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A Review on Pearl Farming: the Rising Trend in India

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Abstract Pearl farming, the ideal blend of production of gems and water. It is being considered as a practice that has sustainability and innovation that is not only economically but ecologically helpful too. China is the most prominent producer by fresh water pearl cultures in large scale. Behind Japan, there are Akoya pearls- high quality pearls and the exotic black pearls of French Polynesia. These two countries have jointly established a multibillion-dollar pearl industry in the world. Pearl farming continues to be in its nascent stage in India with the initiatives that were taken by the CMFRI (Central Marine Fisheries Research Institute) in starting of 1970. Despite demonstrations that have shown that it is practical through successful experiences with *Pinctada fucata* and freshwater mussels such as *Lamellidens marginalis*, the uptake is low. Nevertheless, the prospects are in satisfying the increasing demand of the global and domestic market of ornamental pearl, diversification of aquaculture and the creation of jobs in the rural areas. The pearl farming business in India is facing major challenges such as the technical expertise in surgical nucleation, inadequate infrastructure and high start-up capital despite the potential of the industry being enormous. India can transform this sector by concentrating on research, skill building and by coming up with favourable government policies. This would not only tie in sustainable aquaculture with economic growth but also make the country one of the key international markets in terms of pearl.

Keywords Pearls; Aquaculture; *Lamellidens* spp.; Oysters; Sustainable marine farming

1 Introduction

A Pearl is naturally produced gem, or gemstone that is produced within the soft tissues of some mollusc species such as oysters in the sea waters and mussels in the freshwater environments. This gem is highly lustrous, or has an assortment of colours, and is often a perfect round. It consists of 85% calcium carbonate, 12 percent organic matrix and water. The primary constituent is calcium carbonate that may have the form of aragonite or calcite. It surrounds all foreign particles or irritants that might have entered and lodged within the interior of the shell of the mollusc. The pearl has hardness value between 3.5 and 4.5 and specific gravity 2.7. Any mollusc may produce any form of pearl; but the finest pearls are those produced by those which have nacre on the outer shell. Pearls are grouped into three categories of natural pearls, cultured pearls and artificial pearls (Alagarswami, 1974).

Pearl farming/pearl culture is a subdivision of aquaculture which denotes the cultivation of pearls in a controlled or semi-controlled environment through the rearing of pearl oysters or freshwater mussels. To make a pearl, a nucleus and mantle tissue transplantation is surgically inserted into the mollusc that then secretes shells of nacre (calcium carbonate and organic matrix) around the implant. There are several processes involved in pearl farming which requires 12~24 months to produce the first pearls.

2 Global History of Pearl Farming

The earliest, free and round man-made/cultured pearl of India was produced at Pearl Culture Laboratory, a division of the Central Marine Fisheries Research Institute, at Veppalodai, near Tuticorin in July 1973. It was prepared by using Indian pearl oyster *Pinctada fucata*. Cultural technology has now produced pearls of different sizes and colour. Pearls began to be cultivated first in Japan in 1893 when half-pearls on shells were produced, and then in 1907 with the successful breeding of spherical ones. It has since been dominated in the production, marketing and technology of cultured pearls, in the world. In 1956, Australia began to farm pearls with Japan, and

Philippines and Burma also joined in such partnerships. In Hong Kong, Palau, Celebes and some other South-West Pacific islands, limited-scale production has been taken up. In the majority of joint ventures, Japan exports technical knowledge and does marketing, whereas the host country contributes primarily to the creation and maintenance of farms. Past studies have identified the Japanese approaches and pointed out the possible potential of India in the cultured pearl (Nagai, 2013).

3 History of Pearl Farming in India

In the Gulf of Kutch and Gulf of Mannar, India has a history of pearl fishing of natural pearls. But there are ups and downs in oyster production in these regions, and between productive fisheries, there are some seasons when the oysters are barren. Since 1900 the Gulf of Mannar has had only 12 seasons of fishing, the seven-year grand series of 1955 to 1961. India has ceased pearl fishing in Gulf of Mannar (after 1961) and in Gulf of Kutch (1966-1967). Oysters were collected in the pearl banks of Tuticorin by means of diving and using SCUBA, and then transported to the farm where they were cleansed and measured. They were outlawed in rafts and placed in sandwich-like frame nets with repeat laboratory tests on purity and growth checks. Even though the oysters were fairly healthy, barnacle infestation became an issue of serious concern and resulted in certain mortality. The vigorous of shell margin indicates that the sea of Veppalodai is an appropriate location where oysters can grow. The Kallar River contributed to freshwater inflow during the northeast monsoon which reduced the salinity marginally but did not have any adverse effects. Light penetration was poor, in the 4-meter-deep farm field (approximately 1.5 meters) and total water clarity was poor (Alagarswami, 1974).

4 Major Species and Regions

The main species of pearl production that is cultivated in freshwater systems are the Indian pond mussel (*Lamellidens marginalis*). Its adaptability to the conditions of the Indian environment and the possibility to grow high-quality pearls under conditions characterized as controlled habitats (pond, tank, integrated multi-trophic aquaculture systems, etc.) contribute to its popularity (Saurabh et al., 2022). There are approximately 3,270 molluscan species that inhabit India, 1 100 of which are bivalves. These include 625 species of marine bivalves of which 88 are endemics. Approximately, 52 mussel species have been reported in freshwater ecosystems and these are found in both stagnant and low-moving water bodies. Large-scale pearl production in India, despite such diversity, is temperately reliant upon three freshwater mussel species that belong to the Unionidae family -*Lamellidens marginalis*, *Lamellidens corrianus*, and *Parreysia*.

CIFA (Central Institute of Freshwater Aquaculture), Bhubaneswar, has been a leader in establishing and distributing freshwater pearl culture technologies in India (Saurabh et al., 2022). Marine pearl farming is instead based on the Indian pearl oyster (*Pinctada fucata*), especially in coastal states (such as Tamil Nadu, Kerala, and Andhra Pradesh). In India, freshwater pearl mussels and marine pearl-producing oysters are very prolific. *Pinctada margeretifera* in Andaman and Nicobar Islands and *Pinctada fucata* in the Gulf of Mannar, Palk Bay, and the Gulf of Kutch are pearl-producing oysters (Sharma, 2005).

5 Classification of Pearls

5.1 Natural pearls

In a case of swallowing a foreign particle by a pearl oyster without any human intervention the natural pearl is formed. The natural pearls consist of nacre crystallized into pearls of greater thickness. It is unevenly shaped and comparatively smaller. The reason for its uneven shape is edge formation of covering crystals of aragonite (Birunagi et al., 2024).

5.2 Cultivated pearls

It is alike naturally occurring pearls but, the nucleus is surgically implanted into the mussel instead of natural swallowing of any foreign particle. This culturing technique of making natural pearls can yield the required size, shape, colour and lustre of the pearl. They can be spherical, semi-spherical or designer pearls depending on the size and shape of the nucleus (Alexander and Kumar Verma, 2023).

5.3 Imitation or artificial pearls

To replace actual or cultured pearls, imitation pearls are prepared by applying tough, round bases, with materials that mimic the qualities of pearls. The coating may show a difference in response to inexpensive glittering paints, imitated pearl essences crafted of fish scales, and so on. The artificial pearls leave a trace on their smooth surface when pressed against a sharp object in contrast to natural or cultivated pearls (Alexander and Kumar Verma, 2023) (Figure 1).

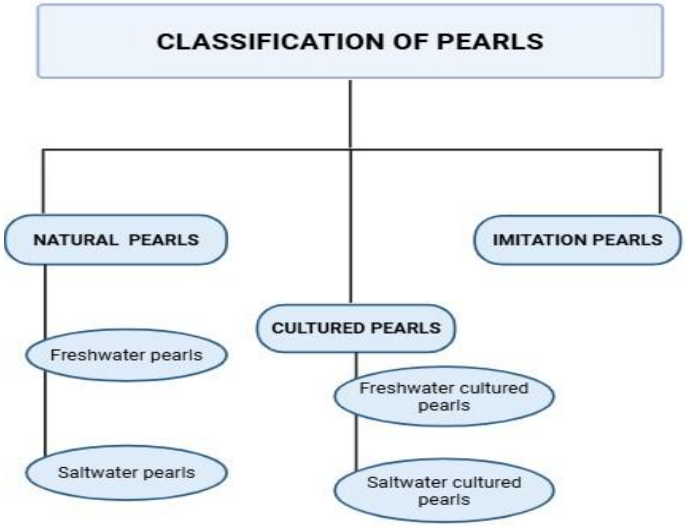

Figure 1 Classification of pearls

6 Biological and Technological Aspects

The pearls are formed by placing an irritant, usually a tiny bead or tissue lining, surgically into the mollusc into which the nacre is embedded to form the pearl in a few months to years (Saurabh et al., 2022). It is of paramount importance to maintain optimal water quality because physiological stress caused by such factors as ammonia may negatively influence the state of mussels and the quality of pearls. As an example, high levels of ammonia may disrupt important enzyme functions and antioxidation defences in *Lamellidens marginalis*, proving that the quality of water is reviewed and managed to ensure sustainable pearl culture (Chhandaprajnadarsini et al., 2025).

In order to facilitate operational efficiency, smart monitoring systems adoptions, including the use of IoT-enabled water quality sensors, application of machine learning models to predict the environment, etc. have become increasingly prevalent. Such technologies are able to forecast variations in such parameters as dissolved oxygen and pH to allow farmers to make appropriate interventions in time (Singh et al., 2022).

6.1 Immune and stress responses of marine pearl oysters

As part of its survival mechanisms, the marine oysters (particularly, *Pinctada spp*.) rely on their in-built immunity or an immune system to counter the environmental pressures like changes in temperature, salinity, the presence of pathogens and pollutants, etc. Antimicrobial peptides, lectins, heat shock proteins, and antioxidant enzymes are activated within them to sustain the cellular homeostasis. The pearl oyster can survive in unpredictable marine conditions with this capability. However, severe stress system may undermine the immunity of oysters and quality of pearls (Adzigbli et al., 2020).

7 Freshwater Pearl Culture

Pearl faming in freshwater involves the following steps sequentially:

7.1 Collection of mussels

The freshwater bodies have the mussels cleared manually and then transported to farm where they are harvested in

a healthy manner. The habitats are primarily submerged in shallow peripheral regions and are primarily concealed by mud or sand. Habitats are in form of immobile stationary ponds, tanks, lakes, rivers, and reservations. Harvested pearl mussels on the natural bed are not always reliable because of their irregular harvest and contaminated water. The mussels seed grown in the hatcheries are much superior regarding the right supply of the pearls mussels to keep up the yearlong production. The mussels are grafted after growing such seed, according to weight, age, the degree to which they have sexual maturation and health in general (Ali and Rawat, 2023).

7.2 Pre-operative conditioning

The native pearl mussel species which were collected as freshwater are then subjected to the two-day pre-operative conditioning. They are kept in 200-liter ferro-cement tanks where the stocking density of the mussel is one mussel per litre. The pre-operative conditioning takes proper care of the relaxation of adductor muscles before surgery. This is important considering the low application of narcotizing methods that are used in the marine pearl production activities (Misra et al., 2009).

7.3 Selection and conditioning for surgery

Oysters that are 20 grams and above, are used to perform operational surgery with a goal of producing good outcome. They should be healthy and non-infected from borers. Oysters with maturing or mature gonads would be inappropriate because the gametes leak out during surgery and obscure the implantation site. Gametes may flow rapidly along the channel and the resultant graft tissue and nucleus may remain in place. Consequently, the selection of the oysters ought to be made of just oysters that are either at the initial stages of gametogenesis or recovering after spawning. The soft areas should be free of shells of sponge borers, polychaete blisters and trematode infections. The oysters should be stripped off all foul organisms.

The oysters are chemically conditioned to operate. Menthol crystals are added into the seawater in troughs of the oysters that are carefully selected. The oysters narcotize within 45~60 minutes and at this stage the valves are open because of adductor muscle's loosening. Once each oyster is stripped, a wooden peg is placed between the valves and rinsed in sea water. The use of such narcotized oysters in the procedure should be as immediate as possible. When the oysters are put in pure seawater after surgery they will heal in 30~45 minutes (Victor et al., 1995).

7.4 Surgical implantation

Surgical implantations can take place in three sections of the mussel, which are of three different kinds depending on the kind of pearl being aimed at. A particular type of implantation is undertaken with each mussel. The mantle cavity insertion method is simple. The mussels of the weight and shell length required are collected prior to operation. They are appropriately opened with a 0.5 cm broad speculum that does not damage the soft tissues and adductor muscle of the mussels. An aperture the size and shape of a planned pearl, say 1 cm is cautiously inserted into the mantle cavity after a small section of the anterior side of the mantle has been detached, with care, at the top shell valve. Then it is driven in deep to avoid being rejected. One mussel may be implanted with the foreign organism that is desired in both of its valves.

Before surgery in the mantle tissue procedure, the mussels that are to be operated upon (the recipient mussels) and those sacrificed (the donor mussels) are separated into two categories. The pallial mantle ribbon of the living donor mussels is excised, clipped to grafts of the appropriate size and c alone or together with a small nucleus (2 mm in diameter). This kind of grafting is performed on both of the mantle lobes. There can be two to eight implantations depending on the size and thickness of the mantle of the recipient mussel.

In preparing the live graft parts to be implanted through the gonadal procedure, the recipient mussels are opened carefully to a depth of about 0.5 cm with a shell opener. Another end of the graft needle has a specialized knife that makes a tiny, precisely calibrated slit when he is making the incision beneath the outer membrane of the gonad. Caution should be observed that one does not make deep cuts into the gonadal tissue in order to avoid injuries to the intestinal coils. Only one implantation per oyster is to be done (Misra et al., 2009).

Precautions: 1) Wash the instruments properly, before and after use. 2) Avoid the use of mature oysters for nucleus implantation. 3) Avoid harming the stomach, heart, or intestine. 4) Make the incision or cut according to nucleus size.

7.5 Post-operative care and culture

Oysters are maintained in a flow-through system after operation until they are narcotized, or frequent water changes are done where flow-through system is not accessible. They spend three to four days in the lab in order to reduce stress by being observed in filtered clean water. Once they have been stabilized, they are taken to the farm and kept in fitting cages. Oysters are kept to low densities, suspended at lower levels and are treated sparingly to avoid stress during the post-operative stage. The period of culture on the nuclei with size in the range 2-5 mm takes 3-12 months in Indian conditions. The last harvest period is based on the harvests that are experimental and monthly observed (Victor et al., 1995).

7.6 Pearl formation

7.6.1 Natural pearl formation

Pearl formation in pearl oysters begins with organic or inorganic nucleus (e.g. sand grains, parasites, molluscan eggs, plant debris, epithelium cells of same animal etc.). These particles invade the oyster during feeding or breathing and sink in between shell and mantle. As an answer, mantle epithelium invaginate the foreign body and create a pearl-sac surrounding it.

Pearls only form after a pearl-sac has been formed, which is formed out of the interior or exterior epithelium of the mantle or gill plate. The secreted nacre of the epithelial cells of the pearl-sac increasingly coats the foreign object to form a pearl. There are seldom natural pearls between the mantle and shell, in the mantle, or in other soft tissues; these pearls tend to be small and irregular-shaped. Large pearls of round shape are very rare. When the irritant is stuck on the shell, forming a blister pearl is possible that only reflects the irritant on the exposed surface (Victor et al., 1995).

7.6.2 Cultured pearl formation

Their creation is anthropogenic. In any form of pearl development two things are indispensable, the outer epithelium of mantle lobe and a nucleus. The human made nucleus is gently inserted into the oyster tissue through appropriate surgery procedure. Grafted oysters are returned to the water in order to keep growing. As the inner epithelium and connective tissue of the mantle is absorbed, the outer cells of the graft tissues divide and form a pearl-sac around the nucleus. The pearl-sac cells produce a nacre (mother-of-pearl) in concentric micro-layers over the nucleus and get nourished by the adjacent tissues. Nacre is made up of aragonite (0.29 0.60 mm thick) and conchiolin, an organic mucopolysaccharide binding layer that is alternately and interchangeably composed of these components. Farmed pearls recreate the same process as nacre deposition and creation of pearls. A covering a few of the nuclei upon the inner of the shell gives half-pearls, the mantle epithelium forming a pearl-sac upon the top of the bare nucleus (Victor et al., 1995).

7.7 Harvest of pearls

The pearl culture period is short in tropical India in comparison with temperate locations. It may take up to 12 months in pond culture, each pond varying in the duration of time according to the size and number of nuclei, the well-being of the mussels and the conditions of the pond. The pearls that are formed as a result of gonadal implantation or grafting of mantle tissue are affected by the mother mussel and the donor mantle graft, and have a colour of silvery white to golden yellow and deep pink. The harvesting involves either killing of the mussel or extracting of the pearls in live mussels at the end of the culture period (12~14 months). Even though the freshwater mussels can produce pearls of gem quality, the size, shape, and colour may change because of natural variation. Pearls that are harvested are often washed, whitened, or dyed to ensure uniformity and value addition (Victor et al., 1995).

7.8 Grading of pearls

Grading of natural cultured pearls according to their quality (Glover et al., 2006) (Table 1).

Table 1 Grading criteria and quality characteristics of cultured pearls

Grading	Properties
AAA	Absolute shine, zero surface irregularities, and a perfect symmetry
AA	Good shine, quality and homogenous in colour with some irregularities on surface
A	Average quality, good shine but poor symmetry, uneven coloration with a few imperfections on surface
B	Good shine with uneven coloration and edgy surface
C	Low shine, weak nacre layer and serious surface flaws, no economic value

7.9 Culture in ponds

India Freshwater mussel is implanted to pearl culture year-round except during the hot months of May-June to reduce post-operative mortality and nucleus rejection. Traditional culture ponds are the most suitable since they are approximately 2.5 meters in depth, have a clay-soil foundation, are slightly alkaline and lack algae blooms and aquatic weeds. Implanted mussels are placed on bamboo rafts of nylon mesh bags (30 × 13 cm, 1.5 cm mesh) at a density of 50 000 mussels/ha (Figure 2).

Figure 2 Pond Culture of Pearl farming in India (Source: The Better India, 2021) .

Pond management is vital in an attempt to maximize the yield of pearl, as well as to maintain the health of mussels. Ferro-cement tanks are fed with algae such as Chlorella, Chlorococcum and Scenedesmus (water green) and fertilized with 10 000 kg/ha cow dung, 100 kg/ha urea and100 kg/ha single super phosphate (SSP) every year to enhance natural food production. Water is fertilized and pumped to ponds when it is green. Freshwater mussels are able to consume a wide range of particulate organic matter as mucoid filter feeders; however, their preferred food items are diatoms, green algae and blue-green algae (Spirulina).

To reduce the cases of death due to parasite infections, inadequate food or internal injuries, frequent health examinations are done after every two weeks. Mussels are removed, checked and washed prior to being repacked in net bags. Physio-chemical factors such as temperature, water level, and nutrient load are all constantly checked; optimum growth occurs at 25 °C~30 °C. Excessive algal growth due to accumulation of nutrients is prevented (Misra et al., 2009).

8 Important Parameters for Pearl Farming

Soil and water quality are critical determinants of successful pearl farming because they directly influence mussel health, nacre secretion, and ultimately pearl quality and yield. Suitable pond soils should maintain a near-neutral pH, adequate organic carbon, and sufficient available nitrogen to support natural productivity, while the absence of hydrogen sulphide is important to avoid toxic stress in bottom conditions (Table 2). In addition, stable water quality is required throughout the culture period; a slightly alkaline pH, appropriate total alkalinity and hardness, and sufficient dissolved calcium provide favorable conditions for shell growth and nacre deposition, since calcium

availability is closely linked to biomineralization processes (Table 3). Maintaining these parameters within the recommended ranges helps reduce environmental stress, improves survival and growth performance of cultured mussels, and supports consistent pearl formation and overall production efficiency.

Table 2 Recommended soil quality parameters for pearl farming

pH	6.5~7.5
Organic carbon	1.0%~2.5%
Available nitrogen	25 to 75 mb/100 gm of soil
Hydrogen sulphide	Nil

Table 3 Recommended water quality parameters for pearl farming

pH	7.5~8.5
Total alkalinity	75 ppm~150 ppm
Total hardness	40 ppm~75 ppm
Dissolved calcium	25 ppm~50 ppm

9 Socioeconomic Significance

Pearl farming also offers some form of diversification of income to fishers and the rural population especially where other stable sources are unavailable. The level of adoption among farmers has gone up due to training, government subsidies, and technology transfer efforts, but issues of water quality, technical expertise, and markets have become more difficult (SATHIADHAS, 2009). The break-even analysis of the aquaculture practices reveals that pearl culture is a lucrative activity particularly where it is integrated with fish, crops and livestock.

Farmers in developing countries such as India lack the understanding of the modern aqua farming methods, such as pearl farming that should be used in their respective sectors. There are already many women, farmers, and business people, interested in this topic, who expressed their interest in the Grade "AAA" that is the highest grade with such wonderful properties as excellent shine, non-existence of surface faults, and needed symmetry. Surface of AA has couple of marks on its surface, even colour, and lustre is good. A medium quality, colour variation, medium lustre, few surface flaws, poor symmetry A B good lustre with some imperfections and an uneven surface and colour (Singh et al., 2023).

10 Environmental and Sustainability Challenges

Productivity and sustainability have also been affected by not only the quality of water but also climate change, unpredictable rainfall, and gaps in skills when managing aquaculture (Singh et al., 2022). In reaction to this, integrated aquaculture such as multi-trophic systems that combine fish, mussels and other aquatic plants or animals is suggested to recycle nutrients and minimize environmental impact, which increases system resiliency and sustainability (Saurabh et al., 2022).

10.1 Impacts of ocean acidification on calcium carbonate deposition in pearls

Near-future ocean acidification (pH ~ 7.6) can cause disruption in nacre deposition in pearl oysters. SEM observations shows that lower pH levels can lead to the production of irregular and disorganized nacre tablets, reducing overall strength of oyster shell. This not only degrade the pearl quality but also increases the vulnerability of oysters to predation. As the cultured pearl industries depends on production of high-quality nacre from cultured oysters, the ocean acidification may lead to devastating effects for them (Welladsen et al., 2010). Increased temperatures can accelerate the impacts of ocean acidification by altering cell membrane permeability, impairing protein activities linked in acid-base regulation and defence, and leading to metabolic stress in marine calcifers (Li et al., 2015).

10.2 Impacts of accelerating sea temperature on quality and growth of pearls

Temperature significantly affect the pearl growth rate in *Pinctada margaritif*era, fastest growth rates are observed between 26 °C~30 °C while the rate declines significantly at 34 °C, followed by reduction in biomineralizing capacity of pearl sac. According to the polynomial equation: G=0.05T2+ 2.65T–33.34 (r=0.81), the optimum

temperature for pearl growth is 27.1°C. Lustre or shine of pearls is also temperature dependant (lower the temperature, higher the lustre) (Le Moullac et al., 2018). Additionally, the Marine Heat Waves (MHWs) can cause damage of tissue in *P. maxima* (especially the gills' tissue) (Xu et al., 2022).

10.3 Importance of pearl farming in carbon sequestration and blue economy

Unlike some edible oysters, pearl oysters support ecosystem by providing services specifically through high filtration capacity. Water filtration capacity varies with size, life stage and species. Juvenile oysters can filter 2-4 litres of water per hour; adults can filter up to 22 litres and large *Pinctada margaritifera* and *Pinctada maxima* oysters have the capacity to filter 50~100 litres water per hour. Along with filtration, pearl faming also contributes to carbon sequestration and nutrient bio-extraction through shell formation. By extracting large quantities of organic nutrients and heavy metals, pearl oysters play a significant role in bioremediation (Farming, 2024).

11 Policy and Technology Transfer

The development of pearl cultivation in India is frequently dependent on the specific training, the sharing of technologies, and the localization. The Central Marine Fisheries Research Institute (CMFRI) and ICAR have played a key role in breeding, seed production, farming methods, training small-scale self-help groups to enhance quality and productivity at small and commercial levels (Jagadis et al., 2018).

Pearl culture has been transferred in India where the method has proved crucial in the transition to commercial application. It has now been possible due to the specialized training programs, on-field demonstration and participatory strategies whereby small farmers and rural self-help organizations have been able to integrate pearl production in their lives. The survival rates and the overall quality of pearls have improved due to diffusion of standard practices that include surgical implantation, pond and water quality management, and post-harvest value addition. Most importantly, such endeavors have shown that pearl farming can be an additional profitable activity to support the normal aquaculture and agriculture, and it can earn additional income. The report, however, notes that long-term sustainability would require uniform technical support, reliability in accessing the market, and sound policy support to encourage the wider adoption (Jagadis et al., 2018).

11.1 Pradhan Mantri Matsya Sampada Yojana (PMMSY)

It is a large initiative to modernize the fishing sector in India in a sustainable way. It was introduced in May 2020. The capital injection would be 20 crores of production, technological, and post-harvest infrastructure deficits over 5 years. The program empowers farmers and fishermen, promotes entrepreneurship and overall development of sectors through financial aid to the fish farming, fish hatchery, fish seeding, and capacity building programs.

11.2 NABARD's support for pearl culture

Cultivation of pearl is eligible to bank loans and NABARD refinance. The NABARD facilitates to qualified organizations such as Agriculture Development Finance Corporation (ADFC), State Cooperative Agriculture and Rural Development Bank (SCARDB), Regional Rural Banks and Commercial Banks to provide their loans on pearl culture facilities. The loan brings a maximum term of 15 years. The ultimate beneficiaries of the investment finance may be cooperative societies, firms, state or individuals and partnership firms (Sharma, 2005).

12 Future Aspects

In India, most farmers do not know much about the modern modes of aquaculture, such as pearl farming. Research and training institutions, especially ICAR-CIFA have eased the transfer of technology with farmers, entrepreneurs and women being trained. There are now freshwater pearl farms situated in states like Odisha, Maharashtra, Gujarat, West Bengal, Bihar, Uttar Pradesh, Chhattisgarh and Kerala. There is a large demand of big and designer pearls and even religious designs. The creation of more employment and more advanced methods of freshwater pearl farming can increase employment, wages and yielding high-quality freshwater pearls within a shorter cultivation cycle (Saurabh et al., 2022).

Indian government has provided subsidies and incentives to pearl farmers in order to reduce the financial risk associated with farming of pearl. Programs that are provided by different state fisheries departments differ. The

technology diffusion programs of ICAR-CIFA, can be considered highly favourable to the farmers, fishery stakeholders, and businessmen who seek to initiate freshwater pearl farms. In its yearly training program, the candidates are taught practically how to practice the various techniques of implantation besides the technology of the culture of the culture which includes the water quality, mussel nutrition and feeding, pre and post care as well as the best conditions to achieve the pearl culture (Alexander and Kumar Verma, 2023).

13 Benefits of Pearl Culture

13.1 Non-perishable output

Production of pearls has benefit that the product is light, non-perishable, and it does not need much processing. Pearl oysters have flourished in isolated tropical atolls where the traditional fisheries are at logistical disadvantage. Pearl farming, with the exception of the grafting process or surgery, is not very complicated and requires no artificial feed, sophisticated infrastructure, or sustained supervision. It is also compatible and is also accessible by people who are adept at boating, diving, and fishing and so on, as an aquaculture occupation (Haws, 2002).

13.2 Revenue generation

The quality of pearls is highly priced hence; pearl farming is a profitable business. Although the prices depend on size and quality, large, round black pearls are priced highly such as an 8 mm good black pearl costing about $40 in 2000 and a 12 mm pearl of the same quality costing as high as $120. Even as prices of smaller, poorer quality pearls have dropped over the past years, large high-quality pearls have been comparatively stable (Haws, 2002).

13.3 Overcoming biodiversity loss

Climate change, overfishing, unregulated coastal development are the major threats to marine biodiversity. Conservation can only be effective when the local communities are involved and economic incentives are incorporated together with preservation of the ecosystems. The practice of cultured pearl farming is a good example of this practice, as environmental management has been a crucial aspect to ensure that production is economically successful (Cartier and Saleem, 2012).

14 Challenges and Constraints

Growing pearls has a number of challenges despite the fact that the pearl farming is a highly profitable business. Among the most significant factors is the capability of the mussel to survive after the implantation. It is another challenge to determine the right quality of the pearl once it has been purchased. Breeding technique standardisation is of great importance to freshwater mussels as successful breeding occurs, but mussel larvae survival is one of the greatest challenges. The attachment of Glochidia to secondary host fish is problematic. The mussel larval cycle requires a secondary host, e.g., a fish. Lack of expertise in pearl farming methods is one among the major problems (Saurabh et al., 2022).

14.1 Constraints for commercialization

Due to the low returns, commercial scale pearl growing has proved challenging to the entrepreneurs in India, despite the successes in the introduction of freshwater and sea pearl cultures in 1989 and 1973 respectively. Some of the challenges include unfavourable biological factors, absence of sheltered bays, turbulent waters, sediment, high oyster mortality, low implantation rates of the oysters, and labour-intensive processes. Moreover, the volume and the quality of the pearls produced in India attract decent prices in the outside world. It is important to save on costs, enhance production and make pearl production profitable, Pinctada maxima beds, local production of high-quality nuclei and development of steel black pearl of *Pinctada margaritifera* of Andaman and Nicobar Islands are all essential (Sharma, 2005).

15 Conclusion

Farming of pearls is a traditional activity in India that is at the cross road of tradition and modernity. Biological knowledge, technology use and policy reinforcement have led to amplified pearl production, rural wellbeing and provision of cultured pearls with confidence in the domestic and export market (Saurabh et al., 2022).

Nevertheless, further focus on water quality, climate adjustment, agriculture education, and market incorporation is necessary in order to realize the full capacity of this aquaculture industry (Chhandaprajnadarsini et al., 2025).

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