

# Review on Fresh Water pearl Culture: Recent Trend in India

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## Abstract

Freshwater pearl farming combines economic opportunity with sustainable inland water use, and while countries like China dominate large-scale production, India's sector remains underdeveloped despite early research by Central Marine Fisheries Research Institute and successful trials with mussels like *Lamellidens marginalis*. Adoption in India is limited by technical skill gaps, lack of infrastructure, and high startup costs, yet the country holds strong potential due to growing demand, suitability of regions such as Karnataka, and interest in eco-friendly aquaculture. With better training, research, and supportive policies, freshwater pearl farming could become a sustainable and profitable sector that boosts rural livelihoods and environmental conservation.

**Key words:** Pearls; Aquaculture; *Lamellidens* spp.; Sustainable fresh water farming

## Introduction

Freshwater pearl farming is a specialized form of aquaculture that produces pearls by inducing mussels to coat an implanted nucleus with nacre over 12–24 months, using natural biological processes that make it sustainable and well-suited to inland water systems. Unlike marine pearl culture, it relies entirely on freshwater mussels, making it more adaptable and cost-effective. The practice dates back to ancient China, later advancing in Japan through the pioneering work of Kokichi Mikimoto, who introduced bead implantation for large-scale production. In India, pearls were traditionally harvested from rivers like the Godavari River and Krishna River, while organized freshwater pearl farming began in the 1990s in states such as Karnataka, West Bengal, and Odisha; today, with improved techniques and growing demand, it is emerging as a promising, sustainable, and economically viable sector in India (Alagarwami, 1974).

## Global History of Pearl Farming

Freshwater pearl farming has evolved into a major global aquaculture industry rooted in early cultured pearl innovations, with significant progress in both marine and freshwater systems. In India, a key breakthrough came in 1973 at the Central Marine Fisheries Research Institute in Veppalodai, where the first free, round cultured pearl was produced using *Pinctada fucata*, marking the start of organized pearl culture research and proving the feasibility of controlled pearl production. Globally, pearl culture began in Japan in the late 19th century, advancing from half-pearls to fully spherical pearls and later spreading through technical collaborations with countries like Australia, Philippines, and Myanmar. In freshwater pearl production, China now dominates due to its vast resources and technological advancements, while Japan continues to excel in premium-quality pearls despite reduced output. Overall, the industry reflects a blend of technological innovation, regional advantages, and growing global demand, with India steadily emerging as a promising contributor (Nagai, 2013).

## History of Pearl Farming in India

Freshwater pearl culture in India is steadily emerging as a viable and economically promising aquaculture activity, with exports reaching about USD 3.79 million in 2022 and increasing adoption across states such as Karnataka, Gujarat, Maharashtra, Bihar, Odisha, Kerala, Rajasthan, Jharkhand, Goa, and Tripura, supported by government initiatives promoting rural livelihoods and diversification. Traditionally, India depended on natural pearl fisheries in regions like the Gulf of Mannar and Gulf of Kutch, but declining productivity and inconsistent oyster availability led to their decline by the mid-20th century, emphasizing the need for more sustainable alternatives. While early marine pearl farming faced issues such as barnacle infestation and high mortality, it provided important technical insights; in contrast, freshwater pearl farming offers greater environmental control and reliability due to stable inland water conditions, positioning it as a sustainable and promising alternative for India's future aquaculture development (Alagarwami, 1974).

## Major Species and Regions

Freshwater pearl culture in India relies mainly on a few suitable mussel species, particularly *Lamellidens marginalis*, which is widely preferred for its adaptability and ability to produce high-quality pearls under controlled conditions in ponds and tanks; along with it, other Unionidae members such as *Lamellidens corrianus*

and *Parreysia* are also used for commercial production. These mussels naturally inhabit slow-moving or still water bodies, making them ideal for inland aquaculture systems. The growth of this sector has been significantly supported by the Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, through research, training, and technology dissemination. While marine pearl oysters like *Pinctada fucata* and *Pinctada margaritifera* are important for coastal production, freshwater pearl farming offers a more accessible, manageable, and scalable option for inland regions, highlighting India's strong potential to expand this sustainable aquaculture practice.

### Classification of Pearls

Pearls are generally grouped into three main types based on their formation process:

**Natural pearls** are formed without human involvement when a foreign particle accidentally enters a mollusc. The organism coats it with layers of nacre, resulting in pearls that are usually smaller and irregular in shape due to uneven crystal deposition.

**Cultured pearls** are produced through human intervention, where a nucleus is carefully inserted into the mussel. This controlled process allows farmers to influence the pearl's size, shape, colour, and luster, leading to more uniform and commercially desirable pearls.

**Imitation (artificial) pearls** are man-made substitutes designed to resemble real pearls. They are created using synthetic materials and coatings that mimic the shine of natural pearls, but they lack the internal nacre structure and can often be distinguished by their surface properties.

### Biological and Technological

In freshwater pearl culture, pearls are produced by surgically implanting a small nucleus or tissue into mussels, which then deposit layers of nacre around it over time. The success of this process depends greatly on maintaining suitable water quality, as poor conditions—such as high ammonia or low oxygen—can stress mussels, disrupt their physiological functions, and negatively affect pearl formation.

Freshwater mussels also possess natural defense systems that help them cope with environmental changes, including fluctuations in water temperature, pH, and the presence of pollutants or pathogens. They produce protective compounds like antimicrobial substances and antioxidant enzymes to maintain internal balance. However, excessive or prolonged stress can weaken these defenses, leading to poor health and lower-quality pearls.

To enhance productivity and sustainability, modern freshwater pearl farming increasingly uses technologies such as IoT-based sensors and data-driven models. These tools help monitor and predict key water parameters, allowing farmers to take timely corrective measures and ensure optimal conditions for healthy mussel growth and high-quality pearl production.

### Freshwater Pearl Culture – Summary

Freshwater pearl farming in India involves a stepwise process, beginning with the collection of mussels from rivers, lakes, ponds, or tanks. Naturally harvested mussels are often inconsistent and may be exposed to contaminants, so hatchery-reared seed mussels are preferred for year-round production. Mussels are selected based on weight, age, health, and sexual maturity before being prepared for grafting.

**Pre-operative conditioning** involves keeping mussels in tanks to relax their adductor muscles, which facilitates surgery. Healthy mussels at early or post-spawning stages are chosen, while mature or infected individuals are avoided to prevent tissue damage or graft rejection. Narcotizing agents like menthol are sometimes used to safely open the mussels for implantation.

**Surgical implantation** places donor mantle tissue, with or without a small nucleus, into the recipient mussel using precise techniques. Depending on the method—mantle cavity or gonadal tissue—one or multiple grafts can be inserted per mussel. Strict hygiene and careful handling are essential to avoid injury to vital organs and ensure successful grafting.

**Post-operative care** involves maintaining mussels in clean, filtered water or flow-through systems to reduce stress. After stabilization, they are transferred to farm cages at low densities, allowing nacre deposition on the nucleus over 3–12 months depending on conditions.

**Pearl formation** occurs when the mussel secretes layers of nacre around the implanted nucleus or naturally entered foreign particles, forming a pearl sac. Freshwater pearls tend to form in the mantle or gill epithelium, often resulting in small or irregular shapes; perfectly round large pearls are rare. Blister pearls can form when irritants remain near the shell surface.

This carefully controlled process in freshwater mussels allows for sustainable pearl production with predictable quality and size, distinguishing it from irregular natural pearl formation.

### **Freshwater Pearl Formation and Harvest**

Freshwater pearls are formed through a human-assisted process that involves implanting a nucleus along with mantle epithelium into mussels, where the grafted tissue develops a pearl sac that secretes nacre—composed of aragonite crystals and conchiolin—in concentric layers around the nucleus; partial coating results in half-pearls, while complete coverage forms full pearls. In India's tropical freshwater systems, using mussels such as *Lamellidens marginalis*, pearl formation is relatively fast, typically taking around 12 months depending on environmental conditions, mussel health, and nucleus size. The resulting pearls inherit traits from both host and donor tissue, displaying a range of colours from silvery white and golden yellow to pink shades, and are harvested either by opening or sacrificing the mussels, followed by cleaning and optional treatments like whitening or dyeing. Overall, this method enables sustainable production of gem-quality pearls, though natural variations in size, shape, and colour are common.

### **Freshwater Pearl Pond Culture**

In India, freshwater mussels used for pearl culture are farmed throughout the year except during the peak summer months of May–June to minimize mortality and nucleus rejection, with species like *Lamellidens marginalis* commonly reared in traditional earthen ponds about 2.5 meters deep that have slightly alkaline clay bottoms and limited weed growth; implanted mussels are typically suspended in nylon mesh bags on bamboo rafts at densities of around 50,000 per hectare. Effective pond management is essential, involving the use of ferro-cement tanks to culture algae such as *Chlorella*, *Chlorococcum*, and *Scenedesmus*, along with fertilization using cow dung, urea, and super phosphate to enhance natural food supply, as mussels feed on organic particles including diatoms and blue-green algae like *Spirulina*. Regular monitoring every two weeks ensures early detection of health issues, while maintaining optimal water conditions—especially temperatures between 25–30 °C and balanced nutrient levels—supports healthy growth and pearl production by preventing stress and excessive algal blooms.

### **Key Parameters for Freshwater Pearl Farming**

Successful freshwater pearl culture relies strongly on proper soil and water quality, as these directly influence mussel health, nacre formation, and overall pearl yield; ideal pond soils should have near-neutral pH, sufficient organic carbon, and adequate nitrogen to support natural food production while remaining free from harmful substances like hydrogen sulphide. Equally important are stable water conditions, including slightly alkaline pH, balanced alkalinity and hardness, and sufficient dissolved calcium, which is crucial for shell development and the biomineralization process involved in nacre deposition in mussels such as *Lamellidens marginalis*. Maintaining these optimal environmental parameters minimizes stress, enhances growth and survival, and ensures the consistent production of high-quality freshwater pearls.

### **Socio economic Significance of Freshwater Pearl Farming in India**

Freshwater pearl farming provides an alternative income source for rural communities and fishers, particularly where conventional livelihoods are limited. Adoption has grown due to training, subsidies, and technology transfer, though challenges remain in water quality management, technical skills, and market access. Integration with other aquaculture or farming systems enhances profitability, and high-grade pearls (AAA, AA, A, B) offer opportunities for premium revenue (Singh et al., 2023).

## Environmental and Sustainability Considerations

Pearl farming faces environmental challenges such as climate change, unpredictable rainfall, and water quality fluctuations. Integrated multi-trophic systems combining mussels, fish, and aquatic plants help recycle nutrients, reduce ecological impact, and improve resilience. Ocean acidification and rising water temperatures can impair nacre formation and pearl quality, while freshwater mussels contribute to carbon sequestration, water filtration, and bioremediation, supporting ecosystem health and the blue economy (Welladsen et al., 2010; Saurabh et al., 2022).

## Policy and Technology Support

Development of freshwater pearl culture in India relies on training, technology transfer, and institutional support. Organizations like CMFRI and ICAR-CIFA have facilitated breeding, seed production, and pond management practices. Government initiatives such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY) and NABARD loans provide financial assistance, infrastructure support, and capacity building to enhance productivity and promote entrepreneurship in pearl farming (Jagadis et al., 2018; Sharma, 2005).

## Future Prospects

With increasing awareness and training programs, freshwater pearl farms are expanding in states including Odisha, Maharashtra, Gujarat, West Bengal, Bihar, Uttar Pradesh, Chhattisgarh, and Kerala. Demand for larger, designer, and religious-themed pearls is growing. Adoption of modern techniques, improved cultivation methods, and value-added practices can boost employment, income, and production efficiency (Saurabh et al., 2022).

## Advantages of Pearl Farming

Pearls are lightweight, non-perishable, and require minimal processing, making them accessible and low-maintenance aquaculture products. High-quality pearls command premium prices, providing substantial income opportunities. Pearl farming also contributes to biodiversity conservation by linking economic incentives to ecosystem management (Haws, 2002; Cartier and Saleem, 2012).

## Challenges and Constraints

Key challenges include mussel survival after implantation, breeding standardization, larval attachment to host fish, and low expertise among farmers. Commercialization is constrained by biological limitations, labor-intensive practices, high oyster mortality, and limited infrastructure. Enhancing local production of high-quality nuclei and developing robust mussel beds are essential for profitable freshwater pearl farming in India (Saurabh et al., 2022; Sharma, 2005).

## Conclusion

Freshwater pearl farming in India combines traditional knowledge with modern techniques, contributing to rural livelihoods, sustainable aquaculture, and a growing domestic and export market. Continued focus on water quality management, climate adaptation, farmer training, and market integration is vital to realize the full potential of this industry (Saurabh et al., 2022; Chhandaprajnadarsini et al., 2025).

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