MASS PRODUCTION OF SIS SEED TO PROMOTE NUTRITION-SENSITIVE INLAND AQUACULTURE IN ASIA

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Persistent malnutrition in Asia necessitates innovative solutions. This article explores the potential of nutrient-rich small indigenous fish species (SIS) to combat undernutrition and promote nutrition-sensitive aquaculture in South Asia. Integrating SIS into carp polyculture systems has great potential to increase the micronutrient productivity of traditional aquaculture, but, until very recently, a lack of techniques for hatchery-based mass production and distribution of SIS seed was a key bottleneck hampering the widespread adoption of SIS aquaculture. This article draws attention to significant new breakthroughs in hatchery-based seed production for multiple SIS in India, and their implications for scaling up nutrition-sensitive aquaculture throughout the region.

Mola carplet (Amblypharyngodon mola) (left) and Pool Barb (Puntius sophore) (right) are two popular and nutrient-dense SIS in India and Bangladesh

Undernutrition has been an enduring challenge throughout Asian history. Asia is home to more than two-thirds of the world's poor, and over 60% of its undernourished people[1]. Most of them are found in South Asia, where nearly half a billion people grapple with undernourishment and food insecurity. Micronutrient deficiencies, especially in vitamins A and D, iron, iodine, and zinc, are widespread in the region. Food-based interventions that enhance dietary quality and diversity to encourage greater consumption of nutrient-rich foods, and increased energy and macronutrient intake can play an important role in addressing this problem.

Small indigenous fish species (SIS) from freshwater ecosystems are an important part of the diets of many fish-dependent populations in South Asia. SIS possess an impressive reproductive capacity, characterised by short lifespans that enable them to multiply rapidly. Regarded as natural 'superfoods,' SIS often surpass larger farmed fish such as carps and tilapias in terms of their micronutrient composition. SIS sourced from capture fisheries were historically critical to food and nutrition security in these countries, but the diversity and abundance of SIS in Asia are now threatened by habitat degradation and conversions, introduction of exotic species, agricultural intensification, industrial pollution, and climate change. The increasing scarcity and rising prices of SIS have made them increasingly inaccessible for lower income people, depriving them of both nutrition and cultural significance.

Paradigm shift: harnessing aquatic foods to combat undernutrition

Despite their high nutritional value, SIS were once considered undesirable in aquaculture and often removed from ponds. However, integrating SIS into polyculture systems has proven to be a smart strategy in boosting overall pond productivity and micronutrient supply, without any reduction in yields of larger species such as carps and tilapia. Unfortunately, the commercial cultivation of SIS has been largely overlooked. The presently high market value of many formerly cheap

[1] *FAO and UNICEF. 2021. Asia and the Pacific – Regional Overview of Food Security and Nutrition 2021: Statistics and trends. Bangkok, FAO. https://doi.org/10.4060/cb7494en*

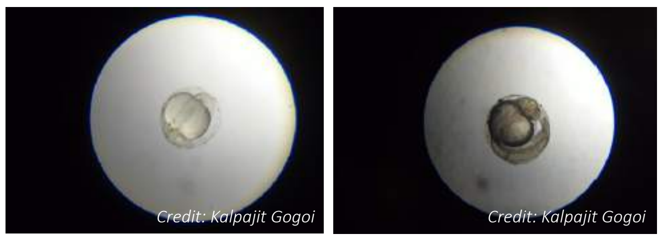
and abundant SIS provides new opportunities for farmers to produce SIS for profit that can be used to buy a more diverse diet, as well as for direct consumption by household members. The time is therefore ripe for scaling up SIS aquaculture, but a lack or reliable techniques for the mass production and distribution of SIS seed constitutes a significant impediment to scaling up nutrition-sensitive carp-SIS cultivation.

Expensive SIS (top) and cheap large farmed fish (bottom) on sale in a Bangladesh supermarket: the SIS sell for around three times more per kg than the tilapia

To overcome this critical technical bottleneck, WorldFish is implementing a project named "Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale" in India (2021-2024)[2]. The project is financially supported by the German Federal Ministry for Economic Cooperation and Development (BMZ). One of its central objectives is to develop easily scalable methodologies for the mass seed production of some important SIS through the standardisation of a hatchery-based breeding approach.

Pioneering potential: identifying ideal SIS candidates for mass production

The selection process for incorporating SIS into carp-based polyculture requires meticulous attention to factors such as nutrient composition, species compatibility, feeding and breeding behaviours, as well as harvesting techniques. The project primarily focused on developing hatchery-based breeding protocols for mola carplet *(Amblypharyngodon mola),* a most popular SIS in India and Bangladesh and considered as a champion species for nutrition-sensitive aquaculture. Mola is a primary consumer, eating phytoplankton, the base of the aquatic food web. Consequently, mola is among the cheapest fish to produce. It boasts elevated levels of essential nutrients like vitamin A, vitamin B12, iron, and calcium, which contribute to its significant market demand. While certain hatcheries have demonstrated successful captive breeding of mola, large-scale seed production has yet to be widely adopted.



Microscopic view of mola (left) and pool barb (right) early-staged hatchling

The other candidate species selected for mass seed production in this project are as follows:

(i) Pool Barb *(Puntius sophore):* Commonly referred to as 'puti' in South Asia, pool barb has a primarily herbivorous diet and contains high amounts of calcium and polyunsaturated fatty acids (PUFAs). Like the mola, achieving mass seed production for the pool barb remains challenging;

(ii) Reba Carp *(Cirrhinus reba):* Reba, a minor carp, sustains itself on plankton, detritus, and insect larvae. It has elevated levels of calcium, and vitamins A and D. Its unique flavour makes it highly demanded in the market. Although there have been instances of induced breeding, large-scale seed production for reba is still in the experimental stages; and

(iii) Tengara Catfish *(Mystus tengara)*: Tengara catfish feeds on zoobenthos and insect larvae and has high levels of calcium, selenium, and vitamin A. Induced breeding successes have been achieved with closely related species, but comprehensive seed production for the tengara catfish is still pending.

2 Project webpage: https://worldfishcenter.org/project/taking-nutrition-sensitive-carp-sis-polyculture-technology-scale

Recent innovations in SIS seed production and scalability

Mass production of SIS seed is difficult due to their small size and delicate nature, making conventional hatchery techniques inappropriate for large-scale production. Consequently, successful SIS breeding requires new methodologies and techniques. Recent research by WorldFish in India has overcome this bottleneck to develop comprehensive seed production protocols for several SIS, including mola and pool barb.

The technique developed combines hormone administration using synthetic GnRH analogue with environmental manipulation to stimulate seed production. For optimising mola breeding, a precise hormone dosage regimen has been devised, with males receiving 0.25 ml/kg of body weight and females receiving 0.5 ml/kg. Due to the high viscosity and minimal dosage required for SIS, the hormone dose is diluted 15 times. The inducing solution is introduced into the peritoneal cavity of mola broodfish using a 1 ml capacity insulin diabetic syringe with 40 graduations. For 1 kg of female mola brood, 8 ml of inducing solution (0.5 ml hormone + 7.5 ml 0.65% NaCl solution) is employed.


Credit: SK Dubey

Aeration tower – a simple innovation of the project that solves the water quality problems in the hatchery

Custom-designed tanks, equipped with a dual hapa arrangement, are used for mola breeding. Continuous infusion of oxygen-rich water through an aeration tower improves breeding efficiency and the survival of larvae. Employing these methods has enabled partner hatcheries in Odisha and Assam to collectively produce nearly 10 million mola seeds and counting since July 2022. Depending on factors such as season, water temperature, and brooder maturity, the protocol allows 1.5-3.0 kg mature female mola brooders in a 1:2 female-to-male ratio to yield approximately 1 million hatchlings in a single batch. These are ready for the market within 3-4 days of hatching. To illustrate the mass seed production of mola through induced breeding, the project has formulated a straightforward 8-step practical guide for farmers[3]. Hatchery-produced seed can be conditioned and packed in clean well-oxygenated water before delivery to farmers, reducing mortalities during transport and stocking.

Applying a similar protocol with slight substrate modifications, the project achieved a second breakthrough by producing a substantial quantity of pool barb *(Puntius sophore)* seed in Assam. To initiate the reproductive cycle, male brooders were administered a hormone dose of 0.25 ml/kg of body weight, while females received 0.5 ml/kg. The eggs were then deposited into the substrate. This research protocol enabled the production of around 1 million hatchlings from 2.5-3.0 kg mature female pool barb in a 1:1 female-to-male ratio.

Following successes with mola and pool barb, the project has extended mass seed production techniques to reba carp *(Cirrhinus reba)* and tengara catfish *(Mystus tengara)*, employing similar hormonal doses. In the case of tengara catfish, the fertilised eggs exhibit high stickiness, while reba carp eggs are non-sticky and transparent. For tengara catfish, approximately 2.5 kg female brooders are required to yield 1 million hatchlings, while 2.5-3 kg mature female reba can produce the same quantity in a single batch.

The hatchery-based induced breeding protocol developed for multiple SIS within the project is straightforward, easily reproducible, and can be adopted by small-scale hatchery owners. The project is also currently experimenting with other nutrient-rich SIS, such as the flying barb *(Esomus danrica)*, banded gourami *(Trichogaster fasciata)*, and dhela *(Osteobrama cotio)*, with the development of breeding protocols underway.

Nurturing future success: the vital role of broodstock and nursery rearing methods

Rearing and maintenance of broodstock play a pivotal role in the induced breeding of SIS. Maintaining brood under conditions of optimal stocking density and water quality, and providing protein-rich supplementary feed are imperative to ensure a supply of healthy and fecund brood fish. When collecting SIS broodstock from the wild, it is preferable to source from multiple places within the same watershed, particularly from sizeable permanent water bodies. Most SIS are renowned for their prolific breeding tendencies, making it vital to segregate males and females to avert spontaneous breeding.

[3] *Gogoi K, Rajts F, Das RR, Dubey SK, Padiyar A, Rajendran S, Belton B and Mohan CV. 2023. Induced breeding of mola carplet (Amblypharyngodon mola) for mass seed production: A practical guideline. Penang, Malaysia: WorldFish. Guideline: 2023-23. https://hdl.handle.net/20.500.12348/5552*

One-month-old mola (left) and Reba carp fry (right) after successful nursery rearing

Successful nursing of SIS fry hinges upon multiple factors, including pond preparation, the introduction of selectively cultured plankton in nursery ponds, and maintenance of appropriate stocking densities. During the initial 3-4 days of nursery rearing, hatchlings require an abundant supply of small zooplankton, primarily consisting of protozoans and rotifers. Mola hatchlings are particularly susceptible to predation from copepods and certain insects and insect larvae, such as backswimmers and dragonfly larvae. Therefore, management strategies must be implemented to selectively eliminate harmful zooplankton while fostering the growth of beneficial protozoans and rotifers.

To curb copepod predation during stocking, introducing hatchlings into nursery ponds within 3-4 days of water filling is recommended. During the initial rearing stages, hatchlings should be fed microencapsulated chicken eggs. Daily organic fertilisation using mustard oil cake is crucial for maintaining a stable plankton population. To counteract disease outbreaks due to plankton shortages, it is advisable to harvest the fry after three weeks of culture. Subsequently, they can be stocked in a carp polyculture grow-out pond at a rate of 5-10 individuals per square metre. In order to disseminate knowledge, the project has developed a simple guideline on nursery rearing of mola seed and stocking protocols into polyculture ponds[4].

From knowledge to action: dissemination and capacity building for expansive impact

Efforts to propagate mola seed distribution and catalyse carp-mola polyculture have gained momentum through strategic collaboration with private sector partner hatcheries. These hatcheries have undertaken the role of marketing and supplying mola seed to a diverse range of beneficiaries, including local farmers, women self-help groups, and indigenous seed growers. Notably, the hatchery based in

For the first time in India, hatchery produced mola seed was sold from Odisha

Oxygen-packed mola seed bag with clean and oxygenated water reduces stress and increases survival during transportation

The project's partner hatchery from Odisha supplied 400 000 mola seed to Goa state through cargo flight in August 2023

Odisha has achieved remarkable success by selling 2.5 million mola hatchlings and 100 000 mola fry, adopting a pricing scheme aligned with carp rates up to August 2023.

Illustrating the tangible impact of these initiatives, consider the example of Asish Kumar Nayak. As a small-scale carp farmer, Nayak took the proactive step of stocking 200 000 mola hatchlings into his homestead pond (three acres) during the previous year. In a span of twelve months, nearly 50 kg of mola catered to his household's consumption. Further, Nayak capitalised on his success by selling close to 200 kg at the farmgate, commanding an average selling price of 160 INR per kilogram. Furthermore, with an estimated surplus of 200 kg still thriving within his pond, Nayak's success story continues to unfold.

Concurrently, the project has orchestrated hands-on training sessions on SIS induced breeding. These training programs have successfully engaged hatchery owners, seed cultivators, farmers, government officials, and researchers. The resulting outcomes are manifold. Besides providing direct training on SIS induced breeding, it strengthens partnership and cooperation between the Department of Fisheries and solidifies the government's commitment to actively participate in the Scaling-SIS project. This approach increases awareness of the availability of mola seed from partner hatcheries as well as shares insights regarding mola seed production

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[4] *WorldFish (2022). Stocking of hatchery produced mola seed (Amblypharyngodon mola): A guideline for farmers. https://worldfishcenter.org/sites/default/files/2022 10/ Mola%20seed%20stocking%20guideline_English_0.pdf*

and farming techniques through local media outlets. Furthermore, this approach facilitates interaction between farmers and government representatives. By capitalising on this two-way exchange, the project amalgamates information dissemination, capacity development, and community engagement into a cohesive strategy to promote nutrition-sensitive aquaculture.

Empowering change: Government's indispensable role in scaling nutrition-sensitive aquaculture

The pivotal role of government commitment cannot be overstated when it comes to elevating public awareness about the importance of nutrition-sensitive approaches. Governments can wield a transformative influence by championing and disseminating these innovative practices. A prime example of this synergy is evident in WorldFish's successful advocacy, which has led to policy shifts within the State administrations of Odisha and Assam. This advocacy has paved the way for the adoption of nutrition-sensitive carp-mola polyculture on a substantial scale across both states. These policies will stimulate a growing demand for mola seed among those who are embracing the government-endorsed carp-mola polyculture program. The surge in demand underscores the need for a robust supply chain of SIS seed to support the expanding adoption of this approach.

Credit: SK Dubey

The project conducted different batches of on-farm training sessions with significant numbers of women participants

Credit: SK Dubey

The project trained government officers and researchers on SIS induced breeding for large-scale dissemination of the technology

Credit: Rashmi Ranjan Das

Asish Kumar Nayek sold 200 kg mola in the past year and consumed 50 kg to cater to the dietary needs of his household

Furthermore, the synergy of a proactive bureaucracy with a grassroots, bottom-up approach is quintessential for the effective scaling and sustainable maintenance of this innovative practice. By focusing on both income enhancement and nutritional enrichment, this strategy is poised to usher in a new era of aquaculture practices that align with contemporary dietary requirements and economic aspirations.

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