



Sustainable Intensification of Mud Crab Fattening Using Recirculating Aquaculture System-Based Vertical Farming

*Debtanu Bera¹, E. Prabu², Santanu Maiti¹ and Krishika Bain³

¹Fisheries College and Research Institute, Thoothukudi, Tamil Nadu, India

²Directorate of Incubation and Vocational training in Aquaculture, Tamil Nadu, Dr. J. Jayalalithaa Fisheries University, ECR, Muttukadu, Chennai, India

³Department of Aquaculture, Dr. M.G.R. Fisheries College and Research Institute, Ponneri, Tamil Nadu-601204, India

*Corresponding Author's email: debtanubera1234@gmail.com

The *Scylla* species of mud crab is highly valued commercially and is widespread throughout the Indo-Pacific region (Keenan, 1999). Renowned for their large size and exquisite flavor, these crabs are considered luxury seafood items, driving their high market demand and value (Trino and Rodriguez, 2002). Mud crab aquaculture has emerged as a growing industry within the global aquaculture sector, particularly in Asian markets (Chavande et al., 2024). This form of farming offers a promising opportunity to promote sustainable aquaculture, providing economic benefits while reducing the pressures of overfishing and habitat degradation. However, traditional farming techniques often face challenges such as limited space, disease outbreaks, and environmental consequences (Chavande et al., 2024). A major issue in mud crab aquaculture is the extended maintenance period, which leads to increased feed costs and operational expenses. Fattening crab farming presents an alternative with a shorter maintenance duration (Usman et al., 2024). Nevertheless, these methods involve relatively high construction costs and depend heavily on abundant water resources (Shelley, 2008). Technological advancements are necessary in this community. Various fattening crab technologies have been developed, including Vertical Crab Culture Technology and Recirculating Aquaculture Systems (RAS), to improve efficiency and reduce environmental impact. This approach arranged mud crab boxes vertically to save space. RAS employs sand, bio, and UV filters to maintain high water quality, reduce water usage, and minimize waste (Phong & Minh, 2019). The integration of Vertical Crab Culture Technology with RAS has shown potential in enhancing productivity, reducing resource consumption, and mitigating environmental impact compared to traditional mud crab farming methods (Chavande et al., 2024).

India's Mud crab industry

A few years ago, mud crab farming in India was thriving, with suppliers from the southeastern region pulling in up to 500 kg of crabs daily (Naveen Nivas et al., 2024). The mud crab industry was key to India's \$7.38 billion seafood export market in 2023-2024. However, now, everything has changed. The first major MCRV outbreak in India, confirmed by Sravani et al. (2022), spread rapidly through farms and wild populations, creating significant challenges. MCRV is a double-stranded RNA virus that attacks crabs' vital organs, leading to rapid death. Farms report infection rates of 80 to 100 percent, and wild populations show rates between 19 and 33 percent, confirming virus spread beyond farms (Ganesan et al. 2023). Infected crabs show discoloration, slow movement, and severe hepatopancreas damage. Along India's east coast, some farmers have lost all stock within 25 days, with

reports suggesting Mud Crab Reovirus (MCRV)—a deadly pathogen that previously impacted China's mud crab industry—may be responsible (Naveen Nivas et al., 2024).

Concept of Vertical crab culture

Traditional crab farming (pond-based or pen culture) requires large areas of land and water, making it less feasible in urban or resource-limited regions. Vertical farming adapts the concept of multi-tier aquaculture, in which crabs are cultured in stacked layers of boxes/cages inside tanks or RAS systems. This reduces space requirements by 60–70% compared to pond culture, while still allowing for high survival, growth, and fattening rates. It is a short-term aquaculture practice in which partially filled, lean, or newly molted crabs are raised in individual containers to ensure that each crab lives separately under controlled conditions for a few weeks (usually 20–45 days) until they become hard-shelled and full of meat. It provides a greater edge over traditional farming practices owing to better water quality management, enhanced biosecurity, space efficiency, faster growth, year-round production, and reduced cannibalism.

Components of RAS in Vertical Crab Culture Technology

A recirculating aquaculture system has crucial elements that maintain water quality and crab health. To develop technology for removing dissolved and fine organic wastes, understanding waste characteristics and recirculating systems is essential (Singh et al., 1999). The components included the following:

Culture Box

Farming crab boxes are essential components of the vertical farming system. The dimensions of the box determine the upper limit on the size of crabs that can be cultivated in the vertical mud crab. Boxes are made from durable, food-safe plastics, such as polypropylene (PP) or polyvinyl chloride (PVC). The crabs were raised in individual containers to ensure that each crab lived separately alongside purified and original water. At present, three variants of crab boxes are in practice: Juveniles (50–150 g) – 20–25 × 20–25 × 15–20 cm, Sub-adults (150–300 g) – 25–30 × 25–30 × 20–25 cm, and Marketable crabs (300–600 g) – 28–35 × 28–35 × 25–30 cm. Along with the culture boxes, small 20-liter water gallons serving as crab houses can be vertically arranged on iron racks and connected to a gravity-fed water circulation system (Usman et al., 2024).

Protein Skimmer

Suspended particles in the water column that cannot settle may obstruct crab growth by interfering with their respiratory system. Protein skimming removes organic substances like proteins and amino acids from food particles and fish waste by leveraging protein polarity. All protein skimmers function by producing tiny particles. Proteins in water interact with the air–water interface according to their characteristics; hydrophilic molecules are attracted to water, hydrophobic molecules repel it, and amphipathic compounds balance both tendencies. Protein skimmers create numerous small bubbles, forming an interface where hydrophobic and amphipathic molecules adhere to bubble surfaces. Smaller bubbles increase effectiveness by providing more surface area to capture organic material. As bubbles rise, water movement accelerates diffusion, and when they burst or are removed, the attached contaminants are carried away, leaving purified water.

Ultraviolet (UV) Filter

Ultraviolet (UV) filters eliminate microorganisms such as viruses, bacteria, fungi, parasites, and algae by altering their genetic material. UV C, particularly at a wavelength of 254 nm, is the most effective type of ultraviolet radiation for disinfection. Microorganisms absorb UV C light photons, which initiate chemical reactions within them. This leads to the formation of covalent bonds between adjacent thymine-thymine pairs in DNA and uracil-uracil pairs in RNA. These covalent bonds cause structural irregularities in DNA or RNA strands, disrupting genetic replication and function. With compromised DNA or RNA, microorganisms cannot replicate accurately or reproduce successfully, resulting in their death or inactivation.

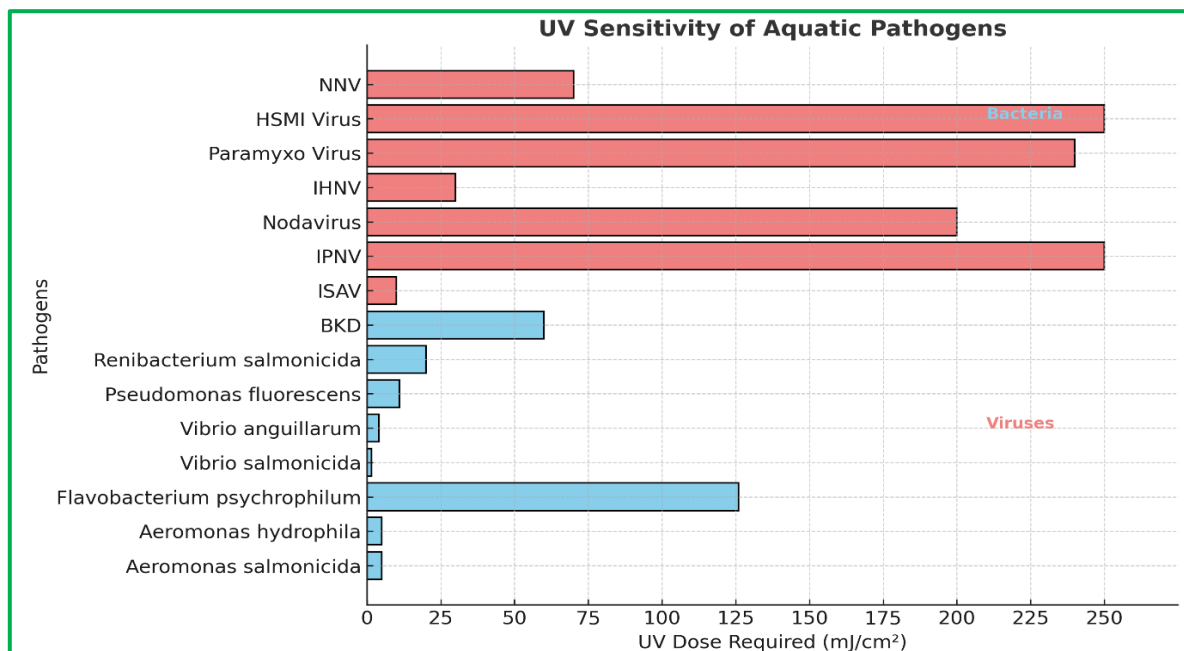


Figure 1: UV doses for other common aquaculture diseases

Sand Filter

The sand filter in a Recirculating Aquaculture System (RAS) is a critical component for maintaining water quality by effectively removing suspended solids and particulate organic matter. It directs water through a sand bed, which captures and retains fine particles, thereby preventing their recirculation into the culture system. This filtration process reduces turbidity and the accumulation of organic waste, thus mitigating adverse effects on crab health and growth. By efficiently removing these solids, the sand filter contributes to maintaining clearer water, supports biological filtration processes, and enhances the overall stability and efficiency of the vertical crab culture system within the RAS.

Biological Filter

Mud crabs eliminate ammonia through capillary propagation, cation exchange, and waste removal. Transforming ammonia into less harmful substances is crucial for water quality and pathogen control. Biofiltration uses nitrifying bacteria to convert ammonia into nitrite (NO₂), then nitrate (NO₃). Establishing optimal conditions for these microorganisms is complex, and farms' success depends on biofiltration expertise (Shelley and Lovatelli, 2011). This process provides surface area for beneficial nitrifying bacteria colonization within the filtration system. Bio-balls, ceramic rings, K1 kaldnes media, and sintered glass are effective biofilter media due to their surface area and porosity for bacterial colonization.

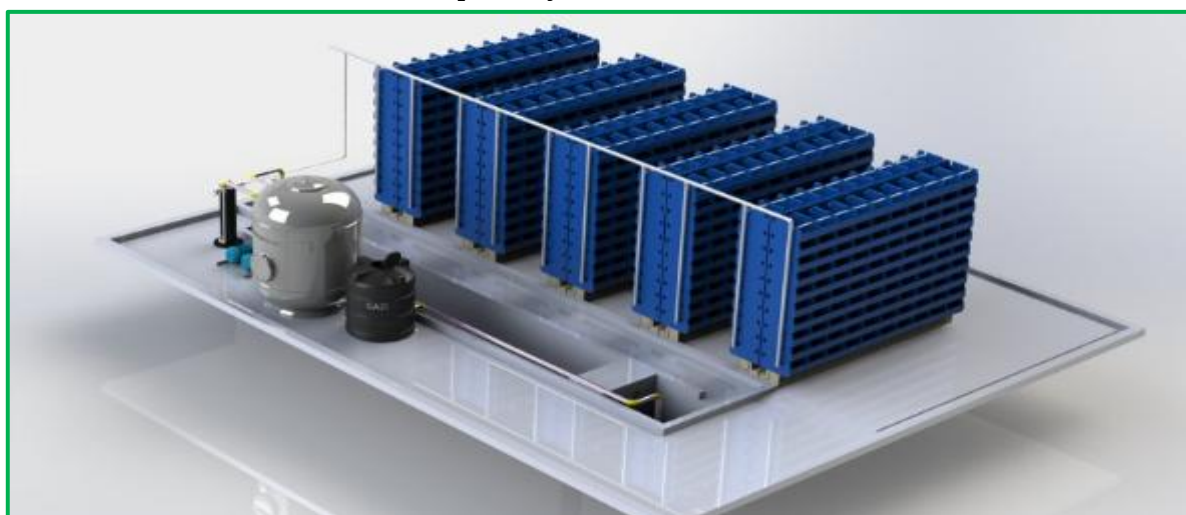


Figure 2: Indoor RAS integrated vertical crab farming model (source: Adapted from RAS Aquaculture, 2025)

Water Quality Management in Vertical Crab Culture Technology with RAS

Maintaining high water quality is essential for mud crab aquaculture success. These crabs require pristine water to optimize survival and growth. The health of crabs depends on effective management of solid waste, biofiltration, oxygenation, pH levels, and temperature regulation. These processes control water parameters affecting crab growth. Although this species can adapt to various salinity levels, prolonged suboptimal conditions impede growth. Keeping salinity within ideal range minimizes energy spent on osmoregulation (FAO,2011).

Table 1. Ideal Water Quality Parameters for Mud Crab Farming

Parameter	Optimal Range
Dissolved Oxygen (DO)	> 5
pH	7.5 – 9.0
Temperature	25 – 35
Salinity	10 – 25
Total Ammonia Nitrogen	< 3
Un-ionized Ammonia (NH ₃)	< 0.25
Nitrite (NO ₂ ⁻)	10 – 15

Source: FAO manual, (2011)

Feed and Feeding

Mud crabs (*Scylla serrata*) exhibit omnivorous and nocturnal feeding behavior, with peak activity during night and twilight hours. Their natural diet consists of fish, mollusks, smaller crabs, shrimps, and worms, with minimal plant matter consumption. Mud crabs favor protein-rich foods, particularly fish and shellfish. Research shows that feeding crabs with squid, clams, and beef liver results in 8.36-11.15 g weight gain after 14 days (Usman et al., 2024). Using combined natural (trash fish) and artificial feed (pellets) demonstrated superior feed efficiency (FCR 1.8) and highest weight gain (270-390 g) after 60 days (Rasda et al., 2025). Feeding can be performed at 10% of body weight daily at night (Mayjuri et al., 2025).

Drawbacks of Mud crab Fattening in RAS with Vertical crab culture technology

Despite its advantages, mud crab fattening in the RAS system faces several challenges that must be addressed to ensure the wider adoption and expansion of this technology. Therefore, addressing these issues is crucial for the sustainable development of RAS-based crab farming.

High Infrastructure Costs

RAS and vertical housing systems for mud crabs (*Scylla* spp.) require substantial initial investment (Naveen et al., 2024). The system includes tanks, biofilters, filters, pumps, aeration units, and monitoring sensors, which ensure environmental stability but raise capital costs compared to traditional ponds.

Continuous Water Quality Monitoring

Mud crabs are sensitive to fluctuations in temperature, dissolved oxygen, salinity, and ammonia. In RAS, maintaining parameters within optimal range (DO >5 mg/L, salinity 10–25 ppt, temperature 25–35°C, and TAN <3 mg/L) is essential. Continuous monitoring using digital sensors is necessary but technically demanding, requiring calibration and trained staff.

Seed Scarcity

Quality mud crab seed supply remains a critical bottleneck. Hatchery-based production technologies for *Scylla serrata* are under refinement in India, with low larval survival due to cannibalism. Most farmers rely on wild seed collection, which is seasonal and unsustainable (Naveen et al. 2024).

Knowledge and Skill Gap

Operating RAS and vertical crab housing requires knowledge of biofiltration, recirculation hydraulics, and crab physiology. Farmers often lack training in these technologies, leading to system mismanagement (Naveen et al., 2024).

Feed Supply Challenges

Without commercially formulated crab feed for *Scylla* spp., farmers depend on trash fish, clam meat, or molluscan flesh, varying in nutrient quality. Development of balanced, water-stable crab feeds remains limited in India.

Exploring the Potential of Aquaponics in Crab Farming

Aquaponics is a specialized application of RAS that combines plant cultivation with crab farming in a closed-loop system. This creates a symbiotic relationship where crabs provide nutrients to crops, while water is filtered by vegetation for the crabs. In this system, crab feces supply nourishment for plants, which remove excess nutrients from water. This natural filtration minimizes water pollution and provides a healthy environment for crabs. Aquaponics offers key benefits: it reduces external fertilizer needs, enhances water quality through biological filtration, and provides additional income through plant harvesting.

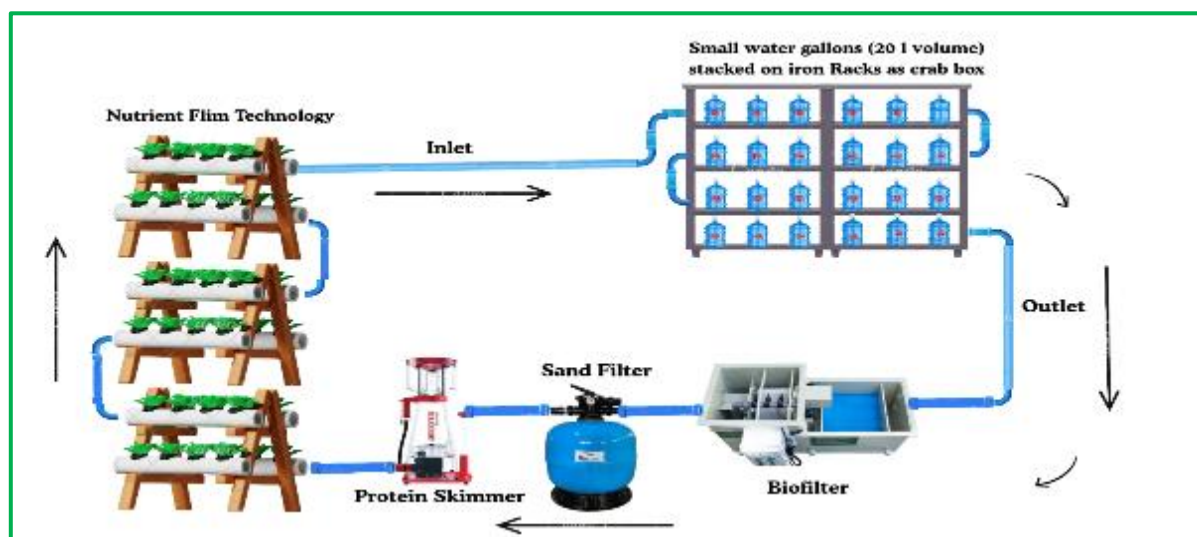


Figure 3: Aquaponics integrated RAS-Vertical crab culture farm model

Conclusion

Vertical crab culture with a Recirculating Aquaculture System (RAS) is a promising innovation for mud crab fattening, offering space efficiency, biosecurity, and improved water quality. Feed type influences growth performance, with combined natural and artificial feeds giving the best results in weight gain, survival, and market quality. Feeding once daily at night was found optimal for survival, growth, and efficiency in RAS conditions. Vertical crab houses minimize cannibalism and allow high stocking densities, making them suitable for sustainable aquaculture. Major challenges remain: high infrastructure cost, continuous monitoring needs, seed scarcity, limited formulated feed availability, and knowledge gaps among farmers. Integration with aquaponics can enhance sustainability by improving water quality and generating income through plant cultivation.

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