA) / International Artemia Aquaculture Consortium (IAAC); and representative of the Alliance of National and International Science Organization for the Belt and Road Regions (ANSO).

The programme was jointly organised by FAO, NACA / IAAC, and by RAOS and ANSO, which provided the financial support that made the activity possible.

The programme featured a series of expert presentations on three themes: Salt lakes, management tools for *Artemia* cyst and biomass harvesting, and *Artemia* biodiversity.

The full programme is appended below, with links to video recordings of the presentations on NACA's YouTube channel.

For more information about the International Artemia Aquaculture Consortium, which is hosted as programme of NACA, please visit the consortium website at:

https://artemia.info

Programme

- Opening remarks
  Yuan Xinhua, Patrick Sorgeloos, and Simon Wilkinson

Salt lakes

- Hydrology and climatology of salt lakes: development and use of appropriate models to safeguard water resources, impact of climate change
  Alishir Kurban

- Presence and role of *Artemia* in salt lakes: biology and ecology, use in aquaculture
  Patrick Sorgeloos

- Urmia Lake, Iran: example of terminal lake, fate of *Artemia* presence
  Naser Agh

- Aral Sea, Uzbekistan: example of terminal lake, fate of *Artemia* presence
  Ablatdyin Musaev

Management tools for *Artemia* cyst and biomass harvesting

- History of the interdisciplinary approach by the State of Utah and stakeholder groups to develop strategy and policy to safeguard Great Salt Lake and its vital resources for wildlife and industry
  Thomas Bosteels and Tim Hawkes

- Management tools and quota systems for the exploitation of *Artemia* resources in China
  Gao Song

- Management tools and quota systems for the exploitation of *Artemia* resources in Siberia, Russia
  Liudmila Litvinienko and Marina Korentovich

- *Artemia* of Greate Yarovoye Lake (Siberia, Russia): characteristics of the population and Artemia resource development
  Galina Tsareva

- Management tools and quota systems for the exploitation of *Artemia* resources in Kazakhstan
  Chingis Sossorbarmayev

- *Artemia* pond production projects
  Nguyen Van Hoa and Patrick Sorgeloos

Artemia biodiversity

- AquaGRIS: the role it can play in characterising, recording and monitoring Artemia genetic diversity
  Graham Mair

- World *Artemia* biodiversity
  Gonzalo Gajardo

- *Artemia* biodiversity in China
  Sui Liying and Xuekai Han

- *Artemia* biodiversity in Russia
  Elena Boyko

- *Artemia* biodiversity in Kazakhstan
  Kamila Adyrbekova

- New techniques for (epi)genotyping of *Artemia* species and strains
  Parisa Norouzitallab

Group discussions

Participants and experts engaged in group discussions on:

- Biological aspects of salt lakes such as models to estimate the role of *Artemia* as a food source for water birds; sampling protocols and methodologies to estimate maximum sustainable yields for *Artemia* cysts and biomass; potential impacts of climate change, ecology and pathogens on *Artemia* populations; and guidelines for establishing sustainable management protocols, harvesting quota and seasons, and measures to enforce / adjust quotas during the harvesting seasons.

- Policy needs and legislative strategies to address issues such as protecting and managing terminal and emerging salt lakes, water resources, salinity regimes, nutrient intake and contamination. The group considered similarities and differences between terminal lakes under different contexts, the policy (legislative) goals required to ensure healthy and sustainable resources, barriers to progress towards these goals and strategies to overcome them.

- Farmed *Artemia* needs to focus on advancing sustainable management and genetic research of *Artemia* resources and salt lake ecosystems. Key actions include establishing a Task Force to apply AquaGRIS, an information system on aquatic biodiversity for food and agriculture (which will be the subject of a follow up article), for commercial *Artemia* sources, developing guidelines for ecosystem monitoring, and promoting sustainable harvest practices. Innovations like satellite imagery and drones should be explored to assess *Artemia* stocks. Joint research should link optimal *Artemia* usage to hatchery outcomes and address climate change impacts. Guidelines for *Artemia* cyst certification, biosecurity, and controlled farming should be developed, alongside preserving gene pools through cyst banks and characterising farmed types for commercial traits.

Videoconference with experts and recommendations

The discussions culminated in the development of a series of recommendations, which were further discussed and agreed during a videoconference on 6 September between the trainees at FAO HQ in Rome and experts at the Palais des Académies in Brussels. The final recommendations were as follows.

- Establish a Task Force to apply AquaGRIS for commercial *Artemia* sources using a stepwise approach to gathering and collating genetic information. The Task Force has been constituted and will begin work shortly.

- Develop guidelines for monitoring, adaptive management, conservation / water rights and sustainable harvest of salt lake ecosystems based on local biology and ecology.
- Share ideas about effective messaging to improve public perception of terminal salt lakes and their role, ecosystem services and socio-economic value.
- Advance the capabilities of *Artemia* stakeholders in translating science into clear and actionable protocols.
- Study the possibility of using innovations such as satellite imagery and drones to evaluate *Artemia* cyst accumulations / stocks and the status of salt lake ecosystems.
- Develop guidelines for *Artemia* cyst certification including good processing practices.
- Implement existing certification schemes for the sustainable harvesting and management of natural *Artemia* resources.
- Recommend good practices including biosecurity for *Artemia* hatching and use in hatcheries as set out in the new FAO *Artemia* Manual and train hatchery technicians in their use.
- Determine the critical role and research the optimal use of *Artemia* in hatchery applications.
- Conduct joint public / private studies to determine the link between optimal *Artemia* usage, both quantity and quality, and its link to good health, growth and harvest outcomes.
- Conduct research on the impact of climate change on natural *Artemia* resources and their host salt lake ecosystems, prioritising commercially or potentially important stocks such as those in Tibet.
- Preserve the gene pool of wild and farmed types through establishment of cyst banks and management of salt lake habitats. It is not good practice to translocate *Artemia* between habitats.
- Establish standardised protocols for the establishment and long-term sustainment of *Artemia* cyst banks and their accession by researchers and industry.
- Promote controlled farming of *Artemia*, including in artisanal ponds, salt affected lands and coastal areas, selecting suitable *Artemia* species / strains for the specific application.
- Evaluate the performance of *Artemia franciscana* relative to other species / strains (including parthenogenetic strains) for use in seasonal farming in different environments / conditions.
- Farmed types should be genetically characterized and their performance evaluated with regards to commercially important traits.
- Evaluate the adaptive capacity (epigenetic and genetic characteristics) of *Artemia* species and strains and their changes over time in different localities / environments.
- Explore opportunities for use of unconventional water bodies for *Artemia* production.
- Produce a summary of key procedures from the new FAO *Artemia* Manual for publication in additional languages and formats / media.

Field trip to Tarquinia salt works

The last day of the programme in Rome featured a field trip to the Tarquinia salt works, a solar facility that has been producing salt since ancient Etruscan and Roman times, with various interruptions, until it finally became uneconomic. While salt production ceased in 1987 the area has since been declared a nature reserve, and a scientific centre has been established on site.

Artemia salina is known to occur in the remains of the salt works. A couple of specimens were sighted by members of the group, but they were not abundant at the time.

Artemia scientists in their natural habitat.

Salt crystals from the floor of the saltern pictured left.

First International Artemia Aquaculture Consortium Conference and Members' Meeting, Ostend, Belgium

IAAC Members' Meeting with online dicussion panels. On screen: Khun Banchong Nissagavanich, shrimp hatchery operator and Artemia biomass farmer.

The first ever IAAC conference was a free half day even held in Ostend, Belgium on 9 September, as a prelude to Larvi 2024, which ran from 9-12 September. NACA would like to thank the Larvi organisers for their kind use of the venue, De Grote Post. Around 80 people attended.

The conference featured twelve presentations introducing the IAAC and providing an overview of many of the issues surrounding *Artemia*, including management of salt lakes habitats that still provide the bulk of global *Artemia* supplies, *Artemia* biodiversity, hatching optimisation, and aquaculture of *Artemia* biomass in tanks and ponds. A key observation from industry, in line with the comments in the Rome training programme, was that shrimp postlarvae survival and growth is significantly improved if the amount of *Artemia* provided is increased past what is currently considered conventional wisdom.

The presentations are listed below, along with links to video recordings on NACA's YouTube channel.

Programme

- Welcome and Introduction (from ISA to IAAC)
  Patrick Sorgeloos

- IAAC organisation
  Simon Wilkinson

- *Artemia* tank cultures: experience from Malaysia
  Yeong Yik Sung

- Development and utilisation of Artemia resources in China
  Liying Sui

- *Artemia* resiliency in response to dramatic changes in Great Salt Lake salinity and volume
  Brad Marden

- Adaptive management of salinity in Great Salt Lake: an adjustable berm provides a unique tool to protect the *Artemia* population
  Phil Brown

- New techniques for (epi)genotyping of *Artemia* species and strains
  Stephanie De Vos

- Predicting *Artemia* nauplii hatching kinetics through temperature measurement
  David Johanson

- Optimising co-feeding strategies for enhanced survival and growth in *Litopenaeus vannamei* postlarvae: a comprehensive study on *Artemia* inclusion and dietary options
  Yattish Ramena

- Reduction of *Artemia* fed to larval shrimp results in inferior pond success
  Robins McIntosh

- Artemia4Bangladesh project
  Meezanur Rahman

- Year-round *Artemia* pond production in monsoon climate in Thailand
  Banchong Nissagavanich

First IAAC Member's Meeting

The first IAAC Members' Meeting was held in the afternoon following the IAAC Conference. The proceedings involved two panel discussions, by the Academic Sector and Private Sector respectively. The panels included remote members participating via Zoom.

The Academic Sector panel was chaired by Gonzalo Gajardo with concluding remarks by Liying Sui, Vice-Chair of the IAAC Steering Committee. The panel featured a series of informative presentations followed by discussions on:

- FAO AquaGris project (Graham Mair).
- *Artemia* China AquaGris (Xuekai Han).
- Genetic stock identification (Li Ke).
- *Artemia*, species-taxonomic issues (Alireza Asem).
- *Artemia*: a model for biological studies (Parisa Norouzitallab and Kartik Baruah).
- Enriching *Artemia* with Bacteria (Annelies Declercq).

The Private Sector panel was chaired by Philippe Léger, who gave a welcome and introduction, with a round up by Patrick Sorgoos and concluding remarks by Yeong Yik Sung, Chair of the IAAC Steering Committee. The panel included presentations and discussions on:

Sustainable harvesting & production: 'Practice' vs 'Ambition'

- 'Ambition' (Tim Hawkes).
- Practice at Great Salt Lake, UT – USA (Thomas Bosteels).
- Practice at Russian & Central Asian lakes (Alexander Nikiforov).
- Practice at China lakes (Gao Song).

***Artemia* cyst certification & labelling**

- Developing guidelines on *Artemia* cyst and biomass certification (Simon Wilkinson).
- Requirements for farmer (David Garriques, Tania Dewolf, Banchong Nissagavanich).
- Situation suppliers: 'can do vs cannot' (Patrick Waty, Thomas Bosteels, Alexander Nikiforov, Gao Song).

***Artemia*, still the preferred live feed? Why/not? – farmer's perspective**

- Why? Perceived constraints? (David Garriques, Tania Dewolf, Banchong Nissagavanich).
- Technology at service (Geert Rombaut).

Future of *Artemia* – Bridging the gap

- Producing more? (Gao Song, Alexander Nikiforov).
- Using less? … using more? (David Garriques, Tania Dewolf, Banchong Nissagavanicho).

Inception workshop: Knowledge brokering for nature-based solutions in aquaculture transformation

Canada's International Development Research Centre (IDRC) is sponsoring the project "Knowledge Brokering for Nature-Based Solutions in Aquaculture Transformation in Asia-Pacific: Support to the Aquaculture Innovation and Investment Hub." The project's inception workshop was held in Bangkok from July 4-5, bringing together project teams from Thailand, The Philippines, and Fiji to discuss approaches and methodologies. The workshop was opened by Dr. Eduardo Leano, NACA Director General, with welcome remarks by Mike Phillips of FutureFish, a co-investigator of the project, and Rebecca McMillan from IDRC.

This project contributes to NACA's recent work with the FAO on aquaculture transformation. FAO and NACA have published a white paper, developed through extensive consultations, that provides a vision for transforming Asia-Pacific aquaculture by 2030. The aim is to create more efficient, inclusive, resilient, and sustainable food systems through innovation, investment, and partnerships. NACA is developing an Aquaculture Innovation and Investment Hub (AIIH) to help realise this vision in the region, providing a facility that will bring together innovators, startups, and investors to accelerate transformation.

Participants in the inception workshop.

The project is part of a wider IDRC AQUADAPT initiative, a four-year partnership running from 2023-2027. AQUADAPT addresses the intertwined challenges of climate change, biodiversity loss, and food insecurity through applied research on nature-based solutions in aquaculture in Southeast Asia and the Pacific region. AQUADAPT emphasises Gender Equality and Social Inclusion (GESI), ensuring that nature-based solutions are inclusive of all genders and marginalised groups.

The project will contribute to developing National Innovation and Investment Plans for Thailand, The Philippines, and Fiji and the development of the hub. As a first step, the project teams will conduct a baseline assessment of the current aquaculture industry structure, performance, policies, innovation and investment activities, status, and needs. This scoping study will address challenges including:

- Climate change.
- Disease prevention and management.
- Environmental sustainability.
- Gender equality and social inclusion.
- Resource utilisation and management.

Country teams will consult widely with the private sector and authorities to identify important innovations in aquaculture, particularly nature-based solutions, that can mitigate challenges, create efficiencies, open new opportunities, or enhance gender equality and social inclusion. This is expected to result in the identification and documentation of innovations, including nature-based solutions, and their adoption.

Each participating country will focus on different aspects of aquaculture based on local contexts. In Fiji, the assessment will cover the whole aquaculture industry due to its relatively small size. The Philippines and Thailand will focus on specific sub-sectors. For example, the Philippines will concentrate on tilapia, milkfish, and seaweed, which are the largest aquaculture sectors nationally and have the most significant economic and livelihood impacts.

The workshop's introductory session included (links to YouTube videos where available):

- An overview of AQUADAPT by Rebecca McMillan, IDRC.
- An overview of the project by Eduardo Leano, NACA.
- Private sector scoping plans by Mike Phillips, FutureFish.
- Gender Equality and Social Inclusion by Sizwile Khoza, Stockholm Environment Institute.
- Innovations and investment opportunities for nature-based solutions by the project teams from Fiji, the Philippines, and Thailand.
- An overview of the Aquaculture Innovation and Investment Hub.

The remainder of the workshop focused on developing guidelines for conducting baseline assessments for each country. Teams discussed the purpose of the National Innovation and Investment Plans, ways to progress implementation of nature-based solutions, and key factors in developing the baseline assessments. They also discussed guidelines for integrating gender equity and social inclusion.

A discussion was held on the private sector scoping activities and an innovation event, which will be held in January 2025 for startups and small and medium enterprises. This event will help businesses realise their ideas in nature-based solutions, overcome key challenges, and access emerging opportunities.

The final methodology for baseline assessments is expected to be ready by the end of August, with fieldwork taking place from September to December. The project's findings will be shared at the next High-Level Meeting in April 2025 in Shanghai, China, and with other AQUADAPT projects.

NACA extends its gratitude to the International Development Research Institute for their financial support, FutureFish, the Stockholm Environment Institute, and the project teams from Fiji, Thailand, and the Philippines for their contributions and collaboration.

For more information please visit the project page at:

https://enaca.org/?id=1361

Reported Aquatic Animal Diseases in the Asia-Pacific Region during the First Quarter of 2024

Listed below are the reported aquatic animal diseases submitted by countries in the Asia-Pacific region, which covers the first quarter of 2024. The original and updated reports can be accessed from the QAAD page.

Finfish Diseases

- Infection with *Aphanomyces invadans* (EUS): Bangladesh in rohu (*Labeo rohita*) and catla (*Catla catla*); and, India in snakehead (*Channa marulius*), freshwater catfish (*Wallago attu*), and mrigal (*Cirrhinus mrigala*).
- Infection with red seabream iridovirus (RSIV): Chinese Taipei in seabass (*Lates calcarifer*); and, India in pearlspot cichlid (*Etroplus suratensis*).
- Infection with Tilapia lake virus (TiLV): India in tilapia (*Oreochromis niloticus*), and Philippines in juvenile tilapia (*Oreochromis* sp.).
- Viral encephalopathy and retinopathy (VER): Chinese Taipei in hybrid grouper (*Epinephelus fuscoguttatus* x *E. lanceolatus)* and seabass (*L. calcarifer*).

Molluscan Diseases

Infection with Abalone herpesvirus: Australia in wild adults black-lipped abalone (*Haliotis rubra*).

Infection with *Perkinsus olseni*: India in mussel (*Perna viridis*), hard clam (*Meretrix casta*), and short neck clam (*Paphia malabarica*).

Crustacean Diseases

- Infection with white spot syndrome virus (WSSV): India in *Penaeus vannamei*; and, the Philippines in *P. vannamei* (PL, juvenile, grow-out culture, and adult), *P. indicus* (grow-out culture), *P. monodon* (PL and grow-out culture) and crabs (grow-out culture and adult).
- Infection with infectious hypodermal and haematopoietic necrosis virus (IHHNV): Philippines in *P. vannamei* (grow-out culture) and *P. monodon* (PL).
- Acute hepatopancreatic necrosis disease (AHPND): The Philippines in *P. vannamei* (PL and grow-out culture) and *P. monodon* (grow-out culture).
- Hepatopancreatic microsporidiosis caused by *Enterocytozoon hepatopenaei* (EHP): India in *P. vannamei*; and, the Philippines in *P. vannamei* (PL and grow out culture) and *P. monodon*.

Amphibian Diseases

- Infection with *Batrachochytrium dendrobatidis*: Australia in an unknown species of frog.

Other Diseases

- Bangladesh reported Infection with *Streptococcus* sp. in Tilapia, and Infection with *Aeromonas* spp. in stinging catfish (*Heteropneustes fossilis*), gulsha (*Mystus cavasius*), and pangas catfish (*Pangasianodon hypophthalmus*).
- India reported Infection with Tilapia parvovirus in *O. niloticus*.

E.M. Leaño
Senior Programme Officer / Director General
Health and Biosecurity

14th Asian fisheries and Aquaculture Forum, India

The 14th Asian Fisheries and Aquaculture Forum (14AFAF) will be held from 12-15 February 2025 in New Delhi, India.

The forum is a scientific meeting organised by the Asian Fisheries Society (AFS) once every three years to understand the global trends and address issues and challenges faced by the fisheries and aquaculture sector.

The main purpose of this Forum is to provide an international platform for eminent scientists, young researchers, and other stakeholders across the globe to share their research experiences and innovative ideas. By facilitating the exchange of diverse range of knowledge and expertise, the Forum with the Theme 'Greening the Blue Growth in Asia-Pacific' aims to address key issues towards developing sustainable fisheries and aquaculture.

The forum will feature technical sessions on:

- Resource Assessment and Management for Sustainable Fisheries.
- Sustainable Aquaculture Intensification and Diversification.
- SMART Aquaculture for Resource-use Efficiency.
- Fish Genetics, Genomics and Biotechnology.
- Aquatic Animal Nutrition, Feed Technology and Alternate Feed Resource.
- Aquatic Animal Health Management and Antimicrobial Resistance.
- Aquatic Biodiversity, Environment and Ecosystem Services.
- Impact of Climate Change on Fisheries and Aquaculture and Resilient Strategies.
- Post-harvest Processing, Value-addition, and Food Safety.
- Socio-economic Dynamics and Extension in Fisheries and Aquaculture.
- Gender in Fisheries and aquaculture.
- Fisheries Education, Skill Development and Technology Incubation.
- Fish Marketing, Value Chains and Trade.
- Fisheries Policy, Law, and Governance.

For more information please visit the 14th Asian Fisheries and Aquaculture Forum website:

https://14afaf.in/

PhD scholarships: Shanghai Ocean University PhD Programme 2025

Shanghai Ocean University (SHOU) is offering full scholarship PhD programmes in a wide range of marine sciences in 2025. Disciplines include: Aquaculture, biology, fishing science, fisheries resources, marine science, food science and engineering, fishery economics and management, marine engineering and information.

Scholarships

The scholarships are open to non-Chinese citizens under 30 years old who have a master's degree with a good academic record and outstanding research potential. The scholarships cover tuition, accommodation, medical insurance and include a monthly stipend.

Applications

Applications are due **1 February 2025**. For details of the programmes, eligibility criteria, required documentation and application procedures, please download the prospectus linked below. If you have any questions, please email admissions@shou.edu.cn or add the Admissions Officer Ms. Louise as a Facebook contact or on WeChat (louise2shou).

Postgraduate opportunities

Postdoc positions are available for excellent graduates and full-time faculty positions are available for excellent international postdocs.

Contacts

International Student Office, Shanghai Ocean University
Phone: +86 21-6190-0763
Email: admissions@shou.edu.cn
Web: https://ieo.shou.edu.cn/18220/list.htm
SHOU Facebook: https://www.facebook.com/SHOU1912/
Instagram: @shou_1912D

Download the prospectus:

https://enaca.org/enclosure/?id=1298

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NACA is a network composed of 20 member governments in the Asia-Pacific Region.