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Soft-Shell Crab Farming: A New Horizon in Coastal Aquaculture

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SUMMARY

Soft-shell crab farming is an emerging and profitable sector in coastal aquaculture owing to increasing global demand for high-value seafood products. Soft-shell crabs are mud crabs harvested immediately after molting, when the newly formed shell remains soft and edible. Their unique texture, high consumer preference, and premium export value have significantly increased commercial interest in soft-shell crab production. Traditional soft-shell crab farming systems mainly relied on pond-based culture using individual crab boxes and floating cages. However, recent advancements in aquaculture technologies have introduced more efficient production systems such as apartment culture systems, vertical crab boxes, greenhouse farming, and recirculating aquaculture systems. These innovations improve water quality management, reduce cannibalism, and increase production efficiency. Modern soft-shell crab farming also incorporates AI -based monitoring systems, deep-learning technologies, and herbal molting stimulants to improve molting detection and production performance. With growing market demand, technological advancement, and increasing emphasis on sustainable blue economy practices, soft-shell crab farming possesses strong future potential for commercial expansion, coastal livelihood development, and sustainable aquaculture growth.

INTRODUCTION

Mud crabs stand as the most economically important crustaceans cultured in tropical and subtropical coastal regions owing to their rapid growth, high consumer preference and premium export value, leading to the emergence of mud crab culture as a significant sector in brackishwater aquaculture across many Asian countries, including India, Indonesia, Thailand, Vietnam, Bangladesh and the Philippines. Traditionally, mud crab culture mainly focused on fattening and grow-out practices for the live crab trade. However, in recent years, increasing market demand and higher commercial returns have accelerated the development of soft-shell crab farming as a specialized and profitable aquaculture practice (Quinitio & Lwin, 2009; Haque et al., 2025).

Soft-shell crabs are mud crabs harvested immediately after molting, when the old exoskeleton has been shed and the newly formed shell remains soft and edible. During the molting process, crabs undergo ecdysis, a natural physiological phenomenon essential for growth. The newly molted crab absorbs water rapidly, causing expansion of body tissues before the shell hardens within a short duration. This brief soft-shell stage is commercially valuable because the entire crab can be consumed without removal of the shell, thereby increasing consumer convenience and culinary appeal (Quinitio & Lwin, 2009). In addition, soft-shell crabs possess desirable texture, flavor, and nutritional characteristics, making them highly preferred in restaurants and seafood markets. Compared with conventional hard-shell mud crabs, soft-shell crabs command substantially higher market prices due to their premium quality and export demand. International markets such as the United States, China, Japan, Singapore and European countries have shown increasing preference for processed and frozen soft-shell crab products (Agustiyana et al., 2024). The growing demand is further supported by expansion of the food service industry, urbanization, and changing seafood consumption patterns in many countries. Consequently, soft-shell crab farming has become an important source of livelihood and income generation for coastal communities, particularly in Southeast Asia.

Conventional soft-shell crab production systems primarily relied on pond-based culture and wild-caught juvenile crabs. Nevertheless, increasing pressure on natural crab resources, inconsistent seed availability, cannibalism, and disease risks have created major challenges for sustainable production. To address these limitations, modern soft-shell crab farming has gradually shifted toward more controlled and technology-oriented production systems, including hatchery-based seed production, apartment culture systems, vertical crab boxes, greenhouse farming, and recirculating aquaculture systems (RAS) (Quinitio et al., 2017; Agustiyana et al., 2024). Recent innovations involving herbal molting stimulants, artificial intelligence, deep-learning-based monitoring and smart aquaculture technologies are also contributing to improved production efficiency and sustainability in soft-shell crab farming (Aini et al., 2025; Effendi et al., 2026). With increasing global interest in sustainable and climate-resilient aquaculture practices, soft-shell crab farming is emerging as a promising component of modern coastal aquaculture. Its high economic return, expanding market potential, and adaptability to innovative farming technologies highlight its future importance in the blue economy sector.

Biology and Molting process of Mud Crab

Mud crabs belonging to the genus *Scylla* are commercially important crustaceans distributed in estuarine and mangrove ecosystems of tropical and subtropical regions. Four major species are widely recognized, namely *Scylla serrata*, *Scylla olivacea*, *Scylla tranquebarica*, and *Scylla paramamosain* (Quinitio & Lwin, 2009). Among these, *S. serrata* is highly preferred in soft-shell crab farming because of its relatively fast growth, larger body size, better survival, and higher market acceptance. These species possess high adaptability to brackishwater environments and exhibit rapid growth through periodic molting, making them suitable candidates for commercial soft-shell crab production.

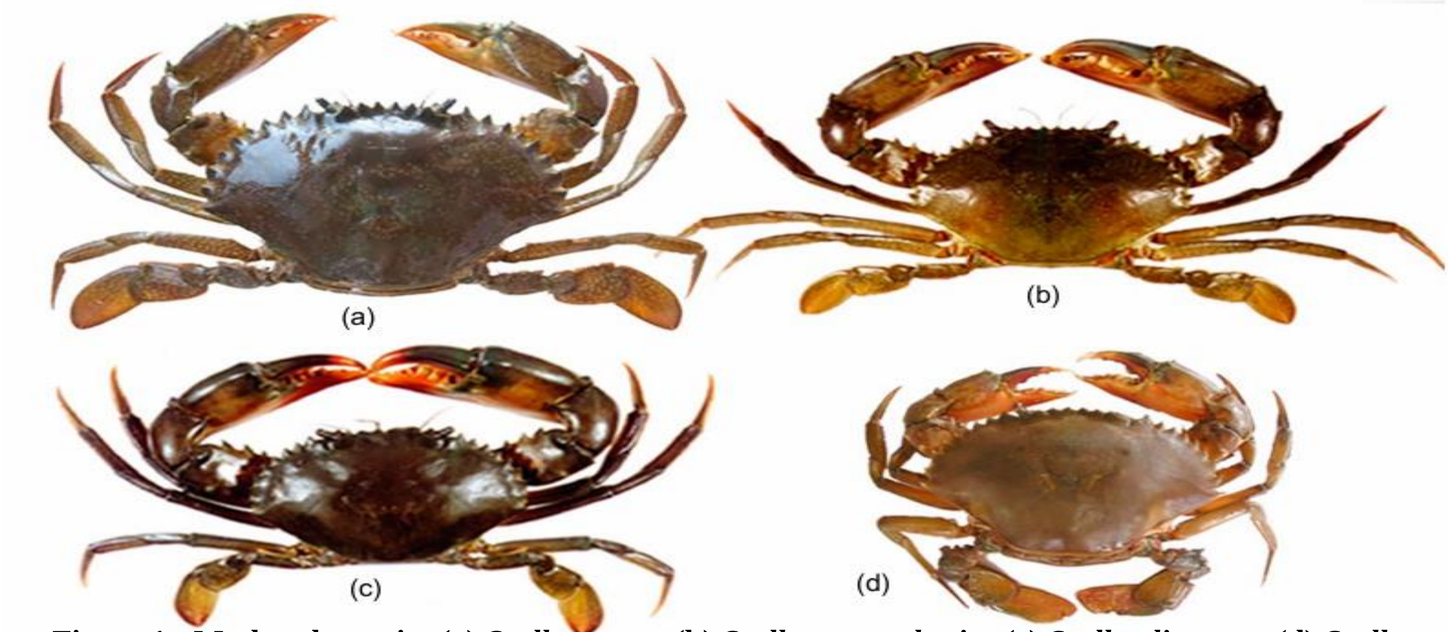

Figure 1 : Mud crab species (a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea* (d) *Scylla paramamosain* (Quinitio & Lwin, 2009)

Growth in mud crabs occurs through a biological process known as molting or ecdysis, during which the old rigid exoskeleton is shed and replaced with a newly formed soft shell. Since crustaceans possess a hard external skeleton composed mainly of chitin and calcium salts, body enlargement is only possible after shedding the old shell. The molting cycle in *Scylla* spp. consists of four major stages: postmolt, intermolt, premolt, and ecdysis (Quinitio & Lwin, 2009). During the postmolt stage, the newly molted crab remains soft and physiologically weak while rapidly absorbing water to expand body tissues. This is followed by the intermolt stage, where the shell gradually hardens and feeding activity becomes active. Premolt is characterized by reduced feeding activity, loosening of the old exoskeleton, and preparation for shell shedding. Finally, during ecdysis, the crab emerges from the old shell and undergoes rapid body expansion before the new exoskeleton calcifies and hardens. The soft-shell stage immediately after molting represents the most economically valuable phase in soft-shell crab farming. Newly molted crabs possess a thin, flexible shell that can be consumed entirely, including the carapace and appendages. However, this stage persists only for a short duration, generally ranging from a few hours to less than one day depending on environmental conditions and crab size (Fujaya et al., 2021). Therefore, timely harvesting is extremely critical in commercial production systems. Delayed harvesting results in rapid shell calcification and hardening, thereby reducing product quality and market value. To prevent shell hardening, crabs are usually monitored continuously and harvested immediately after molting before processing and preservation.

Several biological and environmental factors strongly influence molting frequency, molting success, and shell hardening in mud crabs, among which temperature is one of the most important factors, as it regulates metabolic activity and the hormonal control associated with molting. Optimal temperature conditions promote faster growth and reduced intermolt duration, whereas temperature fluctuations may induce stress and delay molting. Salinity, dissolved oxygen, pH, and water quality also affect molting performance and survival. Poor water quality conditions increase physiological stress and susceptibility to disease, particularly during the vulnerable postmolt phase. Adequate dietary protein, minerals, and energy are essential for tissue regeneration and exoskeleton formation. Recent studies have reported that herbal supplements containing phytoecdysteroids, such as spinach, purslane, and mulberry extracts, can stimulate molting and improve soft-shell crab production efficiency (Effendi et al., 2026). In addition, culture management practices such as stocking density, cannibalism control, individual rearing systems, and stress reduction significantly influence survival and molting percentage in soft-shell crab farming systems. Modern soft-shell crab farming increasingly utilizes controlled production systems to regulate environmental conditions and optimize molting performance. Technologies such as recirculating aquaculture systems (RAS), apartment culture systems, and greenhouse farming provide improved water quality management, biosecurity, and reduced mortality during molting. Understanding the biological mechanisms of molting and the factors affecting shell hardening is therefore essential for achieving efficient, profitable, and sustainable soft-shell crab production.

Production Systems in Soft–Shell Crab Farming

Traditional Pond-based Culture

Traditional pond-based culture is one of the earliest and most widely practiced methods for soft-shell crab production in Asian countries. In this system, mud crabs are generally reared individually in perforated plastic boxes, floating cages, or net pens installed within brackishwater ponds to minimize cannibalism during molting (Quinitio & Lwin, 2009). Individual crab boxes are commonly arranged on floating platforms or pontoons, allowing farmers to monitor crabs regularly and harvest them immediately after molting. This individual rearing technique prevents aggressive interactions among crabs, particularly during the vulnerable postmolt stage when the newly molted crabs possess soft exoskeletons and reduced mobility. Floating cages and pens are also widely used in coastal ponds and estuarine environments for commercial soft-shell crab production. These systems are relatively simple, cost-effective, and suitable for small-scale farmers due to their low infrastructure requirements. Crabs are typically stocked at suitable densities and maintained under semi-intensive conditions with regular monitoring of molting activity. Feeding management plays a crucial role in pond-based systems, where crabs are commonly fed trash fish, mollusks, or formulated feeds containing adequate protein for growth and molting (Quinitio et al., 2017).

Apartment System and Vertical Crab boxes

Recent advancements in soft-shell crab farming have led to the development of apartment systems and vertical crab box culture for more efficient and intensive production. The apartment system consists of vertically arranged individual crab compartments integrated within a controlled culture unit, allowing large numbers of crabs to be reared in a relatively small area (Agustiyana et al., 2024). Each compartment houses a single crab, thereby minimizing physical interaction and reducing cannibalism, which remains one of the major causes of mortality in mud crab farming. Vertical crab box systems improve space utilization efficiency and are particularly suitable for urban and peri-urban aquaculture where land availability is limited. These systems support intensive production by maximizing stocking capacity while maintaining individual crab management. In addition, apartment systems facilitate easier monitoring of molting, feeding, and health status compared to conventional pond-based culture. Agustiyana et al. (2024) reported that apartment systems can improve production efficiency and profitability when optimal stocking density and labor management are maintained. The integration of vertical culture units with controlled water management systems further enhances production stability and biosecurity. The use of apartment systems also supports the development of urban aquaculture by enabling soft-shell crab farming in confined spaces with reduced water requirements. This approach provides opportunities for sustainable aquaculture expansion in densely populated coastal regions where conventional pond culture may not be feasible. Moreover, controlled culture conditions reduce exposure to environmental fluctuations and disease outbreaks, thereby improving survival and production consistency.

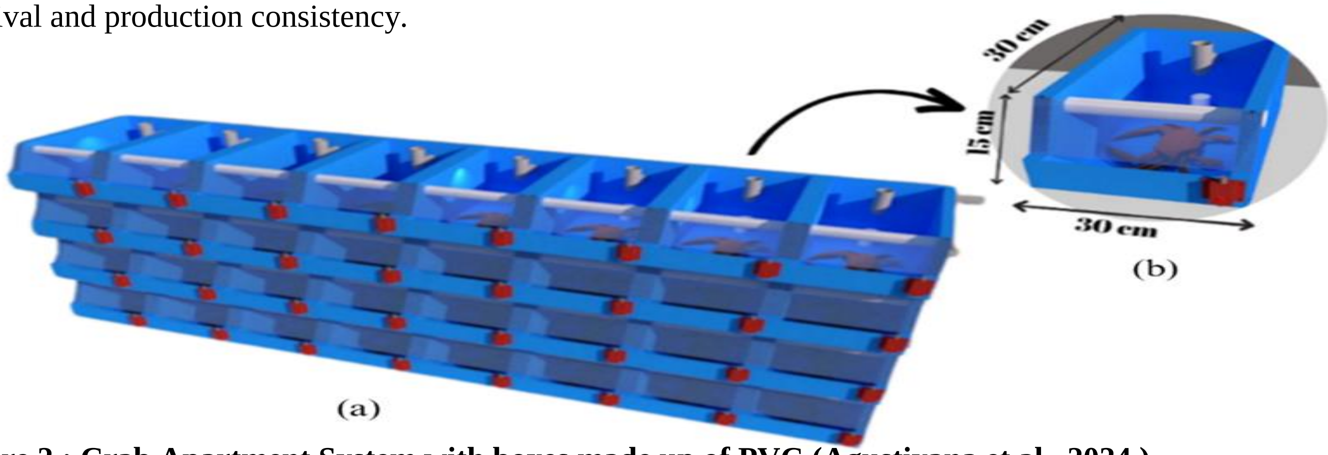

Figure 2 : Crab Apartment System with boxes made up of PVC (Agustiyana et al., 2024)

Recirculating Aquaculture System

Recirculating aquaculture systems (RAS) are increasingly being adopted in modern soft-shell crab farming to improve production efficiency, environmental control, and sustainability. In RAS-based culture, water is continuously recycled through physical, chemical, and biological filtration units before being returned to the culture system (Effendi et al., 2026). This process significantly reduces water consumption while maintaining stable water quality conditions essential for molting and survival. The integration of RAS with vertical crab boxes allows intensive soft-shell crab production under highly controlled conditions. Physical filters remove suspended solids and organic wastes, while biological filtration systems facilitate nitrification processes that reduce toxic ammonia accumulation. Chemical filtration further improves water quality by stabilizing pH and removing harmful substances. Such controlled water management enhances crab health, minimizes stress, and supports higher molting success rates. An important advantage of RAS-based soft-shell crab farming is improved biosecurity. Since water exchange with external environments is minimized, the risk of pathogen introduction and disease transmission is substantially reduced. Controlled environmental conditions also allow better regulation of temperature, salinity, dissolved oxygen, and alkalinity, which are critical factors influencing molting and shell hardening. Effendi et al. (2026) emphasized that RAS integrated with vertical crab box systems can support sustainable intensive farming while improving production performance and resource-use efficiency.

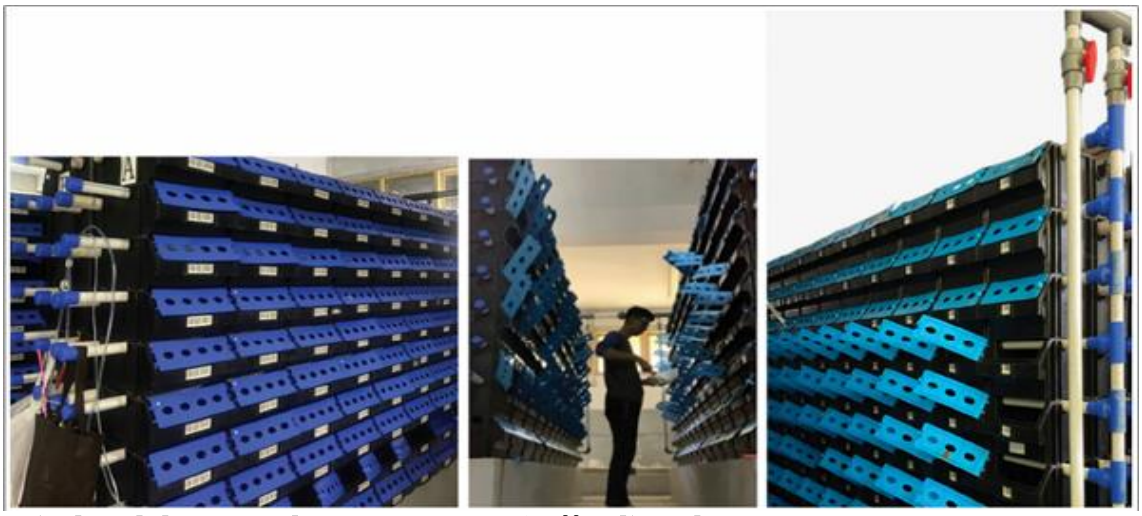

Figure 3 : Vertical crab boxes under RAS system (Effendi et al., 2026)

Molting Induction Techniques

Natural Molting

Natural molting is the conventional method used in soft-shell crab farming, where crabs are reared under suitable environmental and nutritional conditions without the application of artificial molting stimulants. In this method, mud crabs undergo molting according to their normal physiological cycle regulated by endogenous hormones such as molt-inhibiting hormone (MIH) and ecdysteroids (Fujaya et al., 2021). Crabs are generally maintained individually in boxes or cages to reduce cannibalism and are monitored regularly for molting activity. Although natural molting produces soft-shell crabs with complete appendages and normal body morphology, the duration required for molting is relatively long and unpredictable, resulting in lower production efficiency. One of the major limitations of natural molting systems is the extended intermolt period, which increases operational costs associated with labor, feeding, and water management. Delayed molting also reduces the number of production cycles achievable within a culture period. Furthermore, prolonged rearing duration increases the exposure of crabs to environmental stress, disease, and mortality risks. Despite these constraints, natural molting remains widely practiced in traditional soft-shell crab farming because of its simplicity, low technological requirement, and reduced physical stress on cultured crabs.

Autotomy Method

Autotomy is a commonly used molting induction technique in soft-shell crab production that involves deliberate removal of appendages, particularly claws and walking legs, to accelerate molting. The procedure is based on the natural regenerative ability of crustaceans, where loss of limbs stimulates hormonal responses associated with ecdysis and tissue regeneration (Quinitio & Lwin, 2009). In commercial farming, all appendages except swimming legs are often removed manually to induce faster molting and reduce the intermolt duration (Fujaya et al., 2021). The autotomy method is effective in increasing molting percentage and shortening culture duration compared with natural rearing systems. Fujaya et al. (2021) reported that crabs subjected to autotomy exhibited faster molting responses and higher molting rates than untreated crabs. Accelerated molting improves production turnover and allows farmers to obtain soft-shell crabs within a shorter culture period. However, despite its effectiveness, autotomy presents several biological, economic, and ethical concerns. Removal of appendages causes significant physiological stress and energy loss in crabs because substantial metabolic resources are diverted toward limb regeneration following molting. As a result, newly molted crabs often exhibit reduced body weight gain and incompletely regenerated appendages, lowering product quality and market acceptance (Fujaya et al., 2021). In addition, physical injury associated with autotomy may increase vulnerability to infections and mortality, particularly under poor environmental conditions. Ethical concerns have also emerged regarding animal welfare, as the procedure intentionally inflicts injury to stimulate molting. Consequently, there is increasing interest in developing less invasive and more sustainable alternatives for molting induction in soft-shell crab farming.

Application of Herbal extracts and Phytoecdysteroids:

Recent advances in soft-shell crab farming have focused on the use of herbal extracts and phytoecdysteroid-containing plants as environmentally friendly alternatives for molting stimulation. Phytoecdysteroids are naturally occurring plant compounds structurally similar to crustacean molting hormones and are capable of influencing the molting process by stimulating ecdysteroid activity (Effendi et al., 2026). Several plants containing phytoecdysteroids, including spinach (*Amaranthus* spp.), purslane (*Portulaca oleracea*), mulberry (*Morus* spp.), and herbal formulations such as Vitomolt™, have shown promising results in improving molting performance in mud crabs. Herbal molting stimulants may be administered through injection, feed supplementation, or incorporation into formulated diets. Fujaya et al. (2021) demonstrated that herbal extracts significantly improved molting percentage and survival compared with conventional natural rearing systems. Similarly, Effendi et al. (2026) reported that supplementation of purslane, mulberry, and spinach in crab diets enhanced molting frequency and production performance in recirculating aquaculture systems integrated with vertical crab boxes. Compared with autotomy, herbal and phytoecdysteroid-based methods offer several advantages. Since these approaches do not involve physical injury, they minimize stress, reduce the risk of infection, and maintain normal appendage development after molting. Crabs produced using herbal stimulants generally exhibit better body weight gain, improved survival, and more natural morphology than those subjected to limb removal techniques. In addition, dietary administration of phytoecdysteroids is considered more practical and scalable for intensive commercial farming because it reduces labor requirements associated with individual handling and invasive procedures.

Modern Innovations in Soft-shell Crab Farming

Technological advancement is transforming conventional soft-shell crab farming into a more efficient and intelligent aquaculture system. Recent developments in artificial intelligence (AI), deep learning, and Internet of Things (IoT)-based monitoring have improved the accuracy and efficiency of molting detection in soft-shell crab production. Since soft-shell crabs must be harvested immediately after molting to maintain product quality, continuous monitoring is essential in commercial farming systems. Delayed harvesting results in rapid shell calcification, reducing the commercial value of the product. Aini et al. (2025) introduced an AI-assisted underwater monitoring system using deep learning algorithms for detecting newly molted crabs in greenhouse-based soft-shell crab farming systems. The study utilized YOLO (You Only Look Once), a real-time object detection algorithm widely applied in computer vision technologies. YOLO-based systems can identify underwater crabs rapidly and accurately even under challenging conditions such as reflections, low visibility, and image distortion. The integration of image enhancement techniques with YOLO deep-learning models significantly improved the detection efficiency of moulted crabs in underwater culture systems. Smart monitoring technologies provide several advantages in intensive soft-shell crab farming. Automated detection systems reduce labor dependency and allow continuous real-time monitoring of crab behavior and molting activity. Such technologies also minimize human error associated with manual inspection and improve harvesting precision during the short soft-shell phase. In addition, AI-assisted monitoring contributes to improved farm management through rapid decision-making, better production tracking, and efficient resource utilization. These innovations are particularly important in large-scale intensive farming systems where frequent manual monitoring is difficult and labor-intensive.

Economic potential and Market value

Soft-shell crab farming has emerged as a highly profitable sector within coastal aquaculture due to increasing international demand, premium market value, and expanding seafood trade. Mud crabs belonging to the genus *Scylla* are widely recognized as high-value crustaceans in Asian and global seafood markets. In recent years, consumer preference for processed and ready-to-cook seafood products has significantly increased the commercial importance of soft-shell crabs, particularly in countries such as the United States, China, Japan, Singapore, and several European nations (Agustiyana et al., 2024). The growing popularity of soft-shell crabs is largely attributed to their delicate texture, convenience of whole-body consumption, and high culinary appeal in restaurants and hospitality industries. Compared with conventional hard-shell mud crabs, soft-shell crabs command substantially higher market prices because the entire crab, including the shell, can be consumed after cooking. The short harvesting window immediately after molting adds further commercial value due to the labor-intensive monitoring required during production. Agustiyana et al. (2024) reported that soft-shell crab products possess strong export potential and provide higher profitability than traditional mud crab fattening systems. Similarly, Effendi et al. (2026) emphasized that intensive soft-shell crab farming integrated with recirculating aquaculture systems and vertical crab boxes can improve production efficiency and economic returns under controlled farming conditions.

Global market trends indicate increasing demand for sustainable and high-quality crustacean products, creating favorable opportunities for expansion of soft-shell crab aquaculture. The rapid growth of urban seafood markets, food service industries, and frozen seafood trade has further accelerated the commercialization of soft-shell crab products in international markets. Weng and Azlan (2025) highlighted that technological innovation, sustainable farming practices, and improved production systems are expected to strengthen the future growth of the soft-shell crab industry. Furthermore, declining availability of wild crab resources in many regions has increased the importance of aquaculture-based production to meet market demand sustainably. Soft-shell crab farming also plays an important socio-economic role in supporting coastal livelihoods and rural employment. The farming systems can be adapted to small-scale, household-based, or semi-intensive production units, making them suitable for coastal communities with limited land and financial resources. Continuous harvesting and regular income generation provide economic stability for farmers compared with seasonal capture fisheries. In many coastal regions, soft-shell crab farming has become an alternative livelihood strategy that supports poverty reduction and local economic development. With increasing global demand, premium market prices, and expanding technological innovations, soft-shell crab farming has strong potential to contribute significantly to the blue economy sector. Sustainable production systems combined with market-oriented aquaculture practices are expected to strengthen the economic importance of soft-shell crab farming in future coastal development programs

Challenges in Soft shell crab farming

Despite its high economic potential and increasing market demand, soft-shell crab farming faces several biological, technical, and operational challenges that can affect production efficiency and long-term sustainability. Many of these constraints are associated with seed availability, intensive system management, disease risks, and the requirement for continuous monitoring during the molting process.

One of the major challenges in soft-shell crab farming is the continued dependence on wild-caught juvenile crabs in several producing regions. Although hatchery technologies for mud crab seed production have advanced considerably, large-scale commercial farming in many countries still relies heavily on natural seed collection from estuarine and mangrove ecosystems (Quinitio et al., 2017). Excessive harvesting of juvenile crabs from the wild can contribute to depletion of natural populations and create instability in seed supply. In addition, the seasonal availability and variable quality of wild seed stocks may affect production consistency and farm profitability. Hatchery-reared juvenile production offers a sustainable alternative; however, expansion of hatchery infrastructure and technical expertise remains limited in many coastal areas.

The adoption of intensive production technologies such as recirculating aquaculture systems (RAS), greenhouse farming, and vertical crab boxes has improved production efficiency but also introduced higher operational and investment costs. Installation of filtration systems, pumps, aeration units, monitoring devices, and water treatment facilities requires substantial capital investment (Effendi et al., 2026). Furthermore, continuous electricity consumption, equipment maintenance, and skilled labor increase operational expenses in intensive culture systems. Small-scale farmers may therefore face financial limitations in adopting advanced technologies despite their long-term production benefits.

Disease management represents another significant challenge in soft-shell crab farming, particularly under intensive culture conditions. Newly molted crabs are physiologically weak and highly susceptible to bacterial infections, stress-related mortality, and poor water quality conditions. Fluctuations in temperature, salinity, dissolved oxygen, and ammonia levels can compromise immune function and reduce molting success. In intensive farming systems, improper waste management and inadequate biosecurity may facilitate rapid disease transmission among cultured crabs. Effective health management therefore requires strict water quality control, regular sanitation, proper feeding practices, and careful handling during the vulnerable molting stage. Continuous monitoring remains one of the most labor-intensive aspects of soft-shell crab farming. Since the shell hardens rapidly after molting, crabs must be harvested immediately during the short soft-shell stage to maintain product quality and market value (Aini et al., 2025). Conventional systems often require manual inspection every few hours throughout the day and night, increasing labor demand and operational stress. Although modern AI-based monitoring systems have improved molting detection efficiency, the implementation of such technologies may still be limited by infrastructure costs and technical accessibility. Addressing these challenges through sustainable seed production, farmer training, improved biosecurity, technological innovation, and affordable monitoring systems will be essential for the long-term growth and sustainability of the soft-shell crab farming industry.

Future Prospects

One of the most promising areas for future development is the expansion of smart aquaculture technologies in soft-shell crab farming. Artificial intelligence (AI), Internet of Things (IoT)-based monitoring systems, automated sensors, and deep-learning technologies are increasingly being integrated into aquaculture production systems to improve operational efficiency and production management. AI-assisted underwater monitoring systems using YOLO-based object detection have already demonstrated high accuracy in detecting newly molted crabs under greenhouse farming conditions (Aini et al., 2025). The integration of smart monitoring technologies with automated feeding, water quality control, and environmental regulation is expected to reduce labor requirements, improve harvesting precision, and support large-scale intensive production systems. India possesses substantial potential for commercial-scale expansion of soft-shell crab farming due to its extensive coastline, rich mangrove ecosystems, favorable climatic conditions, and growing aquaculture sector. Increasing domestic seafood consumption and export opportunities further strengthen the commercial viability of the industry. In addition, India's ongoing emphasis on blue economy development, coastal livelihood enhancement, and sustainable aquaculture provides a favorable environment for the growth of soft-shell crab farming. Hatchery development, farmer training programs, technological transfer, and investment in controlled farming systems could significantly improve commercial production capacity in the country. With continued technological innovation, sustainable farming practices, and increasing market demand, soft-shell crab farming is expected to become an important component of future coastal aquaculture and blue economy development. The integration of smart farming systems, environmentally responsible production methods, and modern aquaculture technologies will play a critical role in ensuring the long-term sustainability and profitability of the industry.

CONCLUSION

This article highlights the biological basis of molting, different production systems, and recent technological innovations that have improved the efficiency and sustainability of soft-shell crab farming. Traditional pond-based culture methods are gradually being supplemented by advanced systems such as apartment culture, vertical crab boxes and recirculating aquaculture systems (RAS), which provide better environmental control, improved biosecurity, and higher production efficiency. In addition, the use of artificial intelligence-based monitoring systems and herbal molting stimulants demonstrates the growing role of smart and sustainable technologies in modern aquaculture. Sustainable soft-shell crab farming also contributes to reduced dependence on wild crab resources through hatchery-based seed production and water-efficient farming systems. The sector offers significant opportunities for coastal livelihood improvement, women and youth entrepreneurship, and blue economy development. With continued technological advancement, scientific management, and adoption of environmentally responsible farming practices, soft-shell crab farming possesses strong future potential as a profitable and sustainable aquaculture enterprise.

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