

AQUACULTURE

ASIA

Opportunities in the Brahmaputra lowlands

Gangetic swamp eel potential



Silver biddy breeding

The humane side of data





Aquaculture Asia

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

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NACA

An intergovernmental organisation that promotes rural development through sustainable aquaculture. NACA seeks to improve rural income, increase food production and foreign exchange earnings and to diversify farm production. The ultimate beneficiaries of NACA activities are farmers and rural communities.

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AQUACULTURE ASIA

Simple techniques to cut your *Artemia* costs

If you're using *Artemia* in your hatchery or nursery, I have both good and bad news. If, like me, you were taught to mix up some brine, throw in an airstone, shine a light on it and come back tomorrow, then the bad news is: you are most likely wasting a fair bit of it, or allowing its nutritional value to degrade, and probably without realising. Certainly, you aren't getting the maximum benefit out of it.

The good news is that you can improve the hatch rate, yield, and nutritional value as well as cutting your costs and biosecurity risks by following simple practices to optimise production.

FAO has published a series of fact sheets on good practices in the use and handling of *Artemia* in the hatchery. These provide step-by-step instructions along with diagrams as a visual aid. The fact sheets cover:

- Cyst storage.
- Cyst disinfection.
- Cyst decapsulation.
- Cyst hatching.
- Harvesting nauplii.
- *Artemia* enrichment.
- Nauplii cold storage.

The fact sheets summarise advice from the recently revised *FAO Artemia Manual*, and were developed by the Artemia Reference Center (Ghent University) with expert input from members of the International Artemia Aquaculture Consortium (IAAC).

You can download the fact sheets and the *FAO Artemia Manual* for free from the IAAC website at the link below, or from the FAO Knowledge Repository. Both the fact sheets and the manual will be available in additional languages in due course:

- <https://artemia.info/news/?id=177>

Also in the works, a matching video for each fact sheet will be released on YouTube so that you can see the techniques demonstrated firsthand. The videos should be out within a few weeks and will also be available via the link above.

In the meantime, I encourage you to download both the fact sheets and the manual, and take another look at your *Artemia* production process. As you are no doubt painfully aware, *Artemia* is expensive! These new publications will help you make the most of it.

Simon Wilkinson

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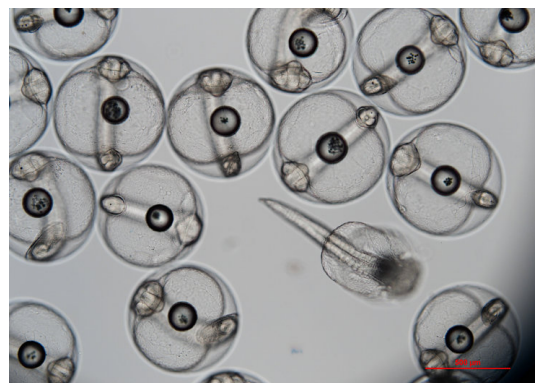
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From hormone to hatchling: A hands-on journey through carp breeding at hatchery

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Catla broodstock (*Labeo catla*).

Breeding life beneath the water

Bangladesh is a predominantly agricultural country, and the sector's contribution to its economy is significant. The abundance of fisheries resources also contributes strongly to socio-economic development. Natural fisheries distributed across the country help to underpin the industry. Bangladesh is currently one of the world's top fish producers, with total production of about 4.915 million tonnes in 2022-2023, up from 4.34 million tonnes in 2018-2019. This growth underscores ongoing commitments to enhance the fisheries sector, which plays a crucial role in national food security, employment and economic development.

According to the Food and Agriculture Organization of the United Nations (FAO, 2020), over the last 10 years Bangladesh ranked third worldwide for inland open-water fish production, and over the last six years it ranked second for freshwater fish production. For crustaceans and marine finfish, the country ranked 8th and 12th, respectively. The fishing industry makes a substantial contribution to socio-economic progress and poverty reduction. Fisheries account for 2.41% of gross domestic product (GDP) (DoF, 2023) and contribute about 25% of total agricultural income. Fish provide about 60% of daily animal protein intake. Against an average daily requirement of 60 g per person, national per-capita consumption is about 62.58 g.

Over the past decade, the fisheries sector has experienced steady GDP growth; over the last five years its contribution to GDP growth was 6.28%. Production trends over the last 36 years, disaggregated by sector, indicate that the contribution of closed reservoirs has more than tripled, reaching 57.39% (DoF, 2023).

Induced breeding

Without artificial reproduction, fish farming is limited. Induced breeding is a process in which an organism is encouraged to reproduce in captivity by administering a specific hormone (or other synthetic hormone) or by providing appropriate breeding conditions. The stimulation prompts the gonads to ripen and for the fish to engage in spawning. Hypophysation is the method of inducing reproduction by removing the pituitary gland and injecting an extract prepared from it into male and female broodstock.

History of induced breeding

After Houssay's production of pituitary extract in 1930, induced breeding was first developed in Argentina. In 1934, Brazil became the first nation to establish a method for hypophysation. Hamid Khan made the first attempt to induce breeding in mrigal *Cirrhinus mrigala* in India in 1937. Ali (1967) was the first to successfully induce spawning in carps in Bangladesh; the procedure was later codified (Islam & Chowdhury, 1976; Ahmed, 1983). About 98% of the country's fry are generated by hatcheries, which are a primary source of seed for fish culture (Amin, 2002).

General information on hatcheries in Bangladesh

The Government of Bangladesh has developed many public-sector hatcheries in various regions of the country following the success of fish-seed production using artificial breeding techniques. Over time, a substantial number of private hatcheries have also been established. Currently, there are 1,078 fish hatcheries in Bangladesh, of which 143 are public and 935 are private (Department of Fisheries, DoF, 2020). The country now produces sufficient carp seed domestically, albeit on a small scale and with high-quality seed. Of the Tk 50 billion incentive to address losses in the agriculture sector during the COVID period, the government offered Tk 1.04 billion (loans at 4% interest) to the fisheries sector.

Understanding carp breeding:

A brief overview

Carp breeding is a foundation of freshwater aquaculture, playing a vital role in ensuring a stable supply of seed for fish farming worldwide, especially in countries such as Bangladesh, India and China. As the need for protein-rich food increases, the importance of efficient, large-scale carp seed production has grown rapidly. To understand how we progress from hormone-induced brood fish to free-swimming hatchlings, it is important to grasp the basic principles behind carp breeding.

The natural vs induced breeding dilemma

In natural waterbodies, carp species such as rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*) spawn during the monsoon season in rivers and floodplains. Their spawning is triggered by environmental cues such as water flow, temperature and rainfall. However, these ideal conditions are not easily replicated in artificial ponds or hatcheries. To overcome this, fish breeders use induced breeding, which mimics the natural reproductive cycle of carps through controlled hormone administration and environmental manipulation. Induced breeding enables hatcheries to produce large volumes of quality seed even outside the monsoon season, ensuring year-round availability of fry for aquaculture.

Key components of carp breeding

Carp breeding typically involves the following steps.

Selection of broodstock

Healthy, mature male and female fish (broodstock) are selected based on size, age and health. Proper broodstock management - including regular feeding and disease control - is essential for successful spawning. Six carp species are used as broodstock here: catla, bighead carp, silver carp, grass carp, Hungarian mirror carp and common carp. This account refers to a commercial hatchery, Sonali Fish Hatchery (23.147401, 89.202167), situated at Chanhra, Jashore Sadar, Jashore.



Incubator.

Hatchery system

Fish fingerlings suitable for stocking in grow-out ponds are produced in hatcheries. A typical farm includes: (i) ponds for stocking brood fish for spawning, serving as donors of pituitary glands and holding spent females and males; (ii) a hatchery proper - often an indoor facility - for spawning, egg incubation, hatching and rearing hatchlings to the post-larval stage; (iii) nursery ponds for feeding post-larvae to the fry stage; and (iv) rearing ponds for raising fingerlings from fry. According to Jhingran et al. (1988), the hatchery is the most essential part of a modern fish farm.

The essential components of a modern hatchery proper are ante-tanks or storage tanks, breeding tanks or ward tanks, incubators or hatching jars, and larval-rearing tanks. Ante-tanks are used to hold selected ripe breeders before injection. The smallest hatchery should have at least two ante-tanks - one for each sex of a species. Sometimes ante-tanks are used for both breeding and larval rearing. Both circular and rectangular breeding tanks are used to facilitate partially natural breeding and fertilisation. In the hatchery described, there was one circular breeding tank. Carp eggs were incubated in funnel-shaped incubators; four incubators were available. The larval-rearing tank functions similarly to an ante-tank, and circular breeding tanks are occasionally also used for larval rearing.

Preparation of induced breeding

Brood fish pond preparation

The use of healthy brood fish is essential for good seed production. The hatchery had six rectangular, drainable brood-fish ponds. The average size of each pond was 1 hectare, with an average width of 25 m, and average water depth of 1.2 m. The ponds were treated with lime and sun-dried before brood fish were released, after which freshwater from the municipal supply was added. Pond water temperature ranged from 25-28 °C and was free of chlorine, pesticides, and undesirable substances. The pond bottom was clay-loam, capable of retaining water. The ponds were fitted to restrict the entry of undesirable fish. These characteristics facilitated brood-fish rearing, netting and feeding.



Ante tank / storage tank.

Feeding of brood fish

Supplemental diets provided essential nutrients such as protein, carbohydrates, vitamins and minerals. The supplemental feed comprised fish meal, mustard oil cake, rice bran and wheat bran, with a total protein content of about 30%. The proximate composition was mainly crude protein (30-40%), crude lipid (10-12%) and carbohydrates (20-30%). During autumn and winter, brood fish were fed at 2-3% of body weight; later, feeding increased to 5% of body weight. Feed should be offered twice daily at fixed times and locations. Diets could be ready-made or farm-made. Supplemental feed such as oilcake, rice bran, molasses, wheat bran, wheat flour, fish meal and vitamins was provided at 2-4% of total body weight per day, morning and evening, to improve seed production (Harvey et al., 1993).

Breeding tank preparation

The hatchery had two circular breeding (ward) tanks, each about 1 m deep. Before receiving brood fish, tanks were cleaned and sterilised with a potassium permanganate solution. Water was supplied from an overhead tank. pH was approximately neutral, and temperature ranged from 20-23 °C. The water was free of contamination, and oxygenated water flowed continuously through the tanks. The water level could be maintained via an outlet. Breeders were held in these tanks for natural spawning and fertilisation.

Netting

Seine nets were typically used for netting operations. For larger ponds, two nets were employed to improve efficiency. Netting was done early in the morning, when conditions are relatively cool and fish are active. Care was taken during netting to minimise stress and injury.

Selection of broodstock: choosing the right parents

To obtain high-quality sperm and eggs, broodfish were harvested during the peak of spawning. Age and weight of the broodfish are significant factors in breeding. The simplest method of selection is based on external characteristics, which farmers can manage with ease due to their experience. Unnecessary fish should be released into the pond immediately.

The proper age and weight of carp broodfish play a vital role in the success of induced breeding. Under standard hatchery practices, some carp species reach appropriate maturity for breeding at around two years of age. For example, both *Hypophthalmichthys nobilis* (bighead carp) and *H. molitrix* (silver carp) should be at least 2 years old and weigh over 2 kg. *Ctenopharyngodon idella* (grass carp) requires a somewhat higher body weight, with a minimum of 3 kg at the same age. Likewise, *Cyprinus carpio carpio* (European common carp) and *Cyprinus carpio* (common carp) should be at least 2 years old, with minimum weights of 2 kg and 1.5 kg, respectively. For *Labeo catla* (catla), a key Indian major carp species, broodfish should also be at least 2 years old and weigh over 2 kg. Ensuring broodfish meet these age and weight thresholds is important for optimal spawning performance and high-quality seed production in carp hatcheries.



Conditioning of brood fish.

Sex determination of breeders

Sex determination is a crucial step for successful reproduction because male and female hormone requirements differ. For induced breeding, males and females were identified and separated. Several physical characteristics help differentiate mature females and males during the breeding period. Female broodfish generally have a conspicuously bulging abdomen that extends beyond the pelvic region to the genital aperture, and the abdomen feels soft to the touch. The genital aperture appears swollen, protruding and turgid, with a pinkish margin. Pectoral fins in females are relatively small and weak, with a smooth inner surface. When gentle pressure is applied to the abdomen, eggs may be released through the genital pore. Females also tend to have a stouter body than males of the same age.

In contrast, male broodfish usually have a less pronounced abdominal bulge and a firmer abdomen. The vent is not protruding and appears pit-like. Males possess relatively long and prominent pectoral fins with a rough inner surface that can be felt by touch. Upon gentle abdominal pressure, whitish milt is released through the genital pore, and the overall body shape is thinner and more linear compared with females of the same age group.

The role of hormones in induced breeding

The choice of hormone depends on many factors, including species, cost, availability and egg incubation. Two main types of inducing agents were used:

- Pituitary gland (PG)
- Compound S-GnRHa (synthetic gonadotropin-releasing hormone analogue) "Ovaprim/Ovulin" fish-spawning hormone.

Pituitary gland is used for *Ctenopharyngodon idella* (grass carp), *Cyprinus carpio* (common carp), *Cyprinus carpio carpio* (mirror carp) and *Labeo catla* (catla). Compound S-GnRHa (Ovaprim/Ovulin) is used for *Hypophthalmichthys molitrix* (silver carp) and *Hypophthalmichthys nobilis* (bighead carp). PG used for induction was procured via marketing channels in

Bangladesh and India; it is favoured for ready availability and comparatively low price. The compound S-GnRHa (Ovaprim/Ovulin) used was manufactured by Shijiazhuang ZDHF Stock-Raising Co., Ltd., China, and is selected for ease of acquisition, relatively low cost and long shelf life.

The dosage of hormones and breeding protocol differ among carp species according to their physiology and spawning characteristics. For common carp, mirror carp and catla, both males and females are typically injected with pituitary gland extract (PG). Females receive a total dose of 6 mg/kg body weight, split into two doses: an initial priming dose of 2 mg/kg followed by a second dose of 4 mg/kg after an appropriate interval; males receive a single dose of 2 mg/kg at the time of the female's second dose. In grass carp, females receive a first dose of 1.5 mg/kg PG followed by 4 mg/kg after 6-8 h, and males receive a single dose of 2 mg/kg at the same time as the female's second dose. Silver carp and bighead carp may be induced using PG or a synthetic hormone such as S-GnRHa. For these species, females are administered a first dose of 230 IU S-GnRHa and a second dose of 7-8 mg PG (or equivalent) 9-12 h after the first. Males receive 2 mg PG at the time of the female's second injection, usually 6-9 h after the first dose. Timing and dosage must be managed carefully to ensure successful spawning and fertilisation.

A high-quality inducing agent is essential for an effective induced-breeding programme. The required PG was taken from storage and dried for 2-3 min on filter paper (each PG weighing about 3 mg). Glands were placed in a tissue homogeniser with distilled water, mixed, and further distilled water added as needed (typically 0.5 mL per kg body weight). The extract was then loaded into a syringe for injection. Alternatively, glands were transferred to a mortar and pestle,

crushed thoroughly and diluted with the required volume of distilled water. For S-GnRHa, the necessary dose was combined with distilled water (about 0.5 mL per kg body weight) and the solution injected.

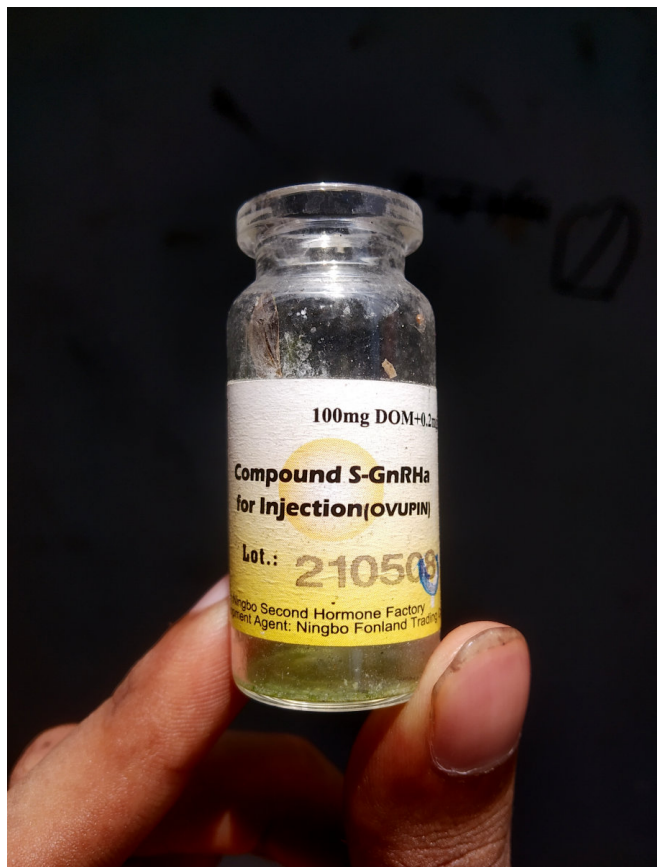
Prepared inducing-agent solutions were administered to breeders at mL/kg body weight. Accordingly, the proper dose of inducing agents and the weight of breeders were measured.

The injection process: timing and technique

Two injection techniques were applied. The initial (stimulating) dose was followed by a second (resolving) dose 6-8 h after the first. Females received both doses; males received a single dose at the time of the females' second injection. There are two possible injection routes: intramuscular and intraperitoneal. When the fluid volume does not exceed 2 mL, the intramuscular route is suitable for smaller fish. The intraperitoneal route is preferred for larger volumes, as the peritoneal cavity provides more space. In this study, injections were given intraperitoneally because volumes exceeded 2 mL. The base of the pectoral fin was the target site. To avoid injury to the heart, a small syringe was used. Broodfish were collected from tanks and covered with cloth during the procedure, with the eyes also covered. Fish were placed on a foam block, and injections were administered at a 45° angle to minimise the risk of internal injury. Fish were returned to tanks immediately after injection.



Pituitary glands.



S-GnRHa hormone.



Injecting the breeders.

Spawning and fertilisation: Nature meets science

After injection, breeders were held in breeding tanks at a 2:1 male:female ratio. Signs of spawning were observed. Artificial breeding was conducted for silver carp, bighead carp, grass carp, common carp, mirror carp and catla. Stripping was performed at a set time after injection. A very soft abdomen in the female indicated readiness. Brood females were removed, wrapped in cloth and, with gentle pressure on the abdomen, loose eggs were released from the genital opening into a plastic dish. The female was then returned to the tank.

Milt was extracted from a male and added to the same dish as the eggs; two males were used per female. The males were then released back to the tanks. Eggs and milt were gently mixed with a feather to achieve fertilisation, then repeatedly washed with clean water. Fertilised eggs were transferred to incubators.



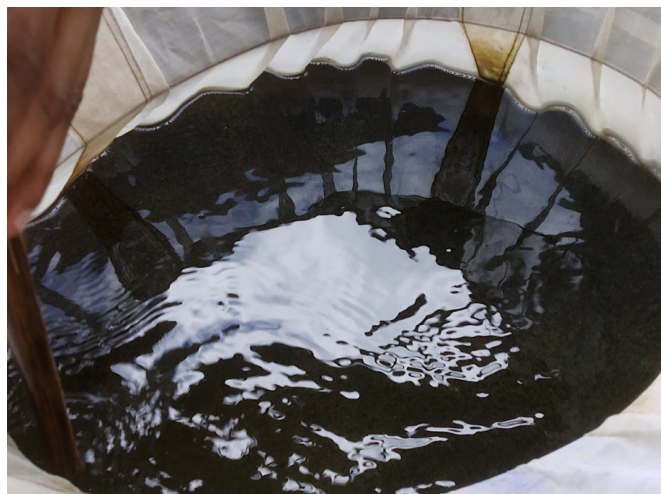
Egg stripping.



Milt stripping.



Mixing eggs and milt with a feather.



Eggs kept for incubation.

Hatching time: Monitoring the miracle

The incubation period is when the fish develops inside the egg. Fertilised eggs quickly swelled and turned slightly whitish. These were then transferred to incubators, where hatching occurred after 24-48 hours. In the hatching tanks, a hapa was placed around the fertilised eggs to prevent them from escaping with the draining water. The timing of hatching was affected by environmental temperature. No additional nourishment was provided during incubation. There were three main phases of egg development: the swelling phase, the cleavage and germ-development phase, and the embryonic development phase.

After 15-20 minutes of stripping, the appearance of the “eye spot” and the enlargement of fertilised eggs allowed for separation from unfertilised ones. Fertilised eggs were transparent, while unfertilised eggs appeared white and opaque. The fertilisation rate was estimated using the following formula:

Fertilisation rate (%) = (Number of fertilised eggs in sample / total number of eggs in sample) × 100

For hatching, fertilised eggs were placed in funnel-type incubators with a continuous flow of water. After 42-48 hours of fertilisation, eggs began to hatch. Hatchlings were collected in a dish, counted visually under a magnifying glass, and recorded. The hatching rate was calculated as follows:

Hatching rate (%) = (Number of hatchlings in sample / total number of fertilised eggs in sample) × 100

After hatching, fry did not consume external food for 70-72 hours, relying instead on their yolk sac for nourishment. After 72 hours, fry were fed boiled egg yolk, ground in a homogeniser, four times daily. Samples were taken after 96 hours to count live fry, and survival rate was calculated as:

Survival rate (%) = (Number of surviving fry in sample / total number of fertilised eggs in sample) × 100

Post-hatch management: Caring for the fry

Hatchlings from hatching jars and incubators were transferred to larval-rearing tanks by siphoning and acclimatised before release. Continuous water flow and aeration were maintained after transfer. On the third day after hatching, samples of hatchlings were observed in a beaker or petri dish to determine readiness for exogenous feeding. Once the yolk sac was mostly absorbed, vertical movement shifted to horizontal swimming, signalling feeding readiness. Artificial feed was introduced at this stage, primarily boiled chicken egg yolk (one yolk per 2-3 kg of larvae). Overfeeding was avoided. Hatchlings were reared for 24-48 hours before being sold.

Delivery and transportation of fry

Fry were transported in double-layered polythene bags placed inside a third outer plastic bag. Fry were collected from the larval-rearing tank using polyester cloth and sold on



Larvae.

a wet-weight basis, measured with a cup. The weighed fry were placed in bags pre-filled with clean groundwater (about 5 L per bag). For transporting 1 kg of fry, four such bags were used. After adding fry, the bag was filled with pure oxygen gas - one-third with water and two-thirds with oxygen. The top was twisted and tightly sealed with a leak-proof knot to prevent oxygen loss during transport.

Challenges in carp hatcheries: Practical insights

Hatchery owners are often unaware of the exact lineage of broodstock, leading to inbreeding depression. The focus tends to be on high output and profit. In the absence of skilled personnel, fish are sometimes handled inappropriately and age records are not maintained accurately. With limited research undertaken at hatcheries, fish-seed quality has not improved. Poor hormone quality, incorrect dosages, the use of immature breeders and rough physical handling all contribute to broodfish mortality - factors that remain poorly understood. Hormones are expensive, and dosing and administration are sometimes incorrect. Pond soil quality may decline over time with repeated use. Hatchery workers may also struggle to maintain hygiene due to insufficient sanitation training. In addition, water supply is frequently disrupted by power failures.

Endnote

The journey from hormone to hatchling encapsulates the delicate balance between scientific precision and hands-on hatchery practice in modern aquaculture. Through induced



Packing.



Filled bags.



Oxygenating bags for transport.



Loading bags onto a truck.

breeding, seasonal and environmental constraints on natural spawning can be overcome, ensuring a consistent and controlled supply of quality carp seed. By understanding each step - from broodstock selection and hormone administration to fertilisation, incubation and fry management - we gain not only technical knowledge but also a deeper appreciation of the vital role hatcheries play in sustaining fish production. This hands-on approach shows how innovation and traditional skill together shape the future of aquaculture, providing important lessons for aspiring professionals and contributing to food security and rural livelihoods.

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Aquaculture opportunities in lowlands of Brahmaputra valley, Assam

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A haul of carps in polyculture system.

The floodplains of the Brahmaputra valley in northeast India are rich in aquatic resources, including rivers, streams, wetlands (beels), ponds and tanks. Studies on the productivity of warm-water fish in lowland water bodies have received much attention in western and central India, but similar research in the northeastern states is lacking. The lowland water bodies of the Brahmaputra valley are important habitats and conservation sites for many native fish species. Developing fish farming technology, seed production and recreational facilities in these areas can improve food security and livelihoods for people living in these fragile but productive lowland regions.

The ICAR-Indian Agricultural Research Institute was established on 26 May 2017 with the laying of the foundation stone by the Honorable Prime Minister Shri Narendra Modi ji in the easternmost Dhemaji district on the north bank of the Brahmaputra valley. The institute serves agricultural research and education across Northeast India and aims to advance higher agricultural education throughout South-east Asia. As the institute has grown, a second centre at Gerua, Hajo in Kamrup (Rural) District was transferred from ICAR-National

Rice Research Institute to ICAR-IARI Assam on 31 August 2025. The Gerua Centre covers 12.20 ha across two sites: Gerua and Abhaypur. One of the centre's mandates is to increase and sustain productivity of rice-based farming under rainfed lowland conditions. With this in mind, an assessment was conducted from 22–26 September 2025 to identify opportunities to integrate fish farming with other agricultural activities at the Gerua campus and its surroundings. The following aquaculture-based research and development programmes showed strong potential in the region.

Integrated farming system

Combining rice cultivation with fish farming using quality fish seed, appropriate stocking sizes, culture duration and ratios in trenches and dugouts along rice fields can increase overall productivity per unit area¹. Growing horticultural crops such as Assam lemon, banana, papaya, betel nut, coconut, dragon fruit, guava and apple bogori on the embankments can further increase production from the integrated unit. Adding suitable duck varieties such as Khaki Campbell and Indian Runner

can boost egg and meat production. Integrating fish farming with pig breeds such as Hampshire and Ghungroo, and poultry breeds such as Kadaknath, Gramapriya, Vanaraja and Giriraja, is a proven option in the northeast. Waste water and muck from the fish ponds can be used as manure for crops on the dykes.

Polyculture

Fish ponds and tanks in the region are mainly carp-based, as in most parts of the country. Farmers are also stocking *Chitala chitala* (chital) and *Piaractus brachipomus* (roopchanda), along with minor carps such as *Labeo calbasu*, *L. gonius*, *L. bata* and *Cirrhinus reba*. Other species such as *Puntius sarana* (seni puthi) are also stocked. Current yields range from 3,500 to 4,500 kg per ha. Low production in these systems is likely due to imbalanced stocking densities, poor-quality seeds from unreliable suppliers, insufficient supplementary feeding and poor water management. Adopting best management practices suited to Assam conditions can increase pond productivity and improve returns for farmers in the region.

Monoculture

Some fish farmers in the region cultivate *Anabas testudineus* (vietnami kawoi). Ponds of 1,000–5,000 m² are used for monoculture. Fertilisers such as urea, single superphosphate and organic manures promote dense plankton growth, visible as green pond water. The fish are reared from April to September, a period of five to six months. Fish seeds are sourced from West Bengal and the nearby district of Nalbari. The species' ability to breathe air and tolerate extreme conditions makes it a strong candidate for aquaculture². The harvested fish are marketed across the Northeast region according to demand.

Fish fingerling production

Another opportunity is short-term nursery rearing, raising day-old fish spawn to fingerling size over two to three months. Spawn can be procured cheaply from a reputable nearby hatchery and reared until fingerlings reach 100 mm, ready for stocking in larger ponds. Water quality, plankton production and fish health management are all important during the pre-stocking and post-stocking process. Fingerlings can be sold to local farmers at a much higher price than the cost of spawn. Selling fish seed is a viable source of income for small-scale farmers. Low-lying areas currently choked with grass and weeds can be converted into fish nurseries to maximise their value.

Ornamental fisheries

Ornamental fish are in high demand across the northeast. The Gerua Centre benefits from its proximity to Guwahati, the capital of Assam. Most inputs for ornamental fish farming - markets, aquarium accessories, fish species, vendors and traders - are readily available in Guwahati. The region's rail and air links are an added advantage for import and export trade. Many commercially valuable exotic and indigenous ornamental species can be reared and bred at the Centre with



Integrated fish with piggery.



A fish pond for polyculture of carps.



Integrated fish cum duck farming.



Monoculture of kawoi (climbing perch).

basic facilities such as glass tanks, small earthen or concrete ponds and FRP tanks. Fish produced at the Centre can be sold locally or traded to distant markets, providing another revenue stream for the Centre. Developing a public aquarium would be a significant step for the institute, generating revenue and promoting public education.

Biofloc technology

Biofloc technology is another promising option. It uses in-situ microorganism production to continuously recycle and reuse nutrients in the culture medium, with minimal or zero water exchange. Air-breathing fish such as *Heteropneustes fossilis* (singhi), *Clarias batrachus* (magur), *Ompok pabda* (pabda), *Anabas testudineus* (koi) and *Pangasianodon hypophthalmus* (pangasius), as well as non-air-breathing fish such as *Cyprinus carpio* (common carp), *Labeo rohita* (rohu) and *Oreochromis niloticus* (tilapia), are reared in this system. Seeds for these species are available from reputable hatcheries in Guwahati and adjoining districts such as Barpeta, Nalbari and Nagaon. A small, suitable site can generate profitable returns for farmers in the region. This technology suits farmers with small landholdings and new entrepreneurs. Skills training and demonstration programmes run by the Gerua Centre can help fish farmers take up biofloc technology as a viable livelihood.

Recirculating aquaculture systems

Recirculating aquaculture systems (RAS) provide a controlled environment for high-density fish culture, reducing water use and land requirements while offering better biosecurity than traditional open-water aquaculture. Water is recycled and reused after mechanical and biological filtration to remove suspended matter and metabolites. Fish are grown at high density in indoor or outdoor tanks rather than in open ponds or raceways. Units can be installed using equipment from local suppliers in Guwahati. Fish produced in this system sell readily in the region, particularly in Guwahati. A RAS could be planned for the Centre, given the available space. RAS allows fish to be reared in a small area, making it suitable for farmers with marginal land, urban settings and areas with limited water. Some local residents have suggested installing RAS units on rooftops.

Freshwater pearl culture

Freshwater pearl farming in India mainly uses the Indian pond mussel (*Lamellidens marginalis*) and involves a culture period of 15-18 months. The process requires nucleation, implantation and rearing, and demands technical expertise. Pearl culture can be practised in ponds and wetlands with the right care and skills. This system has strong prospects in the Hajo region and can deliver significant economic returns. Pearls can be traded easily from the Hajo or Gerua region thanks to the proximity of Guwahati and its transport links. This practice would be an innovative addition to aquaculture in Assam, making use of underutilised aquatic resources. Careful, coordinated effort by aquaculturists, jewellers, traders and entrepreneurs at the Gerua campus could establish freshwater pearl production in the region.



Monoculture of commercially important fish species.



Underutilised aquatic resources of for fish seed trade.



Unmanaged fish ponds for short term seed rearing.



A unit of biofloc for raising high valued fishes.



Freshwater pearl culture as an innovative avenue.

Recreational fisheries

Fish-based recreational attractions can be developed in the region. Hajo is already a tourist destination that draws visitors regularly from Guwahati. The nearby foothills of Bhutan, Meghalaya and Arunachal Pradesh offer additional opportunities for riverine communities and aquaculture entrepreneurs. This could also support conservation of coldwater and hill stream fish species through catch-and-release angling and fish watching. Recreational fisheries could stimulate growth in related businesses such as homestays, trekking, water sports, bird watching, cycling, rafting and souvenir shops. Fish seed ranching programmes can be carried out in natural water bodies to restock depleted fish populations. Other options include managing underutilised open-water systems in wetlands (beels) through cage and pen culture. These wetlands can also be developed as recreational hubs for travellers and tourists.

Wetland fisheries

Wetlands are low-lying areas and an integral part of the Brahmaputra and Barak drainage systems in Assam. The state holds 50% of India's wetlands, locally known as beels. These wetlands provide a substantial fish harvest, and a large part of the state's population depends on them for food and livelihood⁹. The beels are naturally replenished by fish migrating from adjacent rivers through connecting channels. However, the use of intensive fishing gear has led to over-exploitation and declining fish productivity. Plant infestation, heavy siltation, encroachment by human settlement, the introduction of exotic species and illegal



Possibilities of recreational options in low lying wetlands.



Installed cage culture in wetlands.



Fish seed production in cages for restocking in wetlands.

fishing have further reduced fish catches. Given this situation, culture-based fisheries in these wetlands offer an ideal option for fish production. Cage culture is already practised in the region, where fish seeds are stocked for three to four months and then released into the beels. These water bodies are rich in nutrients and live food organisms, supporting rapid fish growth. Species stocked in cage culture include pangasius, koi, roopchanda⁴, carps, magur and singhi. When water levels recede in winter, fish-aggregating devices (katal mara, jeng) are used to harvest fish for market. The beels are usually leased on short-term arrangements by the government to lessees and mohalders.

Conclusion

The Northeast region has great potential for fish-based development, provided the necessary infrastructure is in place. The region's natural environment also offers significant tourism assets. Promoting aquaculture in rural areas requires integrated planning alongside regional economic and social development. No aquaculture plan can succeed unless it is linked to the development of local communities through employment and livelihood opportunities. Developing underutilised wetlands is one important avenue. Aquaculture is a fast-growing industry but still lags behind agriculture and livestock in many aspects of production technology, including improved certified fish seeds, feeds, diversified farming systems, species selectivity, water budgeting, biotechnology and value-added fish products. Further research in these areas can complement traditional practices and improve

the competence and productivity of aquaculture, whether the innovations come from farmers, research institutions, companies or governments.

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Aquaculture potential of *Ophichthys cuchia* in Northeast India: Current understanding and prospects

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Northeast India encompasses eight states (Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura), with diverse freshwater ecosystems including floodplain wetlands, ox-bow lakes (beels), seasonal rice paddies, and extensive river systems fed by the Brahmaputra and Barak river basins. The region supports a wide variety of indigenous freshwater fish, many with significant food, cultural, and economic value for local communities. Among these, the swamp eel *Ophichthys cuchia* occupies a distinct position. The species is well established as a food fish with strong market demand, yet it is almost entirely dependent on wild capture. The progressive decline of natural stocks, combined with growing domestic and international demand, shows the need to assess the potential of captive culture as a conservation and livelihood strategy. This article reviews available scientific information on the biology, nutrition, and culture potential of *O. cuchia*, with particular reference to northeastern India.

Taxonomy and morphology

O. cuchia, first described by Hamilton 1822 and initially assigned to the genus *Monopterus*, belongs to the order Synbranchiformes and the family Synbranchidae. The species is commonly referred to as the Gangetic mud eel, swamp eel, or rice eel, and is known locally as "cuchia" across Assam and northeastern India. The family name Synbranchidae derives from the Greek words syn (fused) and branchi (gills). This reflects the defining anatomical feature of the group: the paired gill openings, which are separate in most teleost fish, are fused into a single median ventral aperture beneath the throat. The body is highly elongated with a circular cross-section. The dorsal and anal fins are fused with the caudal fin, forming a continuous ribbon-like structure along the rear of the body. Pectoral and pelvic fins are entirely absent.



Gangetic mud eel, *Ophichthys cuchia*.

Numerous spots are present over the tail region, and the species lacks a swim bladder. Maximum recorded total length (TL) is approximately 79.7 cm in male or unsexed individuals. Notably, females attain a larger body size than males during the breeding season, with an average weight of 0.34 kg and length of 78 cm - the opposite of the pattern observed in *M. albus*¹.

Internally, gill tissue is present on both sides of the pharynx but is considerably reduced in structure and function. This is compensated by several accessory respiratory adaptations. *O. cuchia* is an obligate air-breather, using the highly vascularised buccal and pharyngeal mucosa, the skin, and a pair of suprapharyngeal air chambers for atmospheric gas exchange - structures absent in *M. albus*. Two suprabranchial chambers are additionally present, each containing a labyrinthine organ. Pharyngeal pouches develop early in life but become functionally active only later. These adaptations collectively underpin the species' remarkable tolerance of hypoxic environments and its capacity to survive without water for extended periods.

Distribution and habitat

O. cuchia is naturally distributed across Pakistan, India, Nepal, Bangladesh, and Myanmar. Within India, it is predominantly recorded from northern and northeastern states, with confirmed presence in Assam, Tripura, and riverine systems in the sub-Himalayan foothills. The species has also been recorded from Maharashtra, and is present in the Buxa, Adma, and Jayanti rivers in the sub-Himalayan zone of West Bengal. It occurs at altitudes from 76 to 1,350 m above mean sea level. The species inhabits freshwater and brackish water environments, favouring ponds, rivers, haors, beels, canals, floodplains, and rice fields with muddy substrates. Adults are reported to hibernate in mud during cold seasons. Males construct and guard nests or burrows, which has implications for captive breeding management.

Feeding ecology

O. cuchia is nocturnal and carnivorous. Natural diet items include small fish, tadpoles, aquatic insects, crustaceans, earthworms, snails, and aquatic invertebrates. In captive trials, the species has accepted supplementary

feeds including animal-based ingredients and mixed diets. Its strong preference for protein-rich, animal-based food is a key consideration for feed formulation, with direct implications for feed cost and the feasibility of partial substitution with plant protein sources.

Reproductive biology

O. cuchia exhibits protandrous hermaphroditism, where individuals begin as males and may transition to female as they mature. This sequential sex change complicates induced breeding programmes, as the sex ratio and transition timing in captive populations are not yet well understood. The gonadosomatic index peaks between April and June in both sexes, with the highest female GSI recorded at 9.04 ± 1.02 and male GSI at 2.52 ± 0.44 in May, declining through November in both sexes². Under Meghalaya agro-climatic conditions, peak male GSI of 3.4 ± 0.8 and female GSI of 7.33 ± 0.081 were recorded in May, with the lowest values occurring in September and December, respectively³. Spawning occurs in burrows constructed and guarded by the male, typically during the summer months. Average fecundity ranges from 150 to 924 eggs, with ova diameter measuring 3 to 4 mm between September and May⁴.

Induced breeding of *O. cuchia* remained elusive for many years, with early attempts using PGE, HCG, and GnRH yielding no successful results¹. The first documented success was achieved by Begum et al. (2017), who used pregnyl at a

single dose of 1,000 IU/kg body weight for females and 500 IU/kg for males in pond conditions, with brooders released at a 1:1 ratio. Approximately 3,000 larvae were collected from spawning pits following pond drainage. Of particular relevance to Northeast India, successful induced breeding has been reported under the agro-climatic conditions of Meghalaya. Using Gonopro-FH at 1 mL/kg for females and 0.3 mL/kg for males, researchers achieved 75 to 80% fertilisation and 80 to 85% hatching rates. Fecundity was recorded at 924 eggs from a 344 g female⁴. In larval rearing trials, three-day-old larvae stocked at 1,000/m² were initially fed boiled egg yolk, then earthworms, zooplankton, and chopped tubifex from the third day at 5 to 10% of body weight. The larvae attained 10.68 cm and 1.09 g after four months, with a survival rate of 80%⁵. Despite these advances, standardised protocols suited to Indian agro-climatic conditions across the northeastern states have not been developed, representing a significant gap for commercial aquaculture development.

Nutritional composition

The nutritional profile of *O. cuchia* has been described in several studies, predominantly from Bangladesh. The average protein content of raw muscle is approximately 18.7 g / 100 g. Studies using different cooking methods reported protein content in raw and cooked muscle ranging from 14.5% to 21.3%, depending on thermal treatment. Twenty different fatty acids have been identified in the muscle, with palmitic acid (a saturated fatty acid) being the most abundant,





O. cuchia inhabits freshwater and brackish water environments, favouring ponds, rivers, haors, beels, canals, floodplains, and rice fields with muddy substrates.

occurring at 26.51% to 29.70% in raw and cooked samples. Omega-3 polyunsaturated fatty acids (PUFAs) were recorded at 7.54% to 13.7% in raw muscle, though thermal processing reduces PUFA content. The pattern of fatty acids followed the order: saturated fatty acids (SFA) > monounsaturated fatty acids (MUFA) > polyunsaturated fatty acids (PUFA).

Seven essential amino acids have been identified in the muscle, with lysine occurring in the highest concentration. Eight non-essential amino acids were identified, with glutamic acid, arginine, glycine, and aspartic acid as primary components. Seasonal variation in nutritional composition has been documented, with lipid content showing wider seasonal fluctuation than protein content.

Studies have also characterised the mineral composition of *O. cuchia* muscle, reporting notably high calcium content alongside other essential minerals, making it a recommended dietary source for mineral-deficient populations. The fish is also reported to have high erythrocyte indices, and its iron-rich profile has been associated in traditional practice with managing iron-deficiency anaemia. Across communities in Northeast India and Bangladesh, *O. cuchia* is specifically recommended for pregnant women, nursing mothers, and those recovering from illness, based on the belief that it supports haemoglobin synthesis and blood cell production. These traditional uses are broadly consistent with the known nutritional composition of the fish, though clinical validation of its efficacy in managing anaemia or supporting maternal nutrition has not been reported in the peer-reviewed literature.

Given the high burden of iron-deficiency anaemia among women of reproductive age in Northeast India, this dimension of the species' nutritional value merits formal investigation.

Conservation status and threats

O. cuchia has been listed as a threatened species in Bangladesh. In India, while the species is not currently listed under the Wildlife Protection Act, researchers have noted its progressive decline in natural water bodies across north-eastern states. The IUCN Red List categorises the species as 'Least Concern' (IUCN taxon ID: 166554), but notes that the last assessment was in 2010 and needs updating. The conservation status of *O. cuchia* in the Indian context warrants updated evaluation.

Primary threats include unregulated and intensive wild capture, seasonal and permanent loss of wetland habitat through drainage and agricultural conversion, and siltation of floodplain water bodies. Pesticide contamination of rice-field ecosystems is also a significant concern, given the species' dependence on paddy habitats. The decline of *O. cuchia* has both ecological consequences, given its role as a mid-level predator in freshwater food webs, and socio-economic consequences for communities dependent on wild capture.

Captive culture: evidence and constraints

Organised aquaculture trials for *O. cuchia* have been conducted primarily in Bangladesh, with limited documentation from India. A five-month on-farm management study stocked baby eels weighing 50 to 70 g at a density of 10 individuals/m² in earthen ponds following liming at 250 kg/ha⁶. Researchers installed sanctuary structures including bamboo roots, hollow pipes, and aquatic vegetation to simulate the species' natural burrowing behaviour - a critical welfare and growth consideration. Water quality parameters remained within acceptable ranges throughout, and the study concluded that pond-based culture under this management regime was feasible. Provision of adequate shelter is a non-negotiable husbandry requirement. Semi-intensive monoculture trials assessed three stocking densities - 33, 42, and 51 fingerlings/m² - over 240 days. Under optimised conditions, yields of approximately 1,440 kg/ha over 150 days were reported, with survival reaching 90% and a feed conversion ratio as low as 1.0. Economic analysis from these trials indicated that net monetary profit was achievable, though profitability was sensitive to feed type and stocking density. In a separate study, stocking at 7,410 fingerlings/ha in a 0.14 ha earthen pond resulted in a weight gain of 362.10 ± 5.74 g from an initial weight of 99.10 ± 1.80 g over 240 days. Production reached $2,505.73 \pm 8.38$ kg/ha, with a feed conversion ratio of 1.95 and a survival rate of $93.40 \pm 1.27\%$.

Despite these encouraging results, several constraints continue to limit the scaling of *cuchia* aquaculture. Seed supply remains the most critical bottleneck, as no established hatchery network producing *O. cuchia* fingerlings exists in India, and natural seed collection is unreliable and seasonally constrained. The protandrous reproductive system adds further complexity to controlled breeding efforts. High dietary protein requirements increase feed costs. A formulated diet of 50% fish paste, 40% fish meal, 5% rice bran, and 5% wheat flour has been shown to support growth from 50-70 g to 165-176 g over five months⁶. However, partial substitution of animal protein with plant-based alternatives has not been adequately validated and remains a priority research area.

Disease profiles in cultured populations have received only preliminary attention. Parasitic infections by *Argulus* spp. and *Ergasilus* spp. have been identified as the primary disease agents in captive populations, and cestode infections have also been reported, with prevalence appearing higher in females than in males¹. Effective prevention and treatment strategies nonetheless remain largely undeveloped.

Prospects for aquaculture development in Northeast India

Ecological suitability. The ecological tolerances of *O. cuchia* - including resistance to low dissolved oxygen, capacity for air-breathing, and adaptability to shallow and variable water conditions - make it well suited to the seasonal wetlands, rain-fed ponds, and rice paddy systems that dominate the northeastern states. The species has been recorded naturally in paddy field habitats, and at least one rice field culture trial in Bangladesh demonstrated positive individual growth (310.63 ± 17.59 g over five months) and the highest net

economic return among tested systems when fingerlings were stocked at 5,187/ha under semi-intensive management⁸. Integration of *O. cuchia* into rice-cum-fish farming systems in Northeast India therefore warrants investigation, given the region's extensive rain-fed paddy landscape and the cultural familiarity of farming communities with both rice cultivation and the species itself. However, the burrowing behaviour of the species presents a practical management concern, as burrow construction in embankments may compromise paddy bund integrity and increase the risk of fish escape. Reinforced bunds, barrier netting along embankment walls, and the provision of trench refugia would likely be necessary structural modifications. Critically, the complete exclusion of pesticide application is a prerequisite for any viable rice-cuchia integration system, which has direct implications for the pest management practices of participating farmers. Controlled trials examining these parameters under northeastern Indian agro-climatic conditions are currently absent from the literature and represent a clear research opportunity.

Market demand and economic potential. Market demand for *O. cuchia* in northeastern India is well established. The species commands a notably higher price than most commonly cultured freshwater fish in local markets across Assam and Tripura, a reflection of both its perceived medicinal value and its declining wild availability. A 2025 local market survey recorded *O. cuchia* selling at Rs. 800/kg in Manipur, compared to Rs. 150 to 200/kg for common carp - underscoring the considerable premium the species commands over conventionally cultured freshwater fish. Wild-caught individuals in other northeastern markets have been informally reported to fetch between INR 500 and INR 1,000/kg or more, varying by season and locality, with prices rising sharply during periods of low availability. This places it among the highest-value indigenous freshwater fish in the regional market. The international dimension is illustrated by Bangladesh's documented export earnings of approximately USD 25.37 million from roughly 1.3 million kg of mud eel in the fiscal year 2016-17, with exports to over 15 countries including China, Thailand, Japan, Malaysia, and South Korea⁹. While India has not developed a comparable export trade, the proximity of northeastern states to these markets and improving regional trade infrastructure represent a plausible long-term opportunity. However, this would require substantial investment in both production capacity and export certification infrastructure before it could be considered commercially viable.

Livelihood and food security dimensions. Small-scale *cuchia* aquaculture has potential relevance for rural and tribal communities who already possess cultural familiarity with the species as a wild resource. Household-level and semi-intensive farming models, analogous to those demonstrated in Bangladesh, could contribute to household protein security and supplementary income generation. Cemented tanks and locally available water harvesting structures such as *jalkunds* - widely promoted across the hill districts of the region - represent low-cost infrastructure options that could be adapted for small-scale *cuchia* culture without major capital investment. Rearing *O. cuchia* fry in cemented cisterns has been demonstrated experimentally, with fry stocked at 75 individuals/m² attaining a mean body weight of 5.32 ± 0.04 g with $70.34 \pm 1.25\%$ survival after 45 days¹⁰ - supporting the feasibility of such low-infrastructure production systems.

Conservation relevance. Successful captive culture, by reducing dependence on wild-captured individuals, could contribute to relieving fishing pressure on natural populations. However, hatchery seed production would need to be established at meaningful scale before this benefit becomes practically significant.

Research priorities

The following areas require priority attention to enable evidence-based aquaculture development of *O. cuchia* in Northeast India. Induced breeding protocols under controlled conditions must be developed and validated for Indian agro-climatic settings. Larval rearing methodology, including early nutrition requirements, represents a critical but poorly characterised phase. Region-specific growth performance and survival data are needed. Feed formulation research is required to identify cost-effective, partially plant-protein-based diets that meet the species' nutritional requirements without compromising growth and survival. Disease surveillance and pathogen characterisation in captive populations require systematic attention. Finally, farm-level economic analysis specific to northeastern Indian input costs and market conditions must be conducted to assess the practical viability of different production systems. At the policy level, active promotion of *O. cuchia* farming through existing government schemes such as the Pradhan Mantri Matsya Sampada Yojana, combined with targeted extension support for northeastern farmers, could help translate research findings into field-level adoption.

Conclusion

O. cuchia is a nutritionally and commercially valuable indigenous freshwater fish with established market demand and a strong ecological fit with northeastern India's water bodies and farming systems. Available evidence from captive culture trials, primarily from Bangladesh, demonstrates that the species can be maintained and grown under managed conditions with reasonable production efficiency. However, the absence of hatchery infrastructure, standardised breeding protocols, and region-specific production data means that large-scale aquaculture development in Northeast India remains at an early stage. Systematic investment in applied research, seed production capacity, and farmer-level extension is necessary to translate the biological and market potential of this species into a viable and sustainable aquaculture enterprise.

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Successful spawning and rearing of silver biddy, *Gerres oyena* in Abu Al Abyad Island, Abu Dhabi, United Arab Emirates

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Gerres oyena (silver biddy), locally known as *badah*, belongs to the family Gerreidae. It is widely distributed across the Indo-West Pacific region, from the eastern coast of Africa to the Red Sea and the Arabian Gulf, through southern Asia, Polynesia, Australia, and China, supporting significant commercial fisheries (Lieske & Myers, 1994; Froese and Pauly, 2000). In the Arabian Gulf, it is mostly found on sand or mud bottoms and near coral reefs. It is also common in grass meadows in Umm Al Quwain lagoons (Tamaei, 1999) and in mangrove swamps in Abu Dhabi, Umm Al Quwain, and Ras Al Khaimah, where it is one of the dominant species (Al-Ghais, 1993). The species feeds mainly on small organisms and benthic invertebrates, including polychaetes living on sandy substrates, making it a vital part of its ecosystem (Randall, 1995; Lieske & Myers, 2004). Although not caught in large quantities, it has significant economic value as a low-cost commodity, mainly taken by bottom trawls and seines (Shallard, 2003). As *badah* is an important commercial fish, the Environmental Agency Abu Dhabi (EAD) has introduced management measures to address declining stocks and ensure sustainability (EAD, 2020). In the UAE, the species remains under-researched in age, growth, and reproduction.

The Aquaculture and Marine Studies Center (AMSC) on Abu Al Abyad Island conducted induced spawning trials for *Gerres oyena*, with the primary aim of developing methods for successful fingerling production. This work could contribute to the sustainable management and conservation of the species in the Arabian Gulf, reverse declining catch trends, ensure the species' long-term viability, and support regional aquaculture development.



Broodstock source and maintenance

Staff collected 230 females and 120 males of Silver biddy, ranging from 0.1 kg to 0.14 kg, from waters surrounding Abu Al Abyad Island. The fish were kept in circular indoor quarantine tanks with a capacity of 20 tonnes each. Staff treated the fish with 50 ppm formalin for five consecutive days. The fish were fed *ad libitum* with sardines and squid.

After three days, staff began feeding the brooders a supplemented diet three days a week for one year. This consisted of 3% BW Vitals Cal pellets soaked in fresh water (1:1.5 ratio for 24 hours), with 1 g MCP, 2 g vitamin C, 2 g vitamin E, 10 ml fish oil, and 2 g β -glucan (GL300) per kg, prepared over 24-30 hours. The soft pellets were stuffed inside squid before feeding. On the remaining two days, staff fed headless fresh sardines. The fish adapted quickly to captivity and accepted both fresh fish and pelleted

feed. Staff maintained salinity between 35-40 ppt and temperature between 23-26°C.

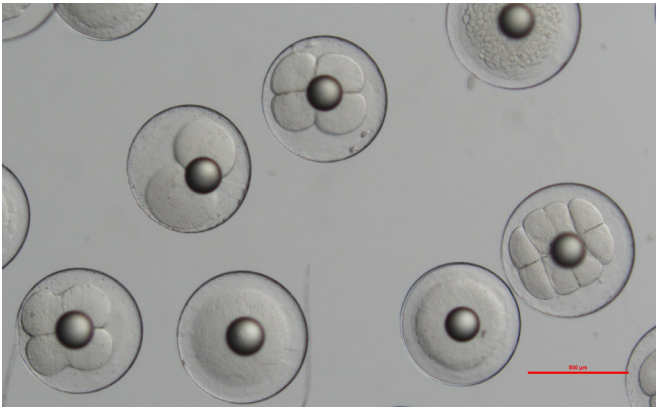
After quarantine, staff transferred the Silver biddy brood stock to the Centre's brood stock cages in Abu Al Abyad waters, where the salinity was 50 ppt, and fed them appropriately before spawning.

Spawning induction and larval development

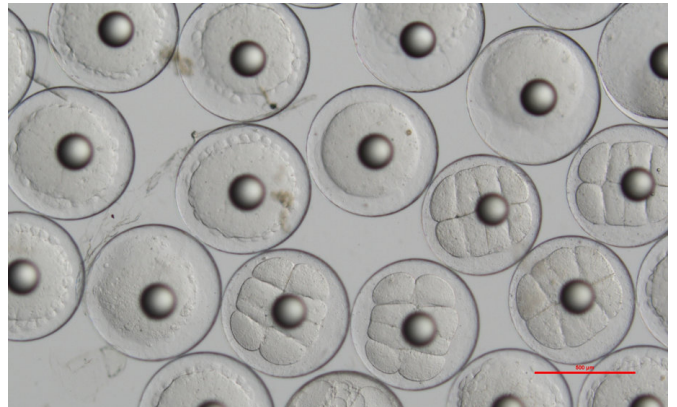
Staff assessed brood stock maturity through ovarian biopsy using a polyethylene cannula. They examined and measured the collected oocytes under a microscope. Females with oocytes measuring $400 \pm 50 \mu\text{m}$ in diameter were selected for spawning induction.

On 17 April 2025, staff segregated 120 males weighing 0.1 kg each that were exhibiting running milt. Staff transferred 230 females and 120 males to four indoor spawning tanks (15-tonne

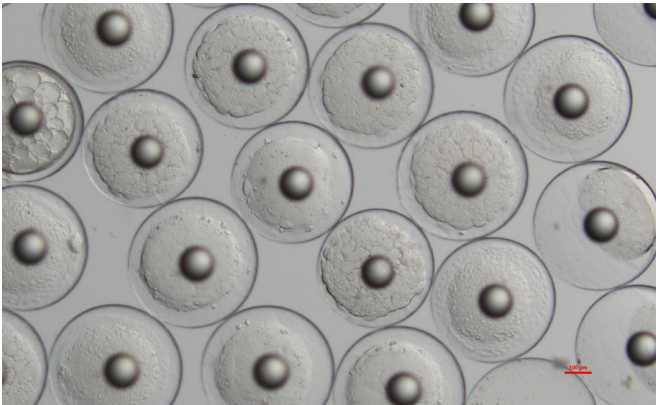
Embryonic development of *Gerres oyena*.



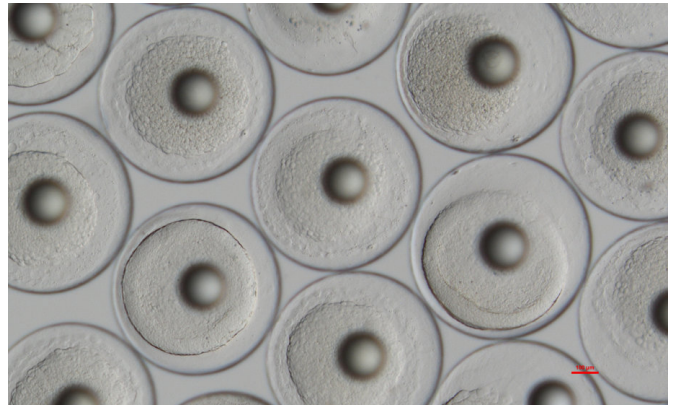
A: 2 and 4 cell stage.



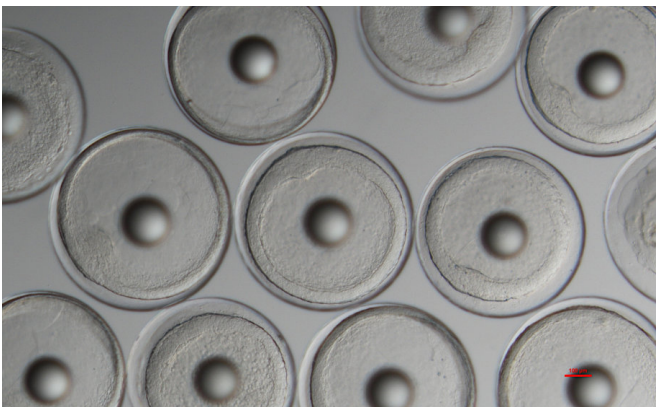
B: 8 cell stage.



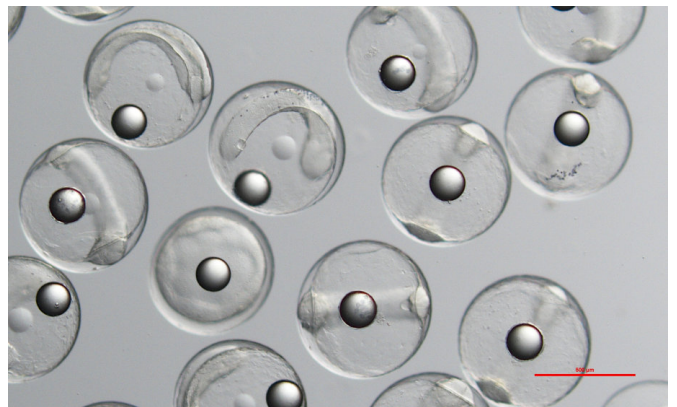
C: Morula and blastula.



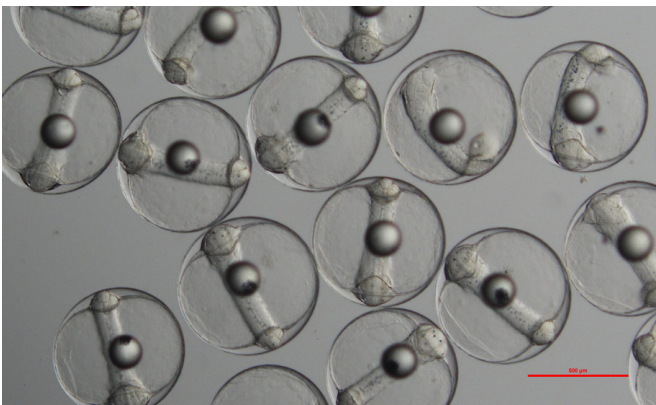
D: Gastrula.



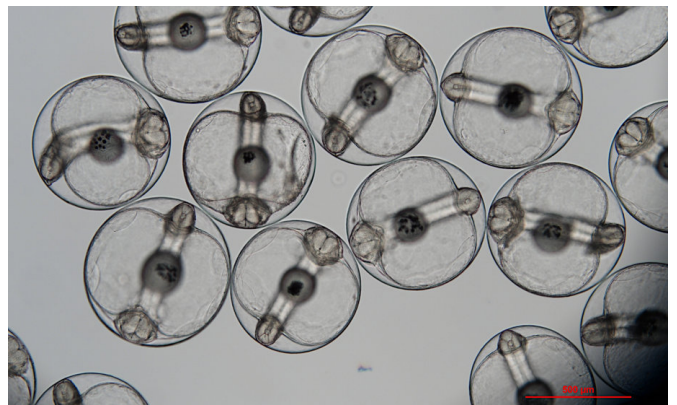
E: Neurula.



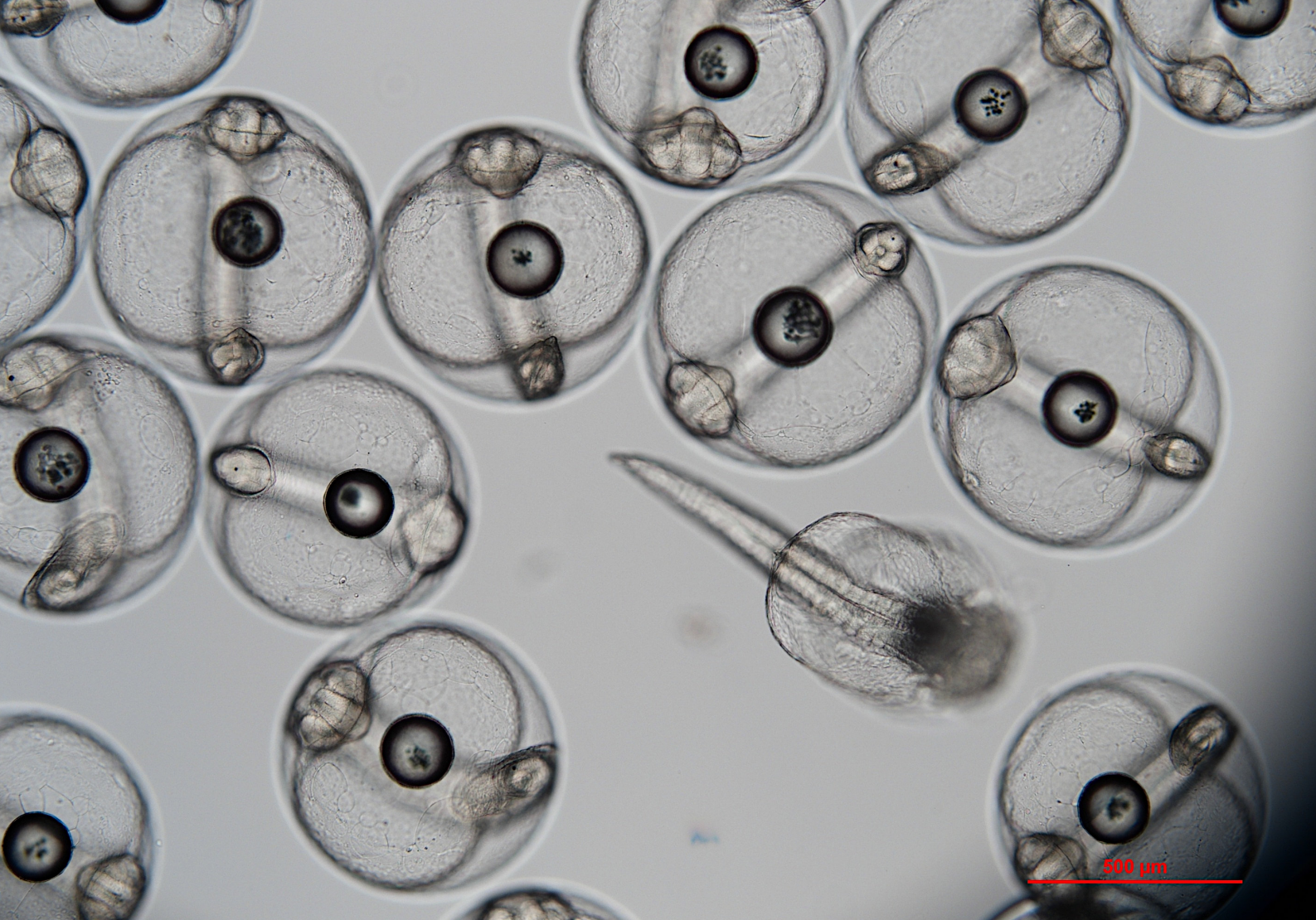
F: 6 somites.



G: 20 somites.



H: Active embryo.



I: Newly hatched larvae.

capacity each), at a stocking density of 50-150 fish per tank (1♀:1♂), after administering HCG at 400 IU/kg to the females. Water temperature was maintained at 28-29°C. After hormone administration, batch-by-batch spawning was observed from 20 April to 31 May. Staff collected 1.71 litres of eggs in total. The 1.45 litres of floating eggs yielded 2.9 million fertilised eggs (table 1).

Staff transferred the fertilised eggs to 200-µm mesh cylindrical incubation baskets in tanks supplied with gently flowing 35 ppt filtered seawater and aeration. The eggs hatched approximately 24 hours later at 28°C. The tanks produced 2.29 million newly hatched larvae, a hatching rate of 76.9%. Staff then stocked the larvae in larval rearing tanks.

Larval rearing

Staff stocked 2.229 million hatched larvae measuring 1.5 ± 0.15 mm in body length in four larval rearing tanks at a density of 15-56 larvae per litre. Staff adjusted water parameters in the larval rearing tanks to match those of the egg hatching tanks. Temperature was maintained at 28-29°C from stocking until harvest and monitored every two hours for stability. Staff added probiotic (Bactosafe) daily at 3 ppm.

From the first day post hatching, staff added mass-cultured algae to maintain green water conditions, checked every four hours to ensure a mild green colour (10,000 cells/ml). Staff introduced screened rotifers as the initial feed at 48 hours

post-hatching, after confirming under a microscope that the larvae's mouths had opened. From days 2 to 6 post hatching, continuous lighting was maintained. From day 12 post hatching, staff fed unscreened rotifers at 3-5 rotifers/ml, three times daily at 7:00 am, 11:00 am, and 5:00 pm.

From 18 days post hatching, staff provided newly hatched *Artemia* at 0.1-0.5 individuals/ml, adjusted the photoperiod to 16 hours light and 8 hours dark, and renewed water flow at 100% to remove uneaten rotifers. Staff introduced artificial feed from 25 to 44 days post hatching. Staff harvested 0.423 million fry at 30-44 days post hatching, a survival rate of about 19% (Table 2).

Larval rearing protocol adopted for *Gerres oyena*.

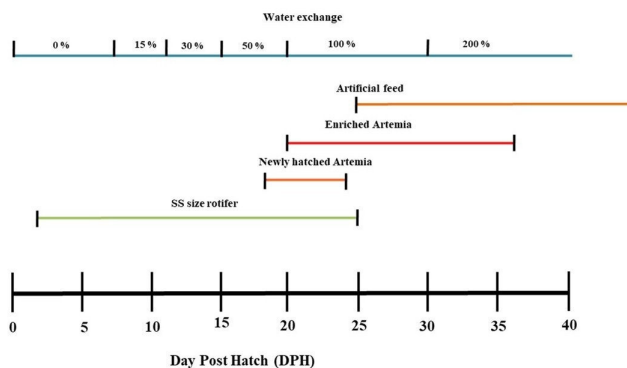


Table 1. Spawning and hatching performance of silver biddy from 19th April to 30th May 2025.

Item	Value
No of females and Males used for spawning	254: 224
No of spawning trials conducted	4
Female: Male ratio in the spawning tank	1:1
Water temperature (°C)	
minimum	26.8
maximum	29.5
Salinity (ppt)	35
Number of eggs collected (x10³):	
Total	3620
Fertilised	2900
Unfertilised	720
Fertilisation rate (%)	80
Incubation period (hrs)	24
Number of larvae hatched (x106)	2229
Hatching rate (%)	76.9



Gerres oyena fingerlings 100 days post hatch DPH (1.8g).

Conclusion

The reproductive peak recorded at Abu Al Abyad during April and May aligns with observations from the Gulf of Suez, Red Sea (Osman M.A. et al., 2020). This successful spawning and larval rearing trial represents a significant milestone for *Gerres oyena* aquaculture in the Arabian Gulf. Given increasing commercial interest in the species and evidence of declining wild populations, establishing a hatchery-based production system is essential for both conservation and economic resilience. To ensure long-term sustainability, further research is needed on larval weaning protocols, health management, and maintaining genetic diversity within brood stock. This achievement is expected to provide a strong foundation for regional aquaculture development and the Centre's stock enhancement programmes.

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Juvenile development and growth in the nursery

Staff harvested *Gerres oyena* fry by plankton dragnet. After harvesting, staff counted the fry and transferred them to the 14-tonne nursery rearing tank at a stocking density of 3-4 fish per cubic metre. On the first day in the nursery, staff hand-fed the fry to satiation with a formulated feed containing 58% crude protein and 15% crude fat. From the second day onward, feeding was set at 6-8% of total estimated biomass throughout the nursery period. The feeding regime used a combination of diets with the same high-quality nutritional profile. Staff distributed feed every three hours from 6:00 am to 6:00 pm.

Daily water exchange of 200-300% was maintained to remove metabolic waste quickly. Each evening, staff siphoned uneaten feed and faeces from the tank bottom to maintain water quality.

Throughout the nursery phase, staff recorded mean water quality parameters: temperature $29 \pm 2^\circ\text{C}$, dissolved oxygen 6.5 ± 0.5 mg/L, pH 7.5 ± 0.2 , ammonia 0.5 ± 0.2 mg/L, and nitrite 0.3 ± 0.1 mg/L.

Staff sampled fish every 15 days to assess growth performance and adjusted feeding rates and management as needed. This monitoring ensured rearing conditions remained optimal. By 100 days post-hatch, juveniles had reached an average weight of 1.8 g, representing a daily weight gain of 1.96%. Survival during the nursery phase was 80%, reflecting the effectiveness of the rearing protocols.

Table 2. *Gerres oyena* fry production results.

Date stocked	LRT No	No. stocked	Stocking density / litre	Age (days)	Number harvested	Survival (%)
19-Apr-25	33	840,000	56	44	169,600	20.2
22-Apr-25	34	239,000	16	42	36,400	15.2
22-Apr-25	21	690,000	46	43	146,600	21.2
2-May-25	22	240,000	16	44	46,400	19.3
31-May-25	20	220,000	15	30	24,000	10.9
Total		2,229,000			423,000	18.97

The humane side of data: When numbers don't speak for themselves

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The prologue to my story

I grew up in Balasore, a small coastal town on Odisha's eastern coast, where life revolves around the Bay of Bengal. This shaped an early fascination with fisheries and the communities that depend on it. This passion guided my choice of study and my decision during the ICAR All India entrance and counselling process.

Wanting maximum practical exposure, I chose the College of Fisheries Science in Veraval, Gujarat. Located on the Saurashtra coast, Veraval is one of India's most prominent fisheries hubs, known for its extensive marine landings, vibrant fishing activities, and industry exposure. Moving far from home to a culturally and socially distinct coastal region was both a challenge and an opportunity, allowing me to experience fisheries beyond textbooks and regional familiarity.

During my final year, I took part in the Rural Fisheries Work Experience Programme (RFWEP), an initiative designed to bridge classroom learning with real-world fisheries scenarios. The RFWEP is part of the ICAR curriculum for the Bachelor of Fisheries Science (B.F.Sc.). It exposes students to rural fishing communities, their livelihoods, and the challenges they face, developing practical skills, improving understanding of grassroots fisheries systems, and sensitising students to the socio-economic conditions of fisherfolk.

What began as an academic pursuit rooted in curiosity would become a deeply transformative experience, reshaping my understanding of research, responsibility, and the lives behind the fisheries sector.

My professors assigned me a socio-economic survey in fishing villages on the outskirts of Veraval Harbour. The survey aimed to collect data on the socio-economic status, livelihood



patterns, and access to government schemes among small-scale fishing communities. Fishing communities in India contribute to food security and coastal economies, yet they often lack access to institutional support and new technology.

Before starting fieldwork, I approached the survey with an academic mindset, expecting structured data collection and research interactions. This article reflects on a turning point during that fieldwork, where a simple oversight transformed a routine survey into a deeply humbling learning experience, reshaping my understanding of research, responsibility, extension, and community engagement.

Sea, life, and livelihoods

Interacting with fishing communities during the survey, I began to see that grassroots fisheries were far more complex than my classroom studies had suggested. The study was conducted in and around Veraval Harbour, one

of the largest and most active marine fish landing centres on India's western coast. It is a major hub for fish landing, processing, and distribution, supporting fishermen, traders, processors, and exporters, and contributing significantly to Gujarat's marine fisheries production (CMFRI, 2020; Government of Gujarat, 2021).

As the survey extended to nearby fishing villages and landing centres - including Jaleshwar, Bhidiya, Kharakuva, Divadandi, Sutrapada, Hirakot, Kodinar, Mul Dwarka, Chorvad, Mangrol, and Patan - a clear contrast emerged. These locations represented a wide spectrum of fisheries systems, from relatively organised markets like Kharakuva and Kodinar to small-scale, village-level landing centres like Jaleshwar and Sutrapada. In many peripheral areas, infrastructure was basic, hygiene was limited, and market organisation was uneven, highlighting the gap between major harbours and smaller fishing settlements.

In villages such as Jaleshwar and Sutrapada, fisheries were predominantly small-scale and artisanal. Fishermen

relied on motorised and traditional craft for their daily livelihoods. These communities faced declining catch trends, seasonal uncertainties due to fishing bans, and infrastructural constraints. In Sutrapada and Chorvad, local fishermen's cooperatives and informal collective systems provided some organisational support, particularly for accessing fishing inputs, subsidies, and shared resources. However, their effectiveness varied across communities.

In contrast, areas like Bhidiya and Mangrol showed relatively better organisation, including active participation of women in fish marketing. In Bhidiya, the Gujarat Fisheries Central Cooperative Association Ltd. provides a more structured fisheries framework, facilitating access to cooperative services and market linkages. This also reflects Bhidiya's proximity to the Veraval industrial belt, including the GIDC area, fish processing plants, and research institutions such as the ICAR-Central Marine Fisheries Research Institute and the ICAR-Central Institute of Fisheries Technology. Such advantages improve access to infrastructure, market networks, technology, and institutional support, contributing to better organisation and economic opportunities compared to more peripheral villages.

Similarly, Mangrol showed strong development through active cooperatives such as the Shree Mahavir Machhimaar Sahakari Mandali Limited, which improve access to fishing inputs, financial support, and collective resource management. Such cooperative-driven systems enhance organisation, strengthen bargaining capacity, and improve economic resilience among fishermen. However, the variation in effectiveness across locations shows that while institutional mechanisms exist, their reach and impact remain uneven. This reinforces the need to strengthen grassroots implementation and extension support.

Despite these differences, a common thread across all locations was the heavy dependence of households on marine resources. Through these observations, it became clear that these communities faced significant socio-economic vulnerability and uncertainty. Income was largely dependent on daily catch and influenced by seasonal variability, market fluctuations, and resource availability. Limited awareness of government schemes, restricted access to education, and lack of technical knowledge further constrained their resilience. I also realised that artisanal fishermen - despite forming the backbone of the fisheries supply chain - often remain overlooked in development frameworks. This points to the urgent need for stronger extension systems and improved last-mile delivery of support.

The echo of disappointment

As part of the RFWEP, my team and I set out to survey the fishing villages on the outskirts of Veraval Harbour with a clear academic objective: to conduct a socioeconomic survey. Equipped with questionnaires, we prepared to collect structured data on livelihoods, income patterns, and access to fisheries-related schemes. Initially, the visits felt like routine field exercises, similar to what we had covered in our coursework.

However, as we began interacting with the small-scale fishermen and women, the situation unfolded very differently. The fishermen welcomed us with unexpected warmth and



seriousness. Within a short time, it became clear that some were not seeing us as students but as government officials who had come to help them. This misunderstanding, subtle at first, soon became unmistakable through their questions and expectations. They began sharing their concerns with a sense of urgency and hope.

One fisherman spoke with visible frustration about how most government benefits seemed to reach only the owners of large, mechanised boats, while small-scale fishermen like him remained overlooked: "*Ben, aa badhi sarkari yojanao to mota boat vala loko sudhi j pahochi jaay chhe... amara jeva nana machhimar sudhi to kai aavtu j nathi.*" Another described how he barely sustained his family during the annual fishing ban on the west coast, when income comes to a complete halt: "*Ban na divaso ma to aavu lage chhe ke jeevan j atki gayu chhe... kamaani bandh, pan ghar na kharcha chalu j hoy chhe.*" In another corner, a widowed fisherwoman - herself unwell - described shouldering sole responsibility for her children with little support and mounting hardship: "*Hu ekli chu ane tabiyat pan sari nathi... pan mara dikra-dikri mate roj kaam karvu pade chhe. Koi saharo nathi, pan himmat raakhu chu.*"

Their voices carried more than information; they reflected years of struggle, exclusion, and resilience. Many spoke about the lack of financial support, difficulties in accessing subsidies, and challenges in sustaining their livelihoods amid declining fish catches and rising operational costs. Some asked about schemes they had heard of but never fully understood or accessed, while others sought technical guidance to improve their fishing practices and income stability. Their expectations were deeply rooted in genuine needs and lived realities, shaped by limited access to institutional support and opportunities.

This moment marked a profound emotional turning point. I realised that despite being central to the fisheries supply chain and food security, many of these fishermen and women lacked even basic awareness of available government schemes and extension services. What struck me most was not just their lack of awareness, but their unwavering trust. They spoke openly, believing that we had the authority and ability to bring change to their lives.

Standing there, I experienced an internal conflict I had never anticipated. As a student and early career researcher, my role was limited to data collection and academic documentation. Yet, in their eyes, I represented something far greater - a source of hope and possible transformation. This gap between my actual role and their expectations left me with a deep sense of responsibility, empathy, and helplessness. In that moment, the survey ceased to be an academic exercise and became a deeply human experience that would shape my understanding of fisheries research and community engagement.

The mistakes that led to false hopes

The most significant mistake was not a technical error in data collection, but a failure to understand the human context of the survey. I had assumed that the fishermen had basic awareness of government schemes and institutional support. I also assumed that the existence of such schemes meant communities could access them. The interactions revealed a stark reality: awareness was minimal, access was fragmented, and benefits rarely reached those who needed them most.

Another mistake was treating the survey as a purely academic data-collection exercise, rather than a process of meaningful human engagement. The questionnaires, which I saw as structured information-gathering tools, unintentionally raised expectations among the fishermen. Their responses

were not just answers; they were expressions of lived struggles, aspirations, and unmet needs, which I had not fully anticipated.

A key part of this mistake was my failure to clearly introduce ourselves as students and explain the purpose and limitations of our visit. I did not explain that we were conducting an academic survey and had no authority to provide solutions or access to government benefits. Instead, I assumed the fishermen already understood what such surveys were for. This gap in communication led to a significant misinterpretation of our role. Our presence unintentionally created a sense of hope that assistance, financial support, or technical intervention would follow. In hindsight, this was deeply unsettling - our interaction, though well-intentioned, had raised expectations we could not fulfil.

There was also a clear lack of pre-field understanding of ground realities. While academically prepared, I had not adequately considered the socio-economic and cultural dynamics of the community. Most importantly, I failed to communicate clearly from the outset - who we were, what our purpose was, and what our limitations were - despite wearing our college ID cards. This lack of clarity contributed directly to the misunderstanding that we were government representatives capable of immediate intervention.

Language differences - I was a non-Gujarati student on an ICAR all-India quota seat - combined with low literacy levels, limited exposure to formal systems, and reliance on informal networks, all shaped how the fishermen perceived us. What I viewed as a routine survey interaction was, for them, a rare opportunity to voice their concerns to someone they believed could bring change.

In hindsight, the mistake was not merely procedural but conceptual: a failure to recognise that in fisheries extension and socioeconomic research, people are not just respondents, but stakeholders whose perceptions, expectations, and realities must be understood with sensitivity and responsibility.



This mistake also highlighted a deeper disconnect between academic training and field realities. While the ICAR Vth Dean's Committee curriculum had equipped us with technical tools for survey design, data collection, and analysis, it was the RFWEP fieldwork that prepared us for the ethical and emotional dimensions of engaging with vulnerable communities. I realised that a lack of reflexivity - questioning one's own assumptions, position, and impact - can lead to unintended consequences, such as raising false expectations or misrepresenting one's role. Even a simple interaction carried weight, as it influenced how the community perceived external institutions and future interventions. This experience made me recognise that responsible research in fisheries extension is not just about accuracy of data, but accountability towards the people who share their realities with us.

Analysis of the situation

The field experience showed that the challenges facing fishing communities are not merely individual hardships but reflect deeper structural issues within the fisheries governance system. A significant gap exists between policy formulation and its actual implementation at the grassroots level.

While government schemes such as the flagship Pradhan Mantri Matsya Sampada Yojana (PMMSY) aim to support fishermen through subsidies, insurance, and welfare measures, their benefits often fail to reach small-scale and artisanal fishers. This reflects weak last-mile delivery systems, where the transmission of information, resources, and services diminishes as it moves from institutions to the community level.

Several barriers compound this issue. Documentation requirements - identity proofs, registration records, and bank linkages - often become obstacles for poor small-scale fishermen who lack formal records or struggle with bureaucratic procedures. Digital illiteracy adds another layer of exclusion, especially as many schemes are now accessed through online portals and mobile applications. Language barriers also play a key role, as information is often disseminated in formats or languages not easily understood by community members, many of whom are illiterate or have only primary schooling. There is also a clear institutional disconnect, where extension systems and support agencies fail to build consistent, trust-based engagement with fishermen, limiting awareness and uptake of available benefits.

It is evident that the exclusion of these communities is not due to a lack of schemes, but to systemic inefficiencies in communication, accessibility, and implementation. Without addressing these ground-level realities, even well-designed policies remain ineffective. This underscores the urgent need for participatory, localised, and inclusive extension approaches that bridge the gap between institutions and communities, ensuring that support systems are not only available but accessible and meaningful to those they are intended to serve.

Learning outcomes and reflection

This experience was a transformative learning moment across academic, professional, and personal dimensions.



Academically, it showed that socioeconomic surveys are not merely tools for data collection but require deep contextual sensitivity. Understanding the lived realities of communities is essential to interpret data meaningfully. It also emphasised the importance of participatory approaches, where communities are treated not as passive respondents but as active stakeholders whose voices shape the research process.

From a professional perspective, the experience reinforced the importance of role clarity during fieldwork. Clearly communicating one's identity, purpose, and limitations is crucial to avoid misinterpretation and unintended consequences. It also highlighted the ethical responsibility researchers hold towards communities, especially vulnerable and marginalised ones. The situation underscored the need for interdisciplinary understanding that integrates fisheries extension, policy frameworks, rural sociology, and socio-cultural dynamics. Technical fisheries knowledge alone is not enough to address real-world challenges.

On a personal level, the experience cultivated a sense of empathy that extended beyond academic learning. Interacting with fishermen and fisherwomen facing daily uncertainties instilled a deep respect for grassroots realities. It also brought

a realisation of privilege - that as students and future professionals, we operate from a position of access and opportunity that many in these communities do not have.

A key lesson was the importance of transparent communication and managing expectations during field engagement. The realisation that data represents real human struggles fundamentally changed my perspective on research. It also clarified the extension gap - while policies and schemes may exist on paper, their reach and accessibility at ground level often remain inadequate.

In retrospect, several aspects of the fieldwork could have been handled more effectively. A pre-survey briefing to the community explaining the purpose and scope of the study would have helped set realistic expectations. Clear communication about our role as students, rather than decision-makers, was essential but overlooked. Even within the limitations of a survey, efforts could have been made to share basic awareness about available schemes and support systems. Linking fishermen to local institutions or extension agencies could have added practical value to the interaction. The focus should also have extended beyond descriptive data collection to gathering actionable insights that could contribute to meaningful interventions.

Conclusion and way forward

This field experience reshaped my understanding of what fieldwork truly means. Fieldwork is not just about data, but about people - their lives, struggles, expectations, and trust. It redefined my understanding of fisheries research and extension - from information extraction to responsibility-driven engagement with communities, where sensitivity, ethics, and impact must guide every step. What began as a routine academic exercise became a profound learning experience, showing how even unintended mistakes can become tools for growth and self-reflection. It reinforced the idea that scientific inquiry, especially in disciplines like fisheries extension and socioeconomics, must be guided by compassion, responsibility, and ethical awareness.

The student research team.

The most significant outcome was a clear shift in mindset - from data collector to responsible researcher. I learned to look beyond numbers and recognise the human realities they represent. The interactions with fishermen and fisherwomen instilled a deep respect for their resilience, hard work, and the challenges they navigate daily. This experience has had a lasting impact on how I approach research, reminding me that meaningful engagement requires sensitivity, clarity, and accountability.

At a broader level, the situation points to the need for systemic improvements. Strengthening fisheries extension systems is essential to ensure that policies and schemes effectively reach marginalised small-scale and artisanal fishermen. There is a pressing need for mobile-based and local-language awareness programmes that can bridge the communication gap. Promoting women's self-help groups and community-based support systems can further enhance resilience and inclusivity. Establishing local help centres for scheme access and improving linkages between institutions and communities can significantly improve last-mile delivery. Most importantly, bridging the gap between academia and communities is crucial to ensure that research contributes not only to knowledge generation but also to real-world impact.

This experience directly aligns with India's broader vision under initiatives such as the PMMSY, which aims to enhance fish production, improve livelihoods, and ensure inclusive growth of fisheries communities. However, the gap observed at grassroots level highlights a critical challenge: while policies are robust in design, their effectiveness depends on last-mile delivery, awareness, and accessibility. Bridging this gap is essential to achieve sustainable fisheries development, strengthen coastal livelihoods, and ensure that small-scale and artisanal fishermen are not left behind as the sector modernises.

This experience also showed me that fisheries students can play a crucial role as bridges between institutions and communities. Positioned between academic knowledge and ground realities, students have the unique ability to:

- Translate technical knowledge into locally understandable information



- Disseminate awareness about schemes and best practices
- Build trust between communities and institutions
- Identify real problems and communicate them back to policymakers

Even small actions - explaining a scheme in the local language, guiding someone on documentation, or simply listening with empathy - can create meaningful impact. When students move beyond data collection and engage with responsibility, they become catalysts for change, contributing to both knowledge generation and community development.

This experience offers an important lesson for future students and researchers. Every field engagement must begin with clear communication of identity, purpose, and limitations. Using local language, building trust, and integrating basic awareness into research activities can make interactions more meaningful and ethical. Surveys should not remain isolated academic exercises but should incorporate an extension component that benefits the community, even in small ways. In essence, this experience taught me that responsible research is not defined by the quantity of data collected, but by the integrity, empathy, and impact with which it is conducted.

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Remembering distinguished scientists who contributed to growth and development in the Indian fisheries and aquaculture sectors

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In this short communication, I have genuinely attempted to compile and present at a glance the dates of birth and passing of as many as sixty-five legendary fishery and aquaculture experts of India as of 10 May 2026, the first anniversary of the passing of Padma Shri Dr S. Ayyappan). They were leaders, educators and mentors. Over the last seventy-five years or so, before leaving this mortal world, they shaped sustainable Indian marine and inland fisheries and aquaculture and strengthened scientific understanding. They were the pioneers of different technologies, and studied and investigated them in depth so they could be transferred. Their research work and leadership have fostered the progress, growth and development of these sectors in India, leading to increased fish production and enriching knowledge in ichthyology and allied fields. I confess that I have missed out the names of other distinguished contributors. This was unintentional, as I could not get information on all.

Excluding twenty-five persons, namely Dr Hora, Dr Ramaswami, Dr Bal, Dr Natarajan, Dr Alagarwami, Dr Sundararaj, Dr Jhingran, Dr Alikunhi, Dr Mitra, Dr Ayyar, Dr Chauhan, Dr Desai, Dr Pillay, Dr Thakur, Dr Datta Munshi, Dr Kapoor, Dr Menon, Dr A. K. Mondal, Dr Janakiram, Dr Sundaramoorthy, Dr A. Mondal, Dr Talwar, Dr Jayaram, Dr Durve and Dr Varghese, I was fortunate to meet all the other forty doyens and experts in Indian fishery and aquaculture in person over the years. I listened to their invited lectures and heard them while they chaired technical sessions. For most of them, I bowed my head down and touched their feet to obtain their blessings at different seminars and symposia in different parts of India over the last twenty-seven years. This began with my first participation in the National Conference titled 'Bridging gaps for attaining self-sufficiency in inland fish production at the dawn of new millennium', organised in Kolkata in June 2000. Now they are no more. Without boasting, I can say that I could even talk humbly for a little while with a few of these great personalities, obtain academic advice from them and

win their affection. They have helped me to become what I am today. I serve the West Bengal Fisheries Directorate in Purba Medinipur district as a West Bengal Junior Fisheries Service Grade-II officer, at the office of the Assistant Director of Fisheries, Government Fish Technological Station and Aquaculture Pathology Laboratory, Junput.

The compiled information is presented in tabular form below.

In this presentation, I have arranged the dates of demise of these persons of eminence in order, from the most distant past to the most recent. Indeed, "Man is mortal, but his legacy remains immortal". Their illustrious research careers, commitment to work and outstanding scientific contributions will continue to shine upon the newer generation for a long way to come. While preparing this communication at 48 years of age, I fondly recall my very small association with the late sirs (only some of those in the table below), and I hold tremendous respect for them.

I have included Dr B. R. Mohanty's name here. He was the most talented researcher of my age I have ever seen. I end here with the hope that some present-day MFSc students in Fishery Colleges/Universities in India would like to read through this information and concise tabular presentation, for an enduring inspiration in their Remembering distinguished scientist contributors to academic pursuits.

Acknowledgement

While preparing this document, I heartily thank Dr Sanjay Bhowmick, Dr H. N. Anjanayappa, Dr Preetha Panikkar, Dr S. M. Shivaprakash, Dr K. V. Jeyachandran, Dr T. V. Anna Mercy, Smt. Bidisha Das, Dr R. S. Chauhan's wife, Dr G. P. Dubey's son, Sri Sujoy Ghosh, Sri Tarun Shyam, Dr Santosh Kumar and Dr L. Kosygin Singh, who provided me with appropriate information on my request.

Name	Birth	Passing	Interest/specialisation	Affiliation / institution
Dr Sunder Lal Hora	22/05/1896	08/12/1955	Ichthyology, Biology of Hill Stream Fishes, Riverine Fish Migration	Director, Zoological Survey of India, Kolkata
Dr Bangalore I. Sundararaj		07/10/1983	Fish Endocrinology, Catfish Reproductive Physiology	Professor of Zoology, Delhi University, New Delhi
Dr L. S. Ramaswami	01/01/1907	18/05/1987	First success in induced breeding of catfishes in India	Professor, Department of Zoology, University of Rajasthan, Jaipur
Dr A. V. Natarajan	1929	1989	Inland Fisheries and Aquaculture Management; Fish Biology	Director, Central Inland Fisheries Research Institute, Barrackpore
Padma Shri Dr Vishwa Gopal Jhingran	18/06/1919	15/01/1991	Composite Fish Culture, Brackishwater Fish Tagging, Mullet Culture	Director, Central Inland Fisheries Research Institute, Barrackpore

Name	Birth	Passing	Interest / specialisation	Affiliation / institution
Dr Nirmal Kumar Thakur	29/09/1941	10/09/1998	Air-breathing Fish Breeding and Culture; Field Trial of Inducing Hormone 'Ovatide'	Joint Director, Central Institute of Fisheries Education, Mumbai
Dr D. V. Bal	1905	01/04/1999	Marine Fisheries, Author of Book on Marine Fisheries	Director, Central Institute of Fisheries Education, Mumbai
Dr Ambat Gopalan Kutty Menon	19/04/1921	11/04/2002	Ichthyology, Taxonomy, Identification of Marine and Freshwater Fishes	Scientist, Zoological Survey of India, Kolkata
Dr Arabinda Nath Bose	Sept. 1922	March 2003	Food Science, Food Processing Technology	Director, Central Institute of Fisheries Technology, Kochi; Vice Chancellor, Jadavpur University, Kolkata
Dr T. V. R. 'Ramu' Pillay	July 1921	09/02/2005	Evolution of Modern-day Sustainable Aquaculture Globally	Leader and Programme Director, Aquaculture Development and Coordination Programme, UNDP/FAO
Sri Gajendra Nath Mitra	Oct. 1916	18/07/2006	Upliftment of Small-scale Inland and Marine Fisheries; Freshwater Prawn Hatchery	Director, Department of Fisheries, Govt of Odisha; Advisor, Ministry of Agriculture, Govt of India
Dr Umesh Chandra Goswami	May 1944	25/06/2009	General and Reproductive Biology of Air-breathing Fishes	Professor of Zoology, Gauhati University, Guwahati
Dr Gyan Prakash Dubey	05/01/1922	28/08/2010	Inland Fisheries Development in Rivers and Reservoirs, Fish Fauna Conservation	Director, Department of Fisheries, Government of Madhya Pradesh
Dr Kolliyil Hameed Alikunhi	27/05/1918	26/09/2010	Hypophysation of Indian major carps and Exotic Carps; Penaeid Shrimp Hatchery Operation	Head, Pond Aquaculture Division, Central Inland Fisheries Research Institute, Cuttack; Director, Central Institute of Fisheries Education, Mumbai
Dr Bikash Ranjan Mohanty	1979	26/10/2010	Fish Disease Edwardsiellosis, Fish Immunology	Postdoctoral Researcher in Fish Microbiology at Pennsylvania University, USA
Dr Dharendra Kapoor		11/01/2011	Fish Chromosome Mapping, Karyotyping, Fish Biodiversity Conservation	Director, National Bureau of Fish Genetic Resources, Lucknow
Dr C. S. Singh	07/05/1937	2011	Hill Fisheries Research and Management	Dean, College of Fisheries, GB Pant University of Agriculture & Technology, Pantnagar
Dr Kottore Chidambaram Jayaram	1926	2011	Taxonomy and Identification of Freshwater Fishes	Joint Director, Zoological Survey of India, Kolkata
Dr Padmakar Vishwanath Dehadrai	21/12/1938	02/06/2011	Biology, Breeding and Culture of Air-breathing Fishes	Deputy Director General (Fisheries), ICAR, New Delhi
Dr Sree Narain Dwivedi	16/12/1933	26/04/2012	Carp Hatchery Model CIFE D-81, D-85, High-tech Aquaculture	Director, Central Institute of Fisheries Education, Mumbai; Additional Secretary, Ocean Development, Govt of India
Dr Mudnakudu Channabasappa Nandeesh	01/07/1957	27/12/2012	Innovations for Fish Farmers, Rural Aquaculture, Synthetic Hormones for Fish Breeding	Professor and Head, Aquaculture, Lembucherra Fisheries College, Tripura
Dr K. L. Sehgal		05/03/2013	Fishery of Mahaseer and Trout, Coldwater Fishes in Himalayan Rivers	Director, National Research Centre on Cold Water Fisheries, Bhimtal
Dr S. A. H. Abidi	04/04/1940	11/07/2014	Induced Breeding of Catfish, Aquaculture Biotechnology	Director, Central Institute of Fisheries Education, Mumbai; Member, ASRB, New Delhi
Dr Hira Lal Chaudhuri	21/11/1921	12/09/2014	Fish Endocrinology, Fish Breeding in Captivity	Head, Pond Aquaculture Division, Central Inland Fisheries Research Institute Cuttack; Chief Technical Advisor, SEAFDEC & FAO/UNDP, Myanmar

Name	Birth	Passing	Interest / specialisation	Affiliation / institution
Dr J. V. H. Dixitulu	February 1926	28/05/2015	Deep Sea Fishery Resources in Indian EEZ	Associated with Fishery Survey of India; Editor and Publisher of <i>Fishing Chimes</i> , Visakhapatnam
Padma Bhushan Dr Syed Zahoor Qasim	31/12/1926	20/10/2015	Estuarine Ecology, Reproductive Biology of Marine Fishes	Professor at Central Institute of Fisheries Education, Mumbai; Director, Central Marine Fisheries Research Institute, Kochi
Dr H. P. C. Shetty	17/05/1930	11/11/2015	Fisheries Research and Education	Professor and Director of Instruction, College of Fisheries, Mangaluru; Senior Aquaculturist, FAO
Dr Jyoti Swarup Datta Munshi	08/02/1930	21/07/2016	Respiratory Anatomy of Air-breathing Fishes, River Ecology	Professor of Zoology, Bhagalpur University, Bihar
Dr Asit Kumar Mondal	Oct. 1935	28/07/2016	Freshwater Aquaculture	Former Principal Scientist at Central Institute of Freshwater Aquaculture, Kalyani Regional Centre
Dr Telikacherla Rajyalakshmi	June 1935	25/11/2016	Brackishwater Aquaculture, Harmful Impact of Shrimp Seed Collection from Estuaries on Environment	Former Director, Central Institute of Brackishwater Aquaculture, Chennai
Dr K. Devadasan	07/08/1946	15/03/2017	Post-Harvest Technology, Farmed Fishery Products	Director, Central Institute of Fisheries Technology, Kochi
Dr Radheyshyam	June 1950	10/10/2017	Aquaculture Technology Demonstration, Rural Aquaculture	Principal Scientist, Central Institute of Freshwater Aquaculture, Bhubaneswar
Dr K. Janakiram		2017	Freshwater Pearl Culture Technology	Director, Central Institute of Freshwater Aquaculture, Bhubaneswar
Dr Naresh Chandra Datta	01/01/1934	19/03/2018	Ichthyology, Fish Anatomy, Aquatic Ecology	Professor of Zoology, University of Calcutta
Dr N. R. Menon	1942	19/03/2018	Impact of Shrimp Farming upon Environment; Marine Living Resources; Environmental Management	Standing Council Chairman for Academics, Kerala University of Fisheries and Ocean Studies
Dr Eric Godwin Silas	10/01/1928	27/04/2018	Marine Fishery, Mariculture, Biology of Tuna	Director, Central Marine Fisheries Research Institute, Kochi and Central Institute of Brackishwater Aquaculture, Chennai; Vice Chancellor, Kerala Agricultural University
Dr Radha Kanta Mandal	29/09/1941	05/10/2018	DNA Satellite Markers and Molecular Characterisation in Fishes, Gene Expression in Transgenic Fishes	Professor of Biochemistry, Bose Institute, Kolkata
Dr Vasant Ramchandra Desai	25/07/1936	12/10/2018	Reservoir Fisheries, Biology of Golden Mahaseer	Officiating Director, Central Inland Fisheries Research Institute, Barrackpore
Dr P.S.B.R. James	January 1934	22/08/2019	Sea Ranching of Marine Fishes and Shrimps, Marine Resource of Silverbelly and Ribbonfish	Director, Central Marine Fisheries Research Institute, Kochi; Professor, College of Fisheries, Mangaluru
Dr Anandamoy Mondal	1964	2019	Fishery Economics and Statistics	Associate Professor, Faculty of Fishery Sciences, WBUAFS, Kolkata
Dr Nihar Ranjan Chatterjee	01/07/1951	15/01/2020	Induced Fish Breeding in Chinese Hatchery; Fish Breeding Standardisation	Professor, West Bengal University of Animal and Fishery Sciences, Kolkata; Visiting Professor in Biotechnology, Rajiv Gandhi University
Dr Alappat Ramachandran	June 1959	26/03/2020	Coastal Zone Management, Seafood Safety, Fishery By-products, Climate Change Impact	Vice Chancellor, Kerala University of Fisheries and Ocean Studies, Kochi

Name	Birth	Passing	Interest / specialisation	Affiliation / institution
Dr Bankim Chandra Jha		04/10/2020	Pen Culture and Cage Culture, Phytoplankton Diversity, Primary Productivity of Aquatic Ecosystems	Principal Scientist and Head of Division, Central Inland Fisheries Research Institute, Barrackpore
Dr Amalesh Choudhury	11/07/1931	30/12/2020	Estuarine Biology, Estuarine Fishes, Biology of Hilsa ilisha	Professor of Marine Science, University of Calcutta
Dr B. Sundaramoorthy	13/06/1965	29/04/2021		Dean, Fisheries College and Research Institute, Thoothukudi
Dr M. Yusuf Kamal		15/05/2021	Fishery Education, Inland Fisheries Development	Vice Chancellor, Sher-e-Kashmir University of Agricultural Sciences & Technology; ADG (Inland Fisheries), ICAR, New Delhi
Dr Methil Narayanan Kutty		02/06/2021	Prawn and Shrimp Aquaculture, Inland Fish Production Enhancement through Aquaculture	FAO/UN and FAO/NACA Expert in Fisheries and Aquaculture; Dean, Fisheries, Tamil Nadu Agricultural University
Dr Amitabha Ghosh	06/01/1947	26/08/2021	Estuarine Fisheries, Fishery Resource of Estuarine Wetlands	Principal Scientist and Head of Division, Central Inland Fisheries Research Institute, Barrackpore
Dr T. J. Varghese		04/11/2021	Fish Breeding; Dietary Requirements of Cultivable Carps	Director of Instruction, College of Fisheries, Mangaluru
Dr Vishwa Raman Prasad Sinha	April 1938	11/12/2021	Fishery Management, Fish Reproductive Physiology; Freshwater Pond Aquaculture	Senior Aquaculturist (Research and Training), UNDP/FAO; Director, Central Institute of Fisheries Education, Mumbai; OIC, Freshwater Aquaculture Research & Training Centre, Bhubaneswar
Dr Ajoy Kumar Ghosh	1944	27/09/2022	Fish Parasitology, Estuarine Fisheries Management	Officiating Director, Central Inland Fisheries Research Institute, Barrackpore
Dr B. N. Singh	15/07/1942	Nov. 2022	Fish Physiology, Fish Nutrition	Assistant Director General (Inland Fisheries), ICAR, New Delhi
Dr Punyabrata Das	19/09/1936	15/12/2022	Fish Genetics, Inbreeding Depression, Fish Biodiversity Conservation, Stock Assessment	Director, National Bureau of Fish Genetic Resources, Lucknow
Dr Subhendu Dutta	15/01/1968	13/02/2023	Fish Toxicology, User-friendly Water Quality Test Kit	Principal Scientist, Central Institute of Fisheries Education, Kolkata Centre
Dr Satyendra Datt Tripathi	04/12/1935	23/08/2023	Sustainable Rural Aquaculture for Livelihoods; Genetic Improvement of Fishes	Director, Central Institute of Fisheries Education, Mumbai and Central Institute of Freshwater Aquaculture, Bhubaneswar
Sri Rai Milon Bhowmick	28/02/1930	06/04/2024	Breeding of IMC and Exotic Carps, Chinese and Glass Jar Hatchery, Carp Spawn Rearing	Fishery Scientist, Central Inland Fisheries Research Sub-Station, Cuttack; Senior Advisor in Fisheries at FAO
Dr P. K. Talwar	14/11/1934	08/04/2024	Identification of inland and commercial marine fishes of India	Scientist-E, Zoological Survey of India, Kolkata
Dr K. C. Alagarwami	13/08/1937	June 2024	Shrimp Disease Prevention, Pearl Oyster Biology	Director, Central Institute of Brackishwater Aquaculture, Chennai
Dr P. Ravichandran		13/11/2024	Best Management Practices in Shrimp Culture, Shrimp Disease Management	Director, ICAR-Central Institute of Brackishwater Aquaculture, Chennai; Member Secretary, Coastal Aquaculture Authority
Dr Kumara (Panicker) Gopakumar	14/04/1942	05/12/2024	Fish-based Value Added Products, Marine Fish Biochemistry	Director, Central Institute of Fisheries Technology, Kochi; Deputy Director General (Fisheries), ICAR, New Delhi

Name	Birth	Passing	Interest / specialisation	Affiliation / institution
Dr Vinayak Sadashiv Durve	21/03/1931	24/02/2025	Pioneer of Limnology and Fisheries in Rajasthan	Head, Department of Limnology and Fisheries, Rajasthan Agricultural College, Udaipur
Padma Shri Dr Subbanna Ayyappan	10/12/1955	10/05/2025	Aquatic Microbiology, Aquaculture, Capture Fisheries	Director, ICAR-Central Institute of Fisheries Education, Mumbai; Deputy Director General (Fisheries), ICAR
Dr Kamarath Viduran Devaraj	29/01/1937	December 2025	Culture-based Capture Fisheries in Reservoirs; Freshwater Aquaculture Management	Vice Chancellor, University of Agricultural Sciences, Bengaluru; Assistant Professor, College of Fisheries, Mangaluru
Dr Rikhi S. Chauhan	10/09/1958	02/02/2026	Additives in Supplementary Fish Feed, Fish Parasitology, Biology of Coldwater Fishes	Dean, College of Fisheries, GB Pant University of Agriculture & Technology, Pantnagar; Director of Fisheries, Uttarakhand
Dr S. Parameswara Ayyar	03/12/1934	02/03/2026	Reservoir Fisheries Management, Major Carp Seed Rearing	Director, Central Inland Fisheries Research Institute, Barrackpore



Introducing the Global Aquaculture Statistics Dashboard

<https://enaca.org/global/>

Good fisheries and aquaculture policy depends on good data. The new Global Aquaculture Statistics Dashboard, based on authoritative FAO data, makes exploring it easier than ever, bringing decades of global fisheries and aquaculture statistics together in one place, ready to use in your browser. This new interactive section of the NACA website puts decades of global fisheries and aquaculture data at your fingertips, ready to explore in seconds. No setup, just open your browser and start asking questions of the data. Download the dataset and take it with you, if you want.

What can you explore?

The Dashboard has six sections, each designed to answer a different family of questions:

- **Global Overview:** The starting point. A stacked area chart tracks the growth of global capture fisheries and aquaculture production from 1950 to the present. A companion chart shows aquaculture production value in US dollars. Filter by any reporting state or by individual species to see how a country's output or a single commodity fits into the global picture. Toggle capture fisheries on or off to focus on aquaculture alone.
- **Production:** Which species dominate world aquaculture, and how is the mix changing? This section ranks species by both volume and value for any selected year. Paired donut charts show the production mix across major taxonomic groups (fish, crustaceans, molluscs, aquatic plants and others). Click any species bar to jump straight to its country-level profile. A year selector lets you step through the time series to see how rankings have shifted.
- **Species Profiles:** Pick any farmed aquatic species, by common name or scientific name, and see which states produce the most of it. Paired donut charts break down production by FAO continental region (volume and value side by side), and horizontal bar charts rank the top producing states. This helps answer questions like "Where is whiteleg shrimp farmed, and who are the biggest producers?"
- **Trade:** Track the volume and value of global fisheries and aquaculture trade over time. Imports and exports appear as separate series and can be toggled independently. Filter by state to see a single country's trade profile - useful for understanding trade balances, import dependency or export market development.



- **Environment:** How is aquaculture production distributed across freshwater, brackishwater and marine environments? This section charts both volume and value time series by production environment, globally or for any individual state. It reveals patterns that aggregate figures hide, for example, that fish aquaculture is overwhelmingly freshwater, even though overall aquaculture tonnage is roughly split between marine and inland production.
- **Consumption:** A world map shows apparent per-capita aquatic food consumption (kilograms per person per year), using the class breaks from the FAO Yearbook of Fishery and Aquaculture Statistics. Hover over any country to see its figure. This view puts aquaculture production into the context of food supply and nutrition.
- A companion **Food Insecurity Map** shows the prevalence of moderate or severe food insecurity by country (SDG indicator 2.1.2, drawn from the FAO Food Insecurity Experience Scale). Viewed alongside the consumption map, it highlights the regions where aquaculture development could have the greatest impact on food security.

Designed for fast, practical use

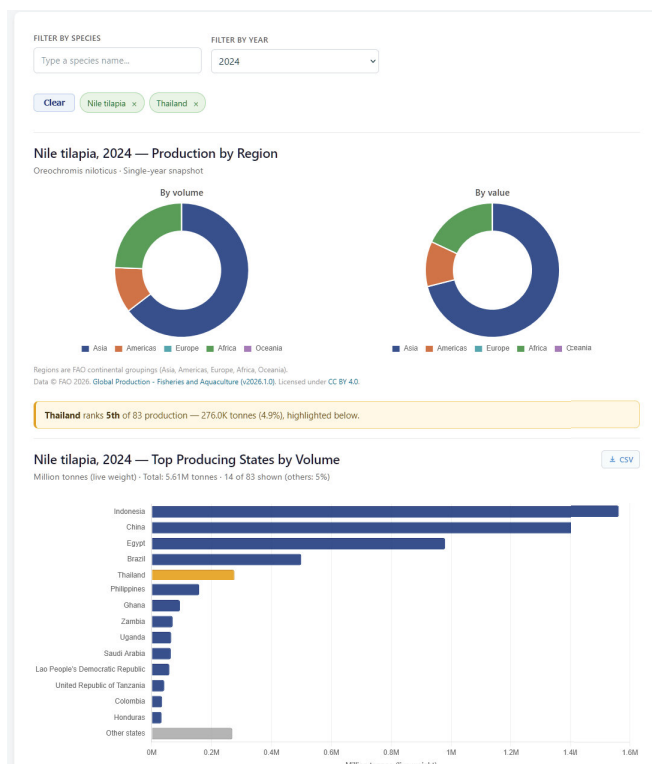
We built the Dashboard for anyone who works with aquaculture data and wants fast-loading charts without having to run queries against raw datasets. Filters update dynamically: select a state, and every chart on the page refreshes in place. There is no waiting for large files to download or process. Several features support practical use:

- **Member state quick-select:** Click a flag icon to instantly filter to any NACA member state. One click filters; a second click returns to the global view.
- **Autocomplete search:** Type any part of a country or species name to filter. You can search species by common name or scientific name.
- **Data export:** Each chart offers a one-click CSV download of the underlying data. The CSV contains the full, unaggregated dataset (not just the bars visible on screen), so it is suitable for reports, spreadsheets or further analysis.
- **Persistent context:** Your state and species filters stay active as you navigate between sections. Select a country on the Global Overview page, move to Trade, and the same country is already active - no need to re-enter it.
- **Interactive tooltips:** Hover over any data point, bar or map region to see the exact figure. Stacked charts show both the individual series value and the total.

Data sources and licensing

The Global Aquaculture Statistics Dashboard draws on several open datasets published by the Food and Agriculture Organization of the United Nations (FAO):

- **Global Fisheries and Aquaculture Production (v2026.1.0):** Capture fisheries and aquaculture production quantities (1950 - present) and aquaculture production values (1984-present). Published by the FAO Fisheries and Aquaculture Division.



- **Global Aquatic Trade Statistics (2025 division):** Imports, exports and re-exports of fisheries and aquaculture products by volume and value. Published by the FAO Fisheries and Aquaculture Division.
- **Consumption of Aquatic Products:** Apparent per-capita aquatic food consumption derived from FAO Food Balance Sheets. Published by the FAO Fisheries and Aquaculture Division.
- **SDG Indicator 2.1.2 (FIES):** Prevalence of moderate or severe food insecurity, measured with the Food Insecurity Experience Scale. Published by FAO as part of the SDG monitoring framework.

The data is published by FAO under the open [CC BY 4.0](#) attribution license. You can access the original datasets from the [FAO Fisheries and Aquaculture Statistics](#) portal.

The State of World Fisheries and Aquaculture 2026

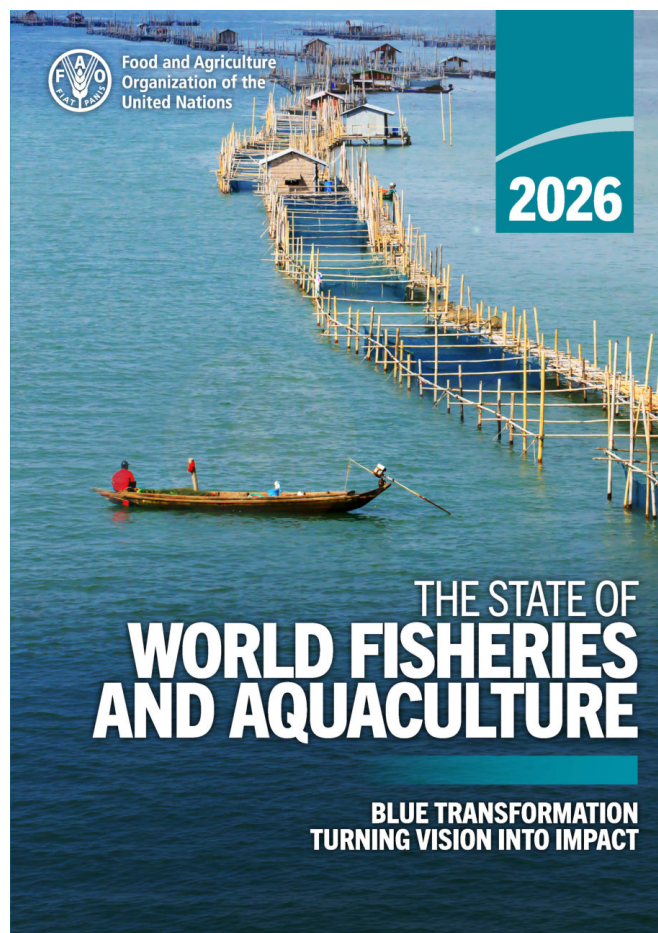
FAO's State of World Fisheries and Aquaculture 2026 (SOFIA 2026) delivers the latest data and insights on the challenges and opportunities shaping the future of the seafood sector. This edition focuses on how the FAO is turning its "Blue Transformation" vision into real-world impact. Through global field projects, the report shows how aquatic foods can fight hunger, reduce poverty, and boost economies using smarter policies and new innovations.

The report has three main sections:

- **Part 1:** The Global Snapshot This section offers a fresh look at global production, jobs, trade, and how aquatic products are used. Thanks to major upgrades in data tracking and analytical tools, these numbers are more accurate than ever.
- **Part 2:** Driving Change Here, the report explores the actual steps being taken to transform the industry. It focuses on three key areas: growing the fish farming sector responsibly, managing wild fisheries effectively, and improving the supply chain from catch to consumer.
- **Part 3:** The Big Picture & Future Outlook This part looks at how local organizations turn international goals into real, regional action. It highlights how climate research helps managers adapt to a changing environment and wraps up with data-driven projections tracking industry trends through 2034.

This report is built for an expanding audience. Whether you are a lawmaker, researcher, business owner, activist, or just a conscious consumer, it provides the essential tools to understand where our aquatic food systems are heading.

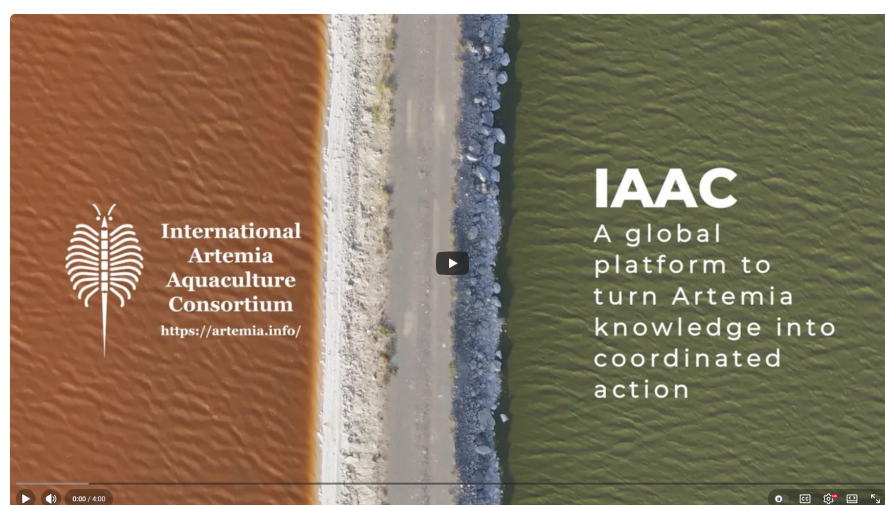
You can explore the data that SOFIA 2026 is based on in the NACA website's [Global Aquaculture Statistics Dashboard](#).



New video on the International Artemia Aquaculture Consortium

A new video produced by University Terengganu Malaysia provides an overview of the International Artemia Aquaculture Consortium, its mission, structure, and collaborative approach to advancing *Artemia* aquaculture.

The Consortium, a research network hosted by NACA, brings together researchers, industry partners, and other stakeholders to promote knowledge exchange, support innovation, and address shared challenges.



The video offers a concise introduction to the Consortium's purpose, research priorities, and commitment to strength-

ening sustainable *Artemia* aquaculture through international cooperation. To view it click the image above or visit:

<https://artemia.info/news/?id=142>

Stakeholders validate new good-practice materials for *Artemia* use in hatcheries



Workshop participants.

TERENGGANU, Malaysia - Researchers, industry representatives, and officials gathered at Universiti Malaysia Terengganu (UMT) from 14–16 June 2026 for Partnerships to Practice: An *Artemia* Workshop. Organised by the Food and Agriculture Organization (FAO) and the Artemia Reference Centre (Ghent University), in collaboration with the International Artemia Aquaculture Consortium (IAAC) and the Global Sustainable Aquaculture Advancement Partnership (GSAAP), the workshop had two objectives: first, to validate new fact sheets and videos illustrating good hatchery practices as an extension to the FAO Manual on *Artemia* Production and Use (2024); and second, to formulate strategic recommendations for future IAAC activities.

The workshop was officially opened by UMT Vice Chancellor Mohd. Zamri Bin Ibrahim, alongside opening remarks from His Excellency Peter Van Acker (Ambassador of Belgium to Malaysia) and Azahari Othman (Deputy Director-General of the Department of Fisheries, Malaysia). Dr. Alessandro Lovatelli, representing the FAO, welcomed the delegates, highlighting the collective effort needed to bridge the gap between academic research and commercial hatchery applications.

The organisers expressed their gratitude to FAO for its financial support to the Laboratory of Aquaculture and Artemia Reference Centre (Ghent University) in preparing the extension materials and organising the meeting. Special appreciation was also extended to UMT for hosting the event and managing local logistics, and to IAAC and NACA for their vital roles in facilitating the sessions.

Operationalising the FAO *Artemia* Manual: The hatchery “starter kit”

The main focus of the workshop was to review fact sheets and videos that translate the FAO *Artemia* Manual into practical guidance on *Artemia* production and use in hatcheries. The goals are to optimise yield and reduce wastage of expensive *Artemia* resources, and to provide instruction on cold storage, enrichment, and biosecurity. The workshop endorsed a multi-channel ‘starter kit’ approach for use by hatchery technicians, including:

- Standard Operating Procedure (SOP) Sheets: Step-by-step instructions for daily hatchery operations.
- Graphical Quick-Reference Sheets: Visually-oriented with diagrams for quick hatchery-floor consultation.
- Demonstration Videos: Short, clear videos demonstrating good practices.
- Checklists & Monitoring Records: Practical tools for tracking parameters, batch success, and troubleshooting.

Overcoming barriers to adoption

The workshop emphasised that successful adoption requires changing operational mindsets, not just supplying technical information - hatcheries must see tangible performance improvements, reinforced through repeated engagement and shared success stories. The endorsement of these materials by FAO and NACA was seen as a major strength, offering an independent, trusted reference for hatchery managers, distinct from commercially motivated recommendations.

Key barriers identified include diverse languages of hatchery staff, the need for repeated on-site training and follow-up, financial constraints, and resistance to altering established routines. In response, delegates proposed expanding future toolkits to include:

- Detailed Biosecurity Guidance: Protocols for minimising pathogen entry.
- Hatchery-Design Recommendations: Optimal layouts for *Artemia* preparation and feeding stations.
- Regional Production Benchmarks: More visual examples representing diverse geographic regions and production systems.

Participants agreed that success within one year would be reflected in adoption of the materials by hatcheries, their incorporation into training programmes and hatchery SOPs, translation into multiple languages, and measurable improvements in hatchery performance.

Options for global *Artemia* genetics & resource inventory

For hatcheries, choosing the right *Artemia* strain has direct consequences on hatching rates, size distribution, and nutritional value. The workshop discussed and broadly supported the potential establishment of a global inventory of *Artemia* resources and protocols for the harmonisation of genetic characterisation research.

If developed, such a database could capture information such as:

- Origin & species: Geographical sourcing and distribution.
- Genetic markers & phenotypic traits: Genetic identity, size, growth potential and environmental tolerances.
- Hatching & nutritional performance: Optimal hatching conditions and nutritional characteristics.
- Disease-related information: Documentation on regional biosecurity profiles.

By standardising these metrics, the industry could gain access to a transparent, reliable catalog of global strains while still preserving local knowledge and unique regional characteristics.

Strengthening networking and collaboration

Delegates underlined the importance of strengthening collaboration across the global *Artemia* community - through IAAC, existing regional networks, alumni networks, industry partnerships, national extension services, regional bodies, and FAO-linked activities. Priorities identified for future collaboration included mapping suitable locations for *Artemia* development, establishing and expanding *Artemia* resource inventories, improving information exchange among stakeholders, and building stronger links between research, industry, hatcheries, and government.

Prof. Anneliese Declercq noted that sustainable impact will require continued collaboration beyond the current project, with IAAC serving as one platform - among others that may be added - to connect expertise, support capacity building, and facilitate future regional and global *Artemia* initiatives.

Dissemination and translation strategy

To ensure the new resources reach remote hatcheries, delegates agreed that effective dissemination will require a mix of top-down and bottom-up channels: FAO, NACA, IAAC and GSAAP; national Departments of Fisheries; industry networks, feed companies and distributors; universities and technical institutions; social media and WhatsApp groups; and direct hatchery engagement through companies. ASEAN networks were singled out as especially valuable for regional uptake.

Multi-lingual access was also a key consideration, with the planned simultaneous publication of the fact sheets in the six official UN languages (English, French, Spanish, Russian, Chinese, Arabic). Workshop participants also volunteered to coordinate translations into Spanish, Russian, Chinese, Uzbek, Arabic, and French.

Particular emphasis was placed on integrating the materials into university curricula and technical training programmes, to reach both current practitioners and the next generation of hatchery managers.

Tour of the UMT *Artemia* Hatchery and Kembang Subur Hatchery

Participants observed local *Artemia* production techniques at local facilities. This included a view of sustainable biomass production at UMT's *Artemia* Hatchery facilitated by Prof. Dr. Yeong Yik Sung and staff of the Institute of Marine Biotechnology, where adult *Artemia* biomass is grown in tanks using local agricultural byproducts, principally palm kernel meal, a byproduct of the Malaysian palm oil industry. Participants also traveled to Kuantan, Pahang for a field visit and tour of the commercial Kembang Subur Hatchery, providing a view of how the newly developed SOPs and technical sheets perform under a different set of commercial operating conditions.

World Bank *Artemia* study reports available!

Scaling Artemia Aquaculture: Synthesis of Global Opportunities

This synthesis report consolidates over half a year's worth of technical research, market analysis, and country level value chain assessments to present a comprehensive investment overview of the brine shrimp aquabusiness. Developed as part of the World Bank's PROBLUE initiative on sustainable aquaculture and blue economy development, the report draws together the findings of six assessments, covering *Artemia* production systems, governance frameworks, markets and trade, emerging use cases, inventories of innovators, and in-depth country value chain studies.

Artemia, or brine shrimp, is a cornerstone input in hatchery-based aquaculture - used in the early life stages of shrimp, marine fish, and increasingly, ornamental species. However, over 90 percent of the global *Artemia* cyst supply is still derived from wild sources, primarily from hypersaline lakes in the United States and Central Asia. This dependence exposes the *Artemia* aquabusiness to supply shocks, price volatility, and environmental risks. Meanwhile, demand for *Artemia* is rising rapidly in response to global aquaculture growth and the search for sustainable, climate-smart solutions for animal feed and human food.

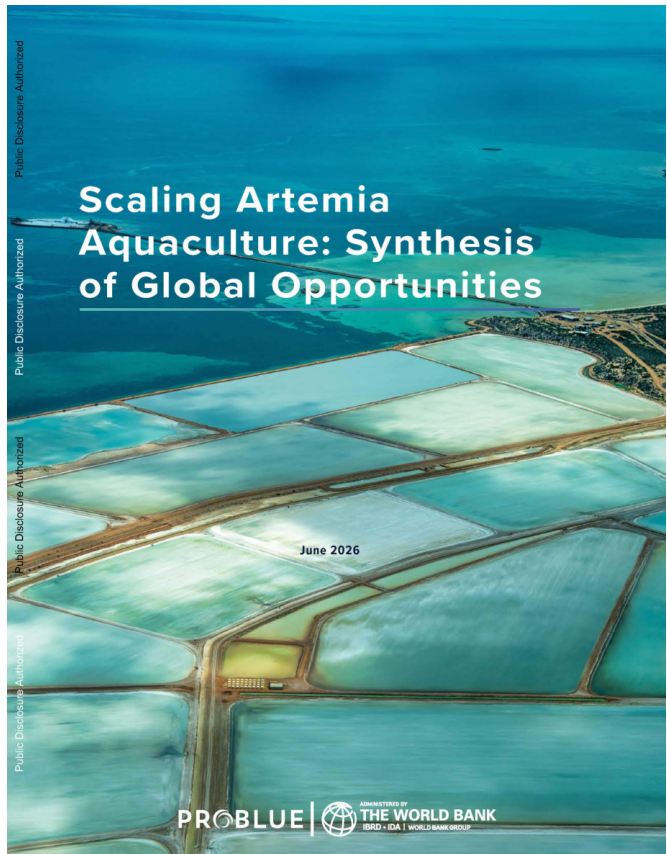
The purpose of this synthesis report is to:

- Provide an integrated overview of the current state and future potential of farmed *Artemia* systems.
- Present investor-ready intelligence on country contexts, production models, and enabling conditions.
- Guide strategic decision-making across public, private, and donor stakeholders through a concise but data-driven road map for investment and scale.

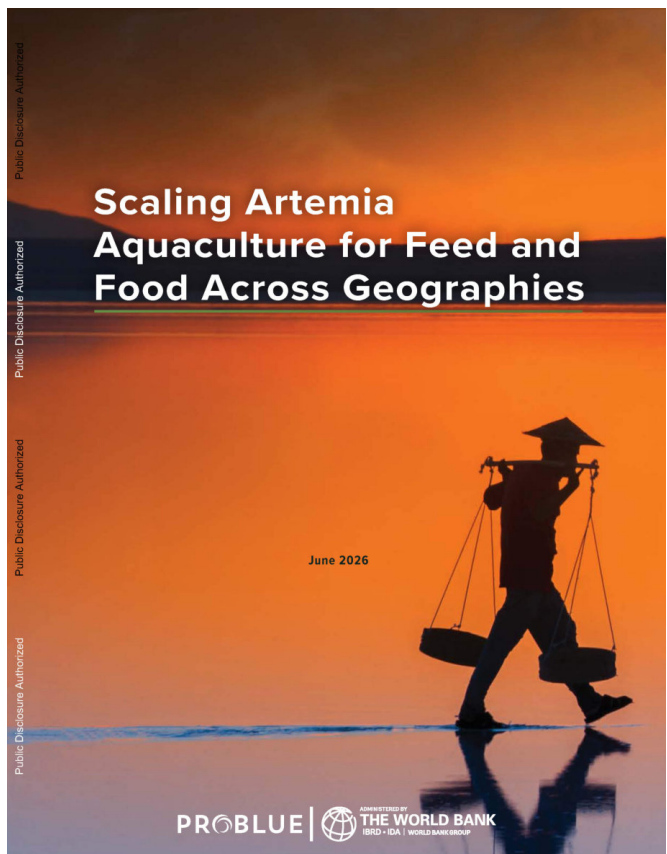
The report builds on field-level insights and technical models drawn from in-depth value-chain analyses in five countries- Bangladesh, Viet Nam, Thailand, China, and Kenya- and a broader investment readiness scan across 27 additional countries identified as high-potential scaling candidates. Using structured criteria around market demand, resource availability, governance, inclusion, and scalability, the synthesis distills lessons into four scalable *Artemia* business models and presents regional investment road maps for Asia, Africa, Latin America, and the Middle East.

Scaling Artemia Aquaculture for Feed and Food Across Geographies

Artemia, commonly known as brine shrimp, is a critical live feed ingredient in aquaculture, particularly for shrimp and marine finfish hatcheries. The global *Artemia* industry is experiencing increasing demand driven by expanding aquaculture production. This report provides an in-depth analysis of *Artemia* in five key countries where *Artemia* aquaculture is established or in early stages of development - Viet Nam, China, Thailand, Bangladesh, and Kenya. The



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studies highlight *Artemia* value chains and associated production systems, market potential, and investment needs.

The findings confirm that *Artemia* can be successfully, profitably, and sustainably produced through aquaculture as cyst or biomass products in hypersaline environments, across diverse systems, providing important and critical products for aquaculture, with potential for wider application and product development as aquafeed and human food.

The productivity and profitability of *Artemia* compares positively with traditional salt production, providing new income and livelihood opportunities for people living in hypersaline and salt-affected coastal and inland regions. A key factor for success is access to markets. Case studies identify important opportunities for investment that include working capital and infrastructure for farm and storage improvements, training and extension activities, product diversification, and post-harvest and market product development, including investing in *Artemia* and novel aquafeed ingredients and human food applications.

The case studies also provide examples of four systems or business cases with potential for wider application and scaling, including (a) Integrated *Artemia*-Shrimp Farming (Viet Nam Model); (b) Solar Saltworks-*Artemia* Integration (China Model); (c) *Artemia* Biomass for Aquafeed & Livestock Feed (Thailand Model); and (d) Smallholder *Artemia* Pond Culture (Bangladesh Model). The potential scalability of these models is assessed by countries in Africa, Latin America, Asia, and the Middle East. The assessment shows significant opportunities for scaling the models in Africa and more globally in hypersaline ecosystems, provided the market, regulatory, and research environment is in place.

The studies provide guidance on potential; the follow up actions would involve more detailed country level assessments and the development of country specific investments strategies for the public and private sector. A coordinated approach for public investment (in research, policy, and investment environment) and private investment (in *Artemia* production businesses, processing, and product marketing) is required.

Scaling *Artemia* Aquaculture Emerging Markets and Trade

This Global *Artemia* Emerging Markets and Trade report offers a comprehensive overview of *Artemia* products and markets, from global trends to country-level case studies. It provides an in-depth assessment of traditional and emerging uses, supply systems, investment opportunities, and strategic risks. The study is global in nature, with illustrative cases of 'farmed' *Artemia* in Bangladesh, China, Thailand, and Viet Nam in Asia and Kenya in Africa and how new farmed products can compete with wild *Artemia* products.

The report provides the quantitative foundation for the synthesis, linking the production and governance analyses with global trade, price, and investment trends. Together, six studies form a coherent analytical suite:

- Global Overview of Production and Conservation - identifies the ecological and biological basis for sustainable *Artemia* supply.
- Governance Frameworks and Regulatory Gaps Assessment - maps national and international policy conditions influencing industry formalization.
- Country Value Chain Studies - provides cost structures and production models from five pilot countries (Bangladesh, China, Thailand, Viet Nam, and Kenya), illustrating diverse pathways from artisanal to industrial *Artemia* farming.
- Human Food Systems Study - explores *Artemia*'s potential as a novel, climate-resilient protein source for food and nutrition security.
- Global Technology and Innovation Inventory - catalogs emerging production technologies, processing tools, and digital innovations.

By connecting these strands, the report situates *Artemia* within a USD 50 billion aquaculture value chain, identifies regional demand drivers (shrimp, finfish, crab, pet food, and nutraceuticals), and highlights investment priorities in production diversification, biomass processing, and quality certification. It directly underpins the synthesis sections



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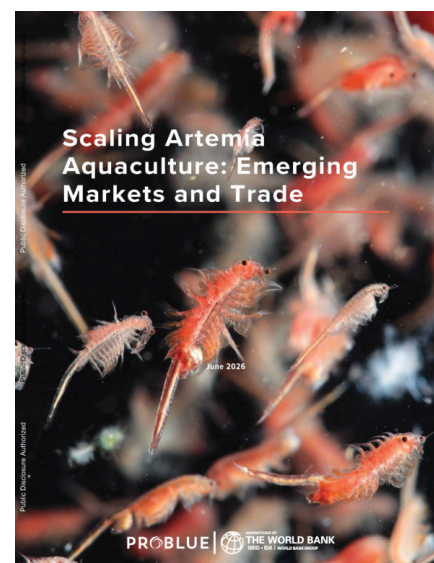
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on competitiveness, business models, and investment pathways, providing the market logic behind the policy, governance, and social findings of the other reports.



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