Brief Communication

Recent advances in bivalve seed production in India: Salient research findings, technologies and their social impact

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Introduction

India, with its vast 7,516.6 km coastline, rich in native bivalve species such as mussels, oysters, and clams, holds untapped potential for aquaculture. Despite this natural advantage, the country lags far behind its Asian counterparts in bivalve production. While India produces less than 10,000 tons of mussels annually from aquaculture, countries like China, Chile, and Spain dominate global production with outputs of 903,000 MT, 369,000 MT, and 284,000 MT, respectively. India's low output is attributed to the scarcity of reliable seed supply, as the bivalve hatchery sector remains underdeveloped and the lack of awareness about the potential of this resource. Most farmers depend on erratic and limited wild-caught seed, restricting bivalve farming to specific areas such as the backwaters in Kerala.

Recognizing these constraints, the project MFD/SEED/16: Techniques for mass seed production of bivalves (2020-2024) was launched in June 2020. The initiative aimed to overcome seed supply challenges by establishing robust hatchery-based technologies for key bivalve species, including green mussels (*Perna viridis*), brown mussels (*Perna indica*), edible oysters (*Crassostrea madrasensis*), and clams (*Paphia malabarica* and *Villorita cyprinoides*). The project's scope extended beyond technical advancements to encompass the socio-economic upliftment of coastal communities, fostering sustainable livelihoods and addressing the growing domestic and export demand for bivalves. This ambitious project also explored innovative solutions such as integrated multi-trophic aquaculture (IMTA), hybrid biofloc systems, and field upweller nurseries, aiming to make bivalve farming accessible and profitable for both small-scale and large-scale farmers. By leveraging recent advancements in seed production and farming technologies, the initiative sought to develop India's capacity to lead in sustainable bivalve aquaculture. Through targeted investments and training, the project promises a brighter future for India's aquaculture sector, contributing to food security, employment generation, and environmental conservation. This project has laid the foundation for the world's first hatchery dedicated to the Asian green mussel (*Perna viridis*), locally known as *Mayilpeeli Kakka* in the south and *Kallinmel Kaya* in the north of Kerala. Set to be established in Valiyaparamba, in Kannur district of Kerala, the hatchery is currently in its final stages of completion and is being developed with the technical support of ICAR-CMFRI. This project has also enabled ICAR-CMFRI to secure a *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) funded project worth ₹154 lakhs, besides two consultancy projects and MoUs with the governments of Kerala and Maharashtra.

Salient Achievements

High-density larval rearing systems

The establishment of a high-density bivalve larval-rearing system represents a transformative step in hatchery technology, benefiting mussels, oysters, pearl oysters, and clams. At its core is the cylindroconical tank, with a

High density larval rearing system

275-liter capacity, replacing traditional rectangular tanks. This innovative design supports stocking densities of 25–100 larvae per milliliter, a significant improvement over conventional systems limited to 1 larva per milliliter. The conical shape ensures uniform water circulation, preventing dead zones and promoting better growth and survival rates by providing optimal feed and oxygen availability. Each tank incorporates a cylindrical net screen, available in various mesh sizes, to retain larvae without harm while allowing efficient water exchange. This modular design enables scalability to meet production needs, enhancing resource utilization with improved food distribution and waste management. By optimizing space and maintaining a stable environment, this system addresses key challenges in bivalve aquaculture, paving the way for sustainable, high-yield hatchery operations.

Development of Micro-nursery systems

The micro-nursery system, comprising down-welling and up-welling subsystems, facilitates the settlement and metamorphosis of bivalve larvae into spat and supports further rearing to seed size suitable for farming. Designed for species such as mussels, oysters, pearl oysters, and clams, the system includes separate reservoir tanks and pumps for water circulation. In the down-welling subsystem, eyed-stage larvae are stocked at high densities for settlement and growth. Once spat reach 4 mm, they are transferred to the up-welling subsystem for further rearing. This innovative system, successfully designed and operationalized, delivers significant advancements in efficiency and scalability. Each system accommodates up to 9.6 million larvae using just two tons of water, compared to traditional systems requiring 32 tons per day for the same output. This not only enhances rearing efficiency but also minimizes water usage and labour,

Micro-nursery system for larval rearing

Cultchless spat in the downweller silos

significantly reducing costs. Its modular design supports large-scale seed production, enabling hatcheries to meet growing demands for bivalve farming.

Integration of Multi-Trophic Aquaculture (IMTA)

A groundbreaking hybrid biofloc system was developed at Vizhinjam Regional Centre, integrating bivalve nursery rearing with shrimp farming, showcasing the principles of Integrated Multi-Trophic Aquaculture (IMTA). The system features a 10,000-liter biofloc tank filled with diluted seawater (25 ppt), supported by Recirculating Aquaculture System (RAS) components such as a biological filter and protein fractionator for effective water quality management. Aeration is provided by two A3 Venturi aerators, two airoxy rings connected to a blower line, and an oxygen concentrator with a diffuser cone for emergencies. White shrimp (*L. vannamei*) are stocked at the PL10 stage, while oyster and mussel spat are placed in downweller silos or attached to ropes immersed in floc water. Nutrient-rich floc water and algae are circulated using an airlift system, supporting high survival and growth rates. The study achieved over 95% survival of bivalve spat, excellent spat growth, and a shrimp stocking density of 200/m^3. This innovative system

Mussel spat grown in hybrid biofloc system

maximizes resource efficiency by recycling waste as nutrients, reduces environmental impact, and sets a benchmark for sustainable aquaculture, combining high productivity with minimal ecological footprint.

Cultchless spat production: a landmark achievement

The production of cultchless spat of *Crassostrea madrasensis* marks a significant technological advancement in oyster

Hybrid biofloc system

farming. The process begins with the biopsy method to extract gametes, followed by standardized sperm activation to induce fertilization and produce larvae. Pediveliger larvae are then treated with epinephrine hormone, which promotes settlement as single spat while preventing attachment to tanks or cultch, resulting in unattached, cultchless spat. These single spats are subsequently transferred to a micro-nursery system for further rearing. This innovative approach achieves a 15-30% success rate in producing cultchless spat. The technology opens doors to the global market by enabling the production of single oysters, which are in high demand internationally. It represents a significant leap in technological advancement through hormone-induced settlement techniques and has been certified by ICAR, underscoring its potential to revolutionize oyster farming in India and establish it as a key player in the global oyster market.

Establishment of field upweller systems

An innovative field upwelling system was developed to support the mass nursery rearing of bivalve seed, including mussels, oysters, and clams, using natural feed sources like phytoplankton and microscopic particles from nearby water bodies. This system, designed to optimize the early growth stages of bivalves, enhances survival rates and promotes robust seed development. It features cylindrical

Field upweller system

Field upweller grown clam (*Paphia*), cultchless oyster and mussel seed

silos installed near coastal bays, estuaries or ponds, where water is pumped upward to create an upwelling effect, delivering nutrient-rich water and oxygen to the nursery. This continuous flow ensures a steady supply of natural feed, reducing the reliance on artificial diets and minimizing operational costs. The system's versatility makes it suitable for rearing various bivalve species and adaptable for both small-scale and large commercial operations. By bridging the gap between hatchery seed production and grow-out farming, this sustainable, cost-effective innovation supports the expansion of bivalve aquaculture practices.

Advances in mussel, oyster and clam hatchery techniques

The project achieved significant progress in developing hatchery techniques for clams and mussels:

Green mussels (*Perna viridis*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Brown mussels (*Perna indica*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Backwater oyster (*Crassostrea madrasensis*): Larval and nursery rearing and grow-out methods were optimized, achieving high survival and growth rates in field trials.

Short-Neck Clams (*Paphia malabarica*): Standardised the captive broodstock maturation of Ashtamudi Short-neck clam, by temperature manipulation and enhanced feeding. In addition to that Hormone-induced spawning protocols were also standardized, resulting in efficient seed production.

Indian pearl oyster, *Pinctada fucata*: standization of mass production of pearl oysters spat seed production using micro-nursery system and field upweller system.

Deciphered the Larval cycle of invasive mussel species *Mytella strigata*: The larval cycle of the invasive mussel species *Mytella strigata* was studied in captivity, with growth monitored up to the post-settlement stage. The study revealed that *Mytella strigata* has a shorter larval cycle, taking only 13–15 days to settle as spat. In contrast, native mussel species such as *Perna indica* and *Perna viridis* require 17–21 days for settlement. This shorter larval cycle may provide *Mytella strigata* with a competitive advantage over native species, potentially influencing ecosystem dynamics and aquaculture practices.

Field demonstrations and farmer outreach

Field trials conducted in Kerala, Tamil Nadu, Maharashtra, and other regions validated the performance of hatchery-produced seeds under real-world conditions.

With Green mussels, an average production of 19.14 kg per metre rope was achieved in Ashtamudi and Neendakara, Kollam and with Brown Mussels demonstrated exceptional growth in Kanyakumari, with an average production 20.4 kg per meter rope achieved.

Socio-economic impact

The project significantly contributed to the socio-economic development of coastal communities by

Employment Generation: Created opportunities for farmers, self-help groups, and hatchery workers.

Field demonstration of hatchery-produced green mussel seed

Enhanced Livelihoods: Enabled small-scale farmers to access affordable, high-quality seed, fostering sustainable farming practices.

Empowerment: Trained farmers, and stakeholders in innovative techniques, equipping them with skills to thrive in the aquaculture industry.

Technological innovations

The project delivered several innovative technologies, including:

Photobioreactor: Designed for the high-density production of microalgae, ensuring a sustainable live feed supply for hatcheries.

Cultchless Spat Technology: Revolutionized oyster farming by enabling single-oyster production.

Capacity building

Extensive training programs and workshops were organized to disseminate knowledge and best practices:

Table 1. List of beneficiaries of technologies/ services provided under the project

List of beneficiaries of seed supplies	Bivalve species	State
Universities /Research institutes /State departments		
Mangrove cell, Maharashtra	Edible oyster seed and green mussel	Maharashtra
Kerala University of Fisheries and Ocean Studies	Green mussel seed	Kerala
ICAR-CMFRI Kochi	Edible oyster	Kerala
Mumbai Regional Station of ICAR-CMFRI	Edible oyster	Mumbai
Green mussel egg larvae and spat supplied to DBT project of ICAR-CMFRI Kochi, "De novo whole genome and transcriptome of developmental stages of *Perna viridis*"	Green mussel egg- 30 million Larvae -19.13 million Spat-0.5 million	ICAR-CMFRI, Kochi
Tuticorin Regional Station of ICAR-CMFRI	Pearl oyster, green and brown mussels	Tamil Nadu
Krishi Vigyan Kendra, Lakshadweep	Pearl oyster	Lakshadweep
TKM College of arts and science, Kollam, ZooAqua self-help group, Vellimon, Kollam (Scheduled Caste students from Dept of Zoology TKM College)	Green mussel and oysters	Kerala
Puri Field centre of ICAR-CMFRI	Oyster seed	Odisha
Farmers and hatcheries		
Tharakan Group	Cultchless oyster spat	Kerala
Saptagiri hatchery, AP	Cultchless spat	Andhra Pradesh
TKM ZooAqua self-help group, Vellimon, Kollam (Scheduled Caste students from Department of Zoology, TKM College)	Green mussel seed	Kerala
Vijayan, Kasaragod	Green mussel	Kerala

Mussel and oyster seed (cultchless and attached) supply to Maharashtra Government

Farmer Training: Covered topics such as breeding, larval rearing, and nursery techniques.

Stakeholder Engagement: Engaged government officials, researchers, and private stakeholders to promote adoption of project outcomes.

Mussel seed distribution to SCSP beneficiaries by Dr. Adeela Abdulla, Director of Fisheries, Kerala

Seed supplied to the farmers and researchers/state departments

The Bivalve seeds produced and supplied to farmers researchers in different parts of the country. The bivalve species included were the Green mussel (*Perna viridis*), Brown mussel *(Perna indica*), Edible oyster (*Crassostrea madrasensis*), Pearl oyster (*Pinctada fucata*) and Short-neck clam (*Paphia malabarica*).

Conservation efforts for the Pearl oyster in the Gulf of Mannar

To restore and revive the Pearl oyster, *Pinctada fucata* bed in the Gulf of Mannar area, hatchery produced spat (5.15 lakhs spats and 16.5 million veliger larvae) were ranched in the *paars* off Thoothukudi located on the south east coast of India.

Sea ranching of Pearl oyster seed

Table 2. Projects resulting from the success of the bivalve seed production project of ICAR-CMFRI

Project title	Project duration	Project cost (₹ in lakhs)
Funded project		
Development of Pilot-Scale Open-Sea Eco-Mussel Farms in India–A Blue Growth Project" – under the Central Sector Scheme Component of '*Pradhan Mantri Matsya Sampada Yojana* (PMMSY)	2024-25	151.21
Consultancy project (seed supply and DPR preparation)		
Preparation of DPR for Bivalve Hatchery Unit at Kasaragod, Kerala, India	2023	3.0
Bivalve seed supply for Mangrove Conservation and Livelihood Generation Funded by–Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra, Govt. of Maharashtra	2022	3.0
Bivalve seed supply for Mangrove Conservation and Livelihood Generation Funded by–Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra, Govt. of Maharashtra Project cost–₹8.21 lakhs	2023-24	8.21
	Total	165.42

Mussel hatchery coming up at Kannur with ICAR-CMFRI technology

Consultancy services to the state departments

With hands on experience of this project, ICAR-CMFRI is serving as the consultant to the state of Maharashtra, Kerala and Tamil Nadu for establishment of mussel and oyster hatcheries. The world's first hatchery dedicated to the Asian green mussel (*Perna viridis*) is nearing completion in Valiyaparamba, located in Kerala's Kannur district. This groundbreaking facility marks a significant milestone in mussel aquaculture, paving the way for sustainable seed production and enhanced farming practices.

Conclusion

The "Techniques for Mass Production of Bivalve Seed" project of ICAR-CMFRI has been a transformative initiative in India's aquaculture sector. By addressing critical challenges in seed supply and introducing innovative technologies, the project has paved the way for a thriving bivalve farming industry. It has demonstrated the potential to significantly enhance India's bivalve production, create sustainable livelihoods for coastal communities, and position the country as a competitive player in the global aquaculture market. With a strong foundation in place, the future of bivalve aquaculture in India is promising. The outcomes of this project underscore the importance of continued investment in research, technology, and farmer training to unlock the full potential of India's coastal resources. This initiative not only represents a step forward for aquaculture but also contributes to the broader goals of food security, economic growth, and environmental sustainability.