HATCHERY-BASED MASS SEED PRODUCTION OF SMALL INDIGENOUS FISH: ADVANCING NUTRITION, LIVELIHOODS, AND FRESHWATER BIODIVERSITY

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Recognising the potential of small indigenous fish species (SIS) in alleviating malnutrition and enhancing rural livelihoods, WorldFish and partners pioneered hatchery-based mass seed production of SIS, achieving a breakthrough in nutrition-sensitive aquaculture. Through innovative breeding protocols, mobile small-scale hatchery systems, and farmer-centred business models, the initiative has scaled SIS aquaculture across India and Bangladesh, generating over 52 million SIS seeds. With formal policy adoption in Odisha and Assam, SIS aquaculture is emerging as a vital instrument for nutrition security, women's empowerment, smallholder income generation, and biodiversity conservation in freshwater systems under climate change pressures.

Women selling nutrient-rich small fish near Deepor Beel in Assam, contributing to local food systems.

Across the freshwater landscapes of South Asia, small indigenous fish species (SIS) have long played an understated, yet vital role in human nutrition and aquatic biodiversity. Despite rarely exceeding 25 cm in length, these tiny fish are ecologically resilient, thriving in highly variable aquatic environments. For generations, they have supported rural communities, serving as both a staple food source and a means of livelihood.

SIS are nutritional powerhouses. Species such as Mola *(Amblypharyngodon mola),* Pool barb *(Puntius sophore),* and Swamp barb *(Puntius chola)* Dhela *(Osteobrama cotio),* and Flying barb *(Esomus danricus)* are exceptionally rich in bioavailable vitamins (A, B12 and C) and minerals (iron, calcium, zinc, iodine and selenium). Their traditional consumption, often whole —including head, bones, and eyes— ensures maximum intake of micronutrients, enhancing their dietary value far beyond that of larger carp or tilapia.

Despite these benefits, SIS remain under-represented in global fisheries records and are often overshadowed by commercially dominant species. Their populations face accelerating decline due to habitat destruction, pesticide and fertiliser runoff, introduction of exotic species, industrial pollution, and climate variability. Once abundant and affordable, SIS are now increasingly scarce and costly, threatening both nutrition and livelihoods. Their disappearance signifies not only a cultural and ecological loss but also a critical gap in rural nutrition security.

Integrating SIS into nutrition-sensitive aquaculture systems

Carp polyculture has dominated freshwater aquaculture in South Asia for decades, providing economic returns and yield but often failing to address micronutrient deficiencies in rural diets. Recognising this gap, integrating SIS such as Mola into traditional carp farming systems represents a transformative approach[1]. These fish thrive alongside carp without additional feed inputs, creating nutrient-rich ponds that enhance the availability of essential micronutrients.

Empirical evidence from Bangladesh, India, and Nepal demonstrates the effectiveness of this integration. In Odisha and Assam, household ponds co-culturing carp and Mola increased access to vitamin A, calcium and iron, particularly benefiting women and children[2]. Importantly, these interventions are low-cost, requiring no additional feed inputs. By

[1] *Dubey SK, Rajts F, Gogoi K, Das RR, Padiyar A, Belton B, Mohan CV and Bhadury P. (2024). Mass scale seed production of indigenous small fish species: A promising solution to scale nutrition-sensitive aquaculture. In Sinha A, Roy A and Gogoi P, eds. Perspectives and Applications of Indigenous Small Fish in India. Singapore: Springer Nature Singapore Pte Ltd, pp: 109-134.* https://link.springer.com/chapter/10.1007/978-981-97-1586-2_5

[2] *Dubey SK, Padiyar PA, Shenoy N, Gaikawad AB, Ratha BC, Mohan CV, Belton B. (2024). Scaling Community-Based Aquaculture for Enhanced Nutrition and Women's Empowerment: Lessons from Odisha, India. Frontiers in Sustainable Food Systems, 8:1412686.* https://10.3389/fsufs.2024.1412686

aligning aquaculture practices with nutritional objectives, this approach addresses malnutrition while maintaining the ecological balance of pond systems.

Despite these advantages, a major barrier persists: limited availability of SIS seeds. Unlike carp, tilapia and catfish, which are produced through well-established hatchery techniques, SIS seed production has historically relied on wild broodstock collection, a method that is labour-intensive, ecologically disruptive, and unsustainable. Artificial breeding techniques, which revolutionised large fish production decades ago, had not been adapted for SIS, despite their superior nutritional profile. Interestingly, related small fish species are bred in the aquarium trade, indicating a largely untapped opportunity for food systems.

Scaling carp–SIS polyculture: Approaches and implementation

Addressing this challenge, the WorldFish-led project "Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale" (2021–2024), supported by the German Federal Ministry for Economic Cooperation and Development (BMZ) and GIZ, aimed to overcome the critical bottleneck of limited SIS seed availability.

The project focused on Assam and Odisha, two ecologically and culturally diverse Indian states where small-scale freshwater aquaculture predominates and SIS are integral to local nutrition, culture, and livelihoods. Interventions were tailored to regional contexts, ensuring that technical innovations aligned with community practices. By establishing hatchery-based mass seed production, the project reduced dependence on wild broodstock and promoted sustainable, high-quality SIS seed for aquaculture.

Hatchery-based mass seed production of SIS: Methodologies and achievements

The project developed breeding and mass seed production protocols for six key SIS species[3]: (i) Mola *(Amblypharyngodon mola):* rich in iron, zinc, calcium, vitamin A, fatty acids and amino acids; (ii) Pool Barb *(Puntius sophore);* (iii) Swamp Barb *(Puntius chola):* rich in fat-soluble vitamins (A, D, E and K), essential minerals, fatty acids, and amino acids; (iv) Tengara Catfish *(Mystus tengara):* high in protein, calcium, iron, zinc, and omega-3 fatty acids; (v) Reba Carp *(Cirrhinus reba):* contains vitamins A and D, selenium, potassium, and omega-3 fatty acids; and (vi) Climbing Perch *(Anabas testudineus):* high protein content, essential micronutrients, omega-3 fatty acids, and essential vitamins.

Producing SIS at scale required careful attention to biological and technical details. Protocols included broodstock pond preparation, harvesting and conditioning breeders, sex identification, induced breeding set-up, hormone dose, spawning, egg incubation, and harvesting hatchlings. Hormone doses were species-specific (0.5–1 ml/kg bodyweight for females; 0.25–0.05 ml/kg for males).

Hormone administration to the peritoneal cavity – the most effective technique for successful SIS breeding.

India's first hatchery-produced Mola hatchlings were sold from Odisha's partner hatchery for the first time in 2022, paving the way for large-scale seed production.

Specialised hatchery infrastructure—including double-hapa tanks, oxygen-rich water and energy-efficient water management systems—ensured optimal spawning conditions. Robust live transport and nursery-rearing protocols enabled large-scale production even in small-scale facilities. The protocols are simple, replicable, and compatible with existing carp hatcheries, allowing operators to diversify species, increase income, and improve access to nutrient-rich seeds for communities.

Over three years, the project successfully standardised protocols for six species and produced over 52.57 million SIS seeds, equivalent to approximately 20 782 kg of surviving fry. These seeds were distributed to farmers, women's self-help groups, cooperatives, NGOs, and research institutions, promoting widespread adoption of SIS aquaculture.

Technological and economic innovations in SIS hatcheries

The project integrated environmental manipulation with hormone-assisted breeding to maximise seed production. A key innovation was the development of multi-utility and mobile hatchery systems. Recognising that large, capital-intensive facilities were inaccessible to smallholders, modular hatcheries were designed to operate efficiently in flood-prone and resource-limited regions[4]. Innovations included customised

[3] *WorldFish (2024). Tiny Treasures, Big Impact. The Vital Role of Small Indigenous Fish in Nutrition and Livelihoods. A Photographic Sojourn of the Project "Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale". New Delhi, India: WorldFish. Photo Book: 2024-88.* https://hdl.handle.net/20.500.12348/6498

[4] *Rajts F, Dubey SK, Gogoi K, Das RR and Padiyar A. (2024). Small-scale alternative hatchery methods for indigenous small fish and minor carp seed production: A practical booklet. Penang, Malaysia: WorldFish. Booklet: 2024-22.* https://hdl.handle.net/20.500.12348/5980

spawning and incubation tanks, cylindroconical incubators, aeration towers and plankton-based nursery and broodstock pond management. These innovations significantly improved hatching success, enabling small-scale hatcheries to produce high-quality SIS seed alongside carp.

The multi-species SIS hatchery of Mr. Saurava Kumar Biswal, a key project partner in Odisha.

In flood-prone and climate-vulnerable regions, mobile and small-scale hatcheries offered flexible, low-cost solutions. These systems required minimal installation and operational costs, were energy-efficient, and adaptable to local conditions. By integrating climate adaptation, water resource management, and sustainable energy use, these models provide resilient solutions for smallholder aquaculture.

Equally transformative was the economic model of SIS hatcheries developed to guide hatchery owners, cooperatives and policymakers[5]. Through detailed cost–benefit analyses, the project identified multiple entry points: integrating SIS seed production into existing carp hatcheries for an investment of around USD 5 500; establishing dedicated SIS hatcheries for USD 10 000; or setting up larger multi-species hatcheries with integrated research facilities for around USD 23 000. These models offered realistic and scalable pathways for small enterprises, cooperatives, and even public institutions to participate in the SIS value chain.

Capacity-building, training, and regional knowledge exchange

In partnership with state and national government agencies in India, the project implemented a comprehensive, multi-layered capacity-building strategy, engaging a diverse set of stakeholders, including government fisheries departments, private hatchery operators, farmers, NGOs and extension officers.

Training programs were designed to combine grassroots empowerment with high-level technical knowledge exchange, ensuring the long-term sustainability and adoption of SIS aquaculture practices. Knowledge exchange across India, Bangladesh and Cambodia enabled replication of SIS breeding protocols, facilitating a regional network of best practices.

[5] *Chand BK, Dubey SK, Padiyar AP, Gaikwad AB, Das RR, Gogoi K and Rajts F. (2025). Economic analysis of the business model for mass seed production of nutrient-dense small indigenous fish species mola (Amblypharyngodon mola). Journal of the World Aquaculture Society, 56(4), e70038.* https://doi.org/10.1111/jwas.70038

Three-week-old nursery-reared Reba Carp fry.

Three-week-old nursery-reared Swamp Barb fry

In Bangladesh, trained hatcheries achieved remarkable success, producing over two million Mola seeds in a single batch, an important milestone illustrating the feasibility of cross-border adoption of the project's innovation. Initially supported by the CGIAR Initiative on the Asian Mega Delta, this SIS breeding package is now being further scaled through the CGIAR Scaling for Impact program, demonstrating the potential for regional expansion.

Overall, the project directly engaged 2 650 individuals, with women representing 35% of participants, which is a significant step toward inclusive, large-scale adoption of nutrition-sensitive aquaculture practices.

Policy integration and institutional adoption of SIS aquaculture

The success of hatchery-based SIS production has informed policy and programmatic decisions. In Odisha, the Department of Fisheries

Hands-on training and capacity-building programs for government officials from various northeast Indian states.

Hands-on training and capacity-building programs, empowering fish farmers under the project.

Mola form one of the most popular and important dried SIS in eastern India.

Dried Mola is a key ingredient in many popular dishes, adding rich flavor and nutrients.

Processing dried Mola into nutritious fish powder to enhance dietary diversity and nutrition.

incorporated Mola hatcheries into State schemes under the World Bank-supported project *Odisha Integrated Irrigation Project for Climate Resilient Agriculture.* Seven hatcheries were established with subsidy support, demonstrating a clear pathway from research innovation to institutional adoption. Earlier initiatives in 2018–19 had already integrated nutrition-sensitive carp–Mola polyculture into community waterbodies via women's self-help groups, providing a precedent for ongoing scale-up.

Future directions for sustainable, nutrition-sensitive aquaculture

Looking ahead, a suite of strategic interventions is essential to sustain and expand the gains achieved in SIS aquaculture. At the national level, SIS should be formally recognised within fisheries and nutrition policies, integrated into flagship aquaculture programs, and incorporated into public nutrition initiatives, including school feeding schemes, maternal nutrition programs, and integrated child development services. Strengthening gender-inclusive policies is critical to promote women's leadership in hatchery management, seed distribution, and decision-making across the value chain. Concurrently, raising awareness of the nutritional benefits of SIS and developing diversified, value-added products, such as dried, smoked, or fermented forms, can stimulate market demand and broaden their accessibility. Applied research remains central to scaling SIS aquaculture effectively. Efforts should focus on expanding hatchery protocols to additional SIS species, optimising carp–SIS polyculture under diverse ecological conditions and stocking densities, and investigating natural breeding dynamics in rice fields and semi-natural systems. Integrating SIS into wetland, floodplain, and open-water fisheries can enhance biodiversity while supporting smallholder livelihoods. The deployment of mobile and climate-resilient hatchery models will further strengthen system adaptability in the face of environmental variability.

Regional centres of excellence can serve as hubs for training, innovation, and cross-learning, ensuring that advances in SIS aquaculture are

A farmer group in Assam, proudly showcasing their SIS catch after adopting Carp-SIS polyculture

A diverse catch of nutrient-rich small fish from a Carp polyculture pond, vital for local diets and food security.

effectively disseminated and sustained. Collectively, these strategies can position SIS aquaculture as a scalable, nutrition-sensitive, and ecologically sustainable approach—simultaneously enhancing rural livelihoods, improving micronutrient intake, and conserving freshwater biodiversity across South Asia.

For further information and resources

To explore more about the initiative and its transformative impact on nutrition, livelihoods, and biodiversity, visit the project[6] webpage: Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale

Discover the project's flagship visual products that capture its groundbreaking journey and outcomes:

Photography book: Tiny Treasures, Big Impact: The Vital Role of Small Indigenous Fish in Nutrition and Livelihoods

Project documentary: Tiny Treasures, Big Impact. The Vital Role of Small Indigenous Fish

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