

Recent Developments in Hatchery and Farming Technologies for Molluscs

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ABSTRACT

Mollusc aquaculture has gained global importance due to its economic value, nutritional benefits, and environmental sustainability. Recent developments in hatchery and farming technologies have significantly improved seed production, survival, growth, and overall productivity. Advances in broodstock conditioning, induced spawning, larval rearing, nursery systems, water treatment, and selective breeding have strengthened hatchery operations. Modern farming methods such as raft culture, rack culture, longline systems, cultchless oyster farming, and integrated multi-trophic aquaculture have enhanced production efficiency and resource utilization. Smart technologies including sensors and digital monitoring are further supporting sustainable expansion of mollusc farming worldwide.

INTRODUCTION

Molluscs are one of the most diverse and economically valuable groups of aquatic animals cultured throughout the world. They include several important shellfish such as Mussel, Oyster, Clam, scallops, and abalones. Molluscs are highly appreciated for their nutritional quality, delicious taste, high protein content, essential

minerals, and increasing demand in domestic and international seafood markets. They are rich in calcium, iron, iodine, zinc, and vitamins, making them an important source of healthy animal protein for human consumption. In addition to their economic value, many molluscs are natural filter feeders that improve water quality by removing

plankton, suspended particles, and excess nutrients. Because of these ecological and commercial benefits, mollusc farming has become an important component of global aquaculture production (Anil & Gomathi, 2023).

Traditionally, mollusc farming depended largely on natural seed collection from coastal waters, estuaries, bays, lagoons, and mangrove creeks. Farmers collected naturally available spat and transferred them to farming areas where they were grown until market size. Although this system was inexpensive, it was highly dependent on seasonal seed availability and environmental conditions. In many areas, pollution, habitat destruction, climate change, overharvesting, and fluctuations in salinity reduced natural seed resources. As global demand for shellfish products increased, it became necessary to adopt scientific hatchery systems and improved farming technologies. During the last few decades, major progress has been made in broodstock conditioning, induced spawning, larval rearing, nursery systems, farm design, water quality management, and digital monitoring. These recent developments have transformed mollusc farming from a traditional practice into a modern and efficient aquaculture industry.

Importance of Mollusc Aquaculture

Mollusc aquaculture is considered one of the most environmentally sustainable sectors of aquaculture. Unlike finfish and shrimp farming, many bivalve molluscs do not require formulated feed during grow-out because they consume naturally available phytoplankton and organic matter from the water (Gallardi, 2014). This greatly reduces production cost and minimizes nutrient waste released into the environment. Shellfish farming therefore has a lower ecological footprint compared with many intensive aquaculture systems. In addition, shellfish beds can improve water

clarity and ecosystem productivity through natural filtration activities.

Molluscs also provide significant socio-economic benefits. Coastal communities in many countries depend on shellfish farming for employment and income generation (Krause *et al.*, 2018). Activities such as seed production, nursery operation, raft making, cage fabrication, harvesting, depuration, processing, packaging, transportation, and marketing create livelihood opportunities for thousands of people. Women often participate actively in processing and marketing sectors. Export of oysters, mussels, clams, scallops, and abalone contributes valuable foreign exchange earnings. Therefore, recent technological developments in this sector are important not only for food production but also for rural development and blue economy growth.

Major Cultured Mollusc Species

Several mollusc species are commercially farmed worldwide depending on climatic conditions and consumer preferences. Mussel are among the most widely cultivated because of their rapid growth, simple farming techniques, and high market demand.



Important mussel species include green mussel (*Perna viridis*), brown mussel (*Perna indica*), Mediterranean mussel (*Mytilus galloprovincialis*), and blue mussel (*Mytilus edulis*). Oysters are another major group cultured

for edible meat and pearl production. Species such as *Crassostrea madrasensis*, Pacific oyster (*Crassostrea gigas*), and Eastern oyster (*Crassostrea virginica*) are commercially important. Clam species are cultured in sandy or muddy bottoms and are highly popular in

many Asian and European markets. Scallops are premium export shellfish with high value, while abalones are luxury seafood items cultured mainly in East Asia, Australia, and South Africa.

Recent Developments in Hatchery Technologies

One of the most important developments in mollusc aquaculture has been the shift from natural seed collection to hatchery-based seed production. Traditionally, farmers depended on natural spatfall by placing collectors such as ropes, coconut fibers, shells, tiles, bamboo poles, or nets in breeding grounds to capture settling larvae. However, the quantity and quality of natural spat often varied greatly from year to year. Climatic disturbances, pollution, heavy rainfall, freshwater influx, and overexploitation reduced reliability. Hatchery production now provides a regular supply of healthy and uniform juveniles throughout the year, allowing farmers to plan production schedules more effectively (Anil & Gomathi, 2023).

Modern hatcheries are carefully designed and located near the sea where clean, pollution-free seawater with appropriate salinity is available year-round. Reliable electricity, road access, transport facilities, and availability of broodstock are also important considerations. Hatchery infrastructure now includes broodstock tanks, spawning rooms, larval rearing tanks, algal culture laboratories, settlement units, nursery systems, filtration plants, and water reservoirs.

Water quality management has greatly improved through the use of advanced treatment systems. Incoming seawater is passed through sedimentation tanks, sand filters, cartridge filters, and sterilization units. Chlorination, dechlorination, ultraviolet radiation, and ozone treatment are commonly used to destroy harmful microorganisms and

pathogens (Zheng *et al.*, 2017). This has significantly improved larval survival and reduced disease outbreaks. Continuous monitoring of temperature, salinity, pH, dissolved oxygen, and turbidity using sensors has made hatchery management more precise.

Broodstock conditioning is another major advancement. Healthy adult mussels, oysters, or clams are selected and maintained under controlled environmental conditions to enhance gonadal maturation. Broodstock are fed nutritious live microalgae such as *Isochrysis galbana*, *Chaetoceros calcitrans*, *Pavlova lutheri*, and *Nannochloropsis*. Proper nutrition improves egg quality, sperm production, fertilization rate, and larval vigor. Temperature and photoperiod manipulation can also accelerate maturation and extend the spawning season.

Induced spawning techniques have become highly reliable. Instead of waiting for natural spawning, hatchery technicians stimulate broodstock using thermal shock, salinity shock, desiccation followed by re-immersion, chemical cues, or serotonin treatment in some species. In stripping methods, eggs and sperm are carefully collected manually and mixed under controlled conditions. These methods allow synchronized spawning and mass production of fertilized eggs.

Larval rearing technology has become more sophisticated. After fertilization, embryos develop into trochophore larvae, then D-veliger, umbo, pediveliger, and settlement stages. Larvae are reared in circular or rectangular tanks with gentle aeration and regular water exchange. Stocking density is scientifically managed to avoid overcrowding. Frequent cleaning prevents bacterial growth and waste accumulation. Automated counting and grading methods are increasingly used in large hatcheries. Balanced mixed algal diets enhance shell formation, growth, and

successful metamorphosis (Anil & Gomathi, 2023).

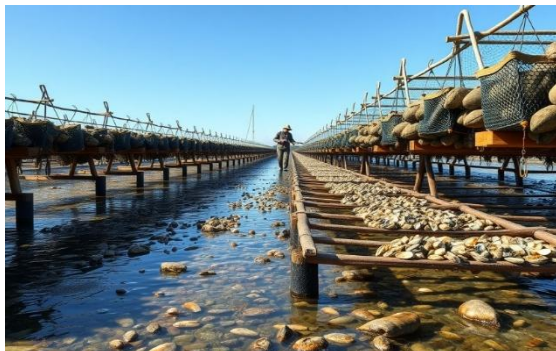
Microalgal feed production has itself become a specialized technology. Hatcheries maintain mother cultures, starter cultures, and mass cultures of selected algal species under sterile conditions. Controlled light, nutrients, aeration, and temperature are used for high productivity. Some hatcheries now use concentrated algal pastes and commercial microdiets to supplement or partially replace live feeds, reducing labor and risk of contamination.

After settlement, young spat are transferred to nursery systems. Recent innovations include downwelling trays, upwelling silos, raceways, floating nursery baskets, and land-based recirculating nursery tanks. These systems improve water flow, feeding efficiency, and growth rate. Seed can be raised rapidly to a robust size suitable for transfer to farms, reducing mortality after stocking.

Selective breeding and genetics are emerging hatchery technologies. Breeding programs now aim to develop strains with faster growth, better shell shape, higher meat yield, tolerance to temperature stress, and disease resistance. Triploid oysters, which often grow faster and have better meat quality, are increasingly produced in some countries.

Recent Developments in Farming Technologies

Grow-out farming systems for molluscs have



also advanced significantly. Rack culture remains common in shallow estuaries and backwaters. In this method, bamboo, wooden, concrete, or synthetic poles are fixed into the bottom and connected horizontally. Seeded ropes or baskets are suspended from the rack. Improved materials such as HDPE pipes and coated ropes now increase durability and reduce maintenance costs.

Raft culture has become highly popular in sheltered coastal waters and bays. Floating rafts made of bamboo, metal, or HDPE frames are supported by drums, plastic floats, or pontoons. Long ropes seeded with mussels or oysters hang vertically into the water column. Better water circulation and continuous food supply in deeper water result in faster growth and higher yields. Modular raft designs and storm-resistant mooring systems are recent improvements.

Longline farming is a modern offshore production system suitable for large-scale commercial operations. Strong main ropes supported by floats are anchored securely at both ends, and multiple dropper lines carrying shellfish seed are suspended vertically. This method allows efficient use of deeper coastal waters and reduces crowding in nearshore zones. Longline systems are now designed to withstand waves, currents, and storms, enabling expansion into exposed marine areas (Thiel & Gutow, 2004).

Bottom culture continues to be widely practiced for clams and some oysters. Seed is broadcast onto prepared sandy or muddy beds and harvested after growth. Recent improvements include predator exclusion nets, laser leveling of beds, rotational harvesting, and mechanized harvesting equipment.

Cultchless oyster farming is an important modern innovation. Instead of growing oysters attached permanently to shells or stones, hatchery seed is stocked in mesh bags, trays,

floating cages, tumblers, or baskets. This produces single oysters preferred by premium markets. It also improves grading, cleaning, stock management, and harvesting efficiency.

Integrated Multi-Trophic Aquaculture (IMTA) has become a major sustainability approach. In IMTA systems, shellfish are grown together with fish, shrimp, or seaweeds. Waste nutrients released from fed species are utilized by filter-feeding molluscs and seaweeds, improving water quality and reducing environmental impact. Such systems increase resource efficiency and diversify farm income.

Smart Farming and Digital Technologies

Recent years have seen increasing adoption of digital technologies in mollusc farming. Water quality sensors provide real-time information on temperature, salinity, dissolved oxygen, chlorophyll, and turbidity. Mobile applications help farmers record stocking, growth, mortality, and harvest data. GPS mapping supports farm zoning and navigation. Remote cameras and drones can inspect offshore farms. Artificial intelligence tools are being developed to predict growth performance, disease risks, and harvest timing. Weather forecasting and storm alert systems are especially valuable for raft and longline farms.

Farm Management Practices

Modern farm management emphasizes regular monitoring and preventive maintenance. Farmers routinely inspect ropes, cages, floats, anchors, and moorings. Fouling organisms such as barnacles, algae, tunicates, and tube worms are removed because they compete for food and add weight to structures. Stock is periodically thinned or graded to prevent overcrowding. Predators such as crabs, starfish, birds, snails, and fish are controlled using nets, traps, or exclusion devices. Proper stocking density and site rotation help maintain growth and reduce stress. (Davis *et al.*, 2021)

Harvesting and Post-Harvest Technologies

Molluscs are usually harvested within six to eighteen months depending on species, seed size, temperature, and farming system. Mechanical lifting devices now reduce labor in raft and longline farms. After harvest, shellfish undergo depuration, where they are held in clean treated seawater to eliminate sand, bacteria, and contaminants. This greatly improves food safety. Mechanical graders sort shellfish by size for uniform marketing. Refrigerated transport and cold chain systems preserve freshness and shelf life.

Value addition has expanded rapidly. Mussels are sold as half-shell frozen products, marinated meats, smoked products, and ready-to-cook packs. Oysters may be marketed live, shucked, frozen, canned, or smoked. Clams and scallops are also processed into frozen or canned forms. Attractive packaging and certification systems improve consumer confidence and export potential.

Challenges and Future Prospects

Despite rapid progress, mollusc aquaculture still faces several challenges. Climate change can alter seawater temperature, salinity, storm frequency, and ocean acidity. Pollution from industry, agriculture, and urban waste can contaminate growing areas. Harmful algal blooms may cause toxin accumulation in shellfish. Disease outbreaks, biofouling, predator damage, labor shortages, and theft also affect profitability.

Future developments are expected in genomic breeding, disease diagnostics, probiotics, automated offshore farms, robotics for cleaning and grading, biodegradable farm materials, renewable-energy-powered hatcheries, and climate-resilient production systems. Expansion of eco-certification and traceability programs will also strengthen international trade.

CONCLUSION

Recent developments in hatchery and farming technologies for molluscs have transformed shellfish aquaculture from a traditional seed-dependent activity into a modern, scientific, and commercially efficient industry. Hatchery seed production, broodstock conditioning, induced spawning, advanced larval rearing, nursery systems, and water treatment technologies have ensured reliable seed supply and higher survival. At the same time, innovations such as raft culture, rack systems, longline farming, cultchless oyster production, IMTA models, and smart monitoring tools have greatly improved productivity and sustainability. With continued research, investment, farmer training, and adoption of modern practices, mollusc aquaculture has immense potential to enhance food security, generate employment, increase export earnings, and support sustainable blue economy development worldwide.

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