International Journal of Marine Science, 2026, Vol.16, No.2, 81-94
http://www.aquapublisher.com/index.php/ijms

Research Insight Open Access

Effects of Different Feeding Regimes on Growth Performance of Mud Crab

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International Journal of Marine Science, 2026, Vol.16, No.2 doi: 10.5376/ijms.2026.16.0007
Received: 27 Jan., 2026
Accepted: 06 Mar., 2026
Published: 19 Mar., 2026

Preferred citation for this article:
Wang H.M., 2026, Effects of different feeding regimes on growth performance of mud crab, International Journal of Marine Science, 16(2): 81-94 (doi: 10.5376/ijms.2026.16.0007)

Abstract Feeding management is one of the most important factors influencing the growth performance, feed utilization, and economic efficiency of mud crab (*Scylla* spp.) aquaculture. This paper reviews the effects of different feeding regimes on mud crab growth performance by examining feeding frequency, feeding time, feeding level, feed type, and feeding strategy. Mud crabs exhibit unique growth characteristics associated with molting, which require precise nutritional support and feeding management. Appropriate feeding frequencies and multiple daily feeding events can improve weight gain, specific growth rate, feed conversion efficiency, and survival rate by enhancing feed intake and reducing nutrient loss. Feeding time also affects feeding behavior, with nighttime feeding generally showing advantages due to the nocturnal feeding habits of mud crabs. In addition, suitable feeding levels promote optimal growth and economic returns, whereas overfeeding and underfeeding may negatively affect water quality, feed efficiency, and crab health. The interaction between feed types and feeding strategies further influences production outcomes, with integrated approaches combining formulated feeds and fresh feeds often providing superior results. Case studies demonstrate that scheduled feeding, high-frequency low-quantity feeding, and intelligent precision-feeding systems can significantly enhance culture performance. Future research should focus on precision feeding technologies, automated monitoring systems, and sustainable feeding strategies to improve productivity and environmental sustainability in mud crab aquaculture.

Keywords Mud crab; Feeding regime; Growth performance; Feed utilization; Precision aquaculture

1 Introduction

Mud crab aquaculture has become an economically important coastal activity, and research increasingly treats feeding management as a central determinant of production efficiency, survival, and sustainability. Scylla species are among the most valuable commercially farmed crabs, with strong live-market demand across the Indo-Pacific and expanding trade in Asia and elsewhere (Paran et al., 2022). At the same time, the industry remains heterogeneous and only partly industrialized, spanning hatchery- and wild-sourced seed, extensive to intensive systems, and culture environments ranging from mangrove areas and ponds to cages and recirculating systems. This flexibility has helped the sector expand substantially in response to market demand and improvements in hatchery and grow-out technologies, especially across Southeast Asia, while also supporting food security, rural income, and broader coastal development (Diamahesa and Rahmadani, 2024). However, mud crab farming still faces persistent constraints, including dependence on wild seed, habitat degradation, disease risk, high production costs, and uneven technological adoption, all of which limit stable long-term growth. In some production regions, aquaculture still contributes only a small share of market supply, as shown in Bangladesh where about 95% of exportable crab reportedly comes from natural sources, underscoring the need for stronger nursery, hatchery, and farm-level innovations. Similar development tensions appear in East Africa and Kenya, where rising export demand, declining wild crab size, and pressure on mangrove ecosystems have driven interest in small-scale culture and silvofisheries as alternatives to capture-based supply. Even where the industry is profitable and technically straightforward, sustainable growth depends on improving seed production, feeding practices, and production management rather than continued reliance on wild resources alone.

Within this broader development context, feeding management is one of the most decisive operational factors in mud crab culture because it directly shapes growth rate, molting success, survival, feed conversion, water quality, and production cost. A recent synthesis of mud crab farming studies concludes that feed type, rearing system, and

stocking density jointly determine productivity and economic performance, with natural trash fish at around 15% of body weight often producing strong growth and feed efficiency during fattening. Feed is also economically critical because it represents a major share of operating costs, especially when high-protein ingredients are required, and this burden tends to increase as culture systems become more intensive. Empirical studies confirm that feed type matters: in juvenile and grow-out phases, some natural feeds such as trash fish or African land snail have produced better weight gain, feed conversion, and profitability than several alternatives (Andal et al., 2025). Formulated feeds also show promise under nursery conditions. In purple mud crab instars, commercial formulated feed outperformed minced fish in survival, growth, and feed conversion, suggesting that nutritionally balanced artificial diets can support more efficient early-stage culture. Likewise, in megalopa-to-crablet nursing of *S. paramamosain*, feed choice altered growth performance even when survival remained high across treatments, with Lansy pellets and frozen Artemia supporting better daily weight gain than pureed shrimp meat or NRD pellets. Beyond feed type, dose and schedule also influence outcomes. Different raw-fish feeding doses significantly affected absolute weight gain and specific growth rate in fattening *S. serrata*, with the best performance reported at the highest dose tested, while fresh-feed trials in single-room systems found that chicken intestine produced the best combination of growth, molting, and feed conversion among the tested diets. By contrast, not every feeding adjustment yields a strong biological response: in a recirculating aquaculture system, changing trash-fish feeding frequency from once to three times daily did not significantly affect growth or survival, although once-daily feeding produced the best observed performance (Mayzuri et al., 2025). These results show that feeding management is not a single-variable issue, but a composite of feed source, nutritional composition, ration size, and feeding frequency that interacts with production stage and culture system.

Against this background, research on different feeding modes is significant because the mud crab industry still lacks universally reliable, cost-effective, and species- or stage-specific feeding strategies. Although live foods such as rotifers and Artemia remain standard in hatchery production, they are expensive, nutritionally inconsistent, and insufficient for fully reliable mass seed production, which has motivated efforts to develop microbound and other formulated larval diets. Experimental work indicates that mud crab larvae and megalopae can respond differently to feeding modes across developmental stages: co-feeding microbound diet with Artemia improved zoea III survival and development relative to total replacement, whereas megalopae were able to ingest and develop on formulated particles with moderate survival depending on ingredient composition. Other studies similarly show that artificial feed supplementation is not always advantageous at every stage; for example, enriched Artemia alone remained sufficient for some larval stages of *S. tranquebarica*, while additional fresh or artificial feeds were more relevant closer to crablet production. In grow-out and fattening systems, the evidence also remains mixed rather than definitive. Some studies identify clear advantages for specific natural feeds such as trash fish, African land snail, or chicken intestine; others report that changing carbohydrate-to-lipid ratios in isoprotein artificial diets does not significantly alter molting, growth, or feed efficiency, despite slight performance trends among treatments. This variation suggests that optimal feeding regimes likely depend on crab species, life stage, rearing environment, stocking conditions, and economic context rather than on a single universal feed formula. Therefore, the present study on the effects of different feeding regimes on mud crab growth performance is important for clarifying which feeding modes most effectively improve growth under culture conditions while maintaining practical relevance for farmers. Its objective is to compare alternative feeding regimes in terms of growth performance and, where applicable, associated production indicators such as survival and feed efficiency, so as to provide evidence that can support more efficient, economical, and sustainable mud crab farming.

2 Growth Characteristics and Nutritional Requirements of Mud Crab

2.1 Growth and molting characteristics of mud crab

Mud crab growth is discontinuous because size increase occurs mainly through molting rather than by steady external enlargement. In juvenile *Scylla serrata*, fresh weight rises abruptly at ecdysis because of rapid water uptake, then increases more moderately during postmolt shell mineralization and tissue deposition, before becoming relatively stable during intermolt (Nguyen et al., 2022). This means that apparent body growth reflects both true tissue accretion and temporary changes in body water, so the molting cycle must be considered when evaluating the effect of feeding regimes on growth performance.

Molting characteristics are shaped by both internal energy allocation and external culture conditions. Juvenile mud crabs consume feed most actively during the first two weeks after ecdysis, and about half of total feed intake during a molt cycle can occur in the first third of that cycle when tissue growth is highest. Environmental factors also modify molt dynamics: in *S. paramamosain*, higher water calcium concentrations shortened molt intervals, accelerated carapace hardening, and increased weight gain during molting, showing that growth responses to feeding depend partly on whether the culture environment supports successful shell formation (Zhang et al., 2024).

2.2 Major nutritional requirements of mud crab

Protein is the dominant dietary requirement for mud crab growth because it supports tissue synthesis, molt-related recovery, and overall biomass gain. A recent review across cultured crab species indicates that crabs generally require about 35%-50% dietary protein and 5%-10% lipid, together with adequate essential amino acids, cholesterol, phospholipids, and long-chain polyunsaturated fatty acids (Esmaeili et al., 2024). For juvenile *Scylla serrata*, graded feeding trials showed that the best growth performance and nutrient turnover occurred near 45% crude protein, with regression analysis estimating an optimum of about 46.9%-47.0% dietary protein for maximum growth and protein deposition.

Lipid quality is also critical because crustaceans depend on dietary sterols and essential fatty acids to support molting, development, and survival. Work on *S. serrata* larvae and megalopae emphasized that lipids provide energy as well as cholesterol, phospholipids, and fat-soluble vitamins, and suggested an optimum dietary cholesterol level of about 0.80% for megalopal development in semi-purified diets. Nutrient source additionally matters in practice: soy protein concentrate sustained good tissue growth and feed utilization in juvenile *S. serrata*, indicating that alternative protein ingredients can partially replace fishmeal when diets remain nutritionally balanced.

2.3 Evaluation indicators of growth performance

Growth performance in mud crab feeding studies is usually evaluated with a set of complementary biological and production indicators rather than with body weight alone. Common measures include absolute weight gain, specific growth rate, survival rate, molting percentage, feed conversion ratio, protein retention, and lipid retention, because these variables together reflect whether a diet improves both biomass production and feed-use efficiency. In nursery studies, daily weight gain and specific growth rate in weight are especially useful for distinguishing the effects of different feeds during early development from megalopa to crablet stages (Ly et al., 2024).

The choice of indicator is important because live weight can overestimate real growth during molt-related water uptake, whereas dry matter better reflects actual tissue deposition. Studies on juvenile *S. serrata* therefore recommend evaluating tissue growth on a dry-weight basis, since body water changes markedly across the molt cycle and can obscure nutritional effects on somatic growth. Feed-based indices are equally informative: in purple mud crab instars, commercial formulated feed produced higher survival, greater weight gain, higher specific growth rate, more frequent molting, and lower feed conversion ratio than minced fish, illustrating how multiple indicators together provide a clearer assessment of feeding regime performance (Thien et al., 2022). In summary, mud crab growth performance is best interpreted through the interaction of molting biology, nutrient requirements, and measurement method. For studies comparing feeding regimes, the most reliable evaluation framework combines growth, survival, molting, and feed-utilization indicators while recognizing that true growth is inseparable from the crab's molt cycle.

3 Main Feeding Modes Used in Mud Crab Aquaculture

3.1 Scheduled and quantitative feeding mode

Scheduled and quantitative feeding mode refers to the provision of feed at fixed times and in predetermined amounts relative to crab body weight. In mud crab fattening, this regime is widely used because it standardizes nutrient delivery and simplifies feed management across culture units. Several studies applied fixed feeding rates of 5%-7% body weight per day, usually divided into one or two meals, and reported acceptable growth, feed conversion, and survival under these controlled conditions (Gabito and Baltar, 2023). For example, feeding mud crabs twice daily at 7% body weight supported 100% survival and favorable growth responses when African land snail was used as

feed, indicating that quantitative scheduling can maintain stable production when ration size is matched to animal demand (Figure 1).

Evidence also shows that the optimal quantitative ration depends on production stage and culture system rather than increasing linearly with feed supply. In fattening with raw fish, increasing ration from 4% to 16% significantly improved absolute weight gain and specific growth rate, although survival and FCR did not differ significantly among treatments, suggesting that growth is more sensitive than efficiency to ration adjustment. By contrast, in a recirculating aquaculture system, changing feeding frequency from once to three times daily did not significantly affect growth or survival, although feeding once daily at night produced the best mean growth values, implying that timing can be optimized without necessarily increasing meal frequency (Mayzuri et al., 2025).

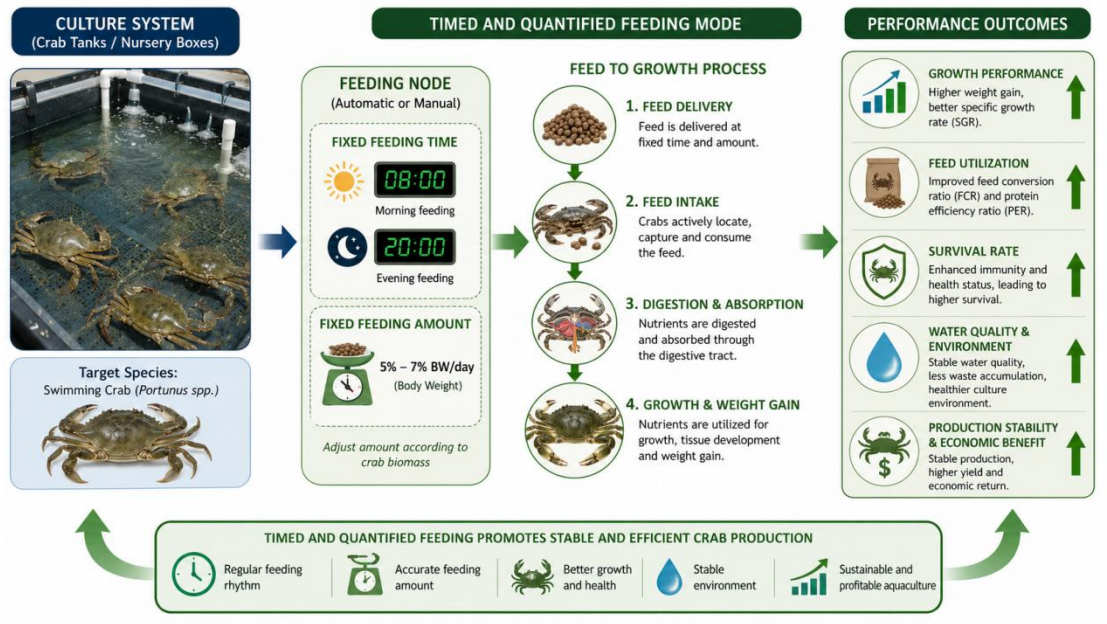

Figure 1 Conceptual framework of scheduled and quantitative feeding management in mud crab aquaculture

3.2 Satiation feeding and restricted feeding modes

Satiation feeding aims to supply feed until intake demand is met, whereas restricted feeding intentionally provides less than that level to improve feed use efficiency or reduce waste. In juvenile *Scylla paramamosain*, reducing ration from optimal to suboptimal and low levels prolonged intermolt duration, increased molting desynchrony, and decreased carapace size and body weight, showing that restriction can directly suppress growth-related processes even when animals still molt successfully (Gong et al., 2022). Starvation was clearly detrimental, because unfed juveniles died without molting, while even low-ration crabs maintained molting success above 95%, indicating that mud crabs tolerate moderate feed limitation better than complete deprivation.

A broader crustacean literature suggests a trade-off between growth maximization under higher feeding allowance and better feed efficiency under restricted rations. In *Penaeus vannamei*, feeding at 80% of apparent satiation improved FCR relative to 100% satiation, but this occurred alongside lower weight gain, demonstrating that restriction can enhance efficiency at the expense of biomass accumulation (Espinoza-Ortega et al., 2026). Similarly, juvenile *Penaeus monodon* showed feed-efficiency benefits under restricted ration and growth benefits from higher feeding frequency, with a significant interaction between frequency and ration size. For mud crab production, these findings support using moderate restriction only when feed cost or water quality control is prioritized over maximum growth.

3.3 Automated and intelligent feeding modes

Automated and intelligent feeding modes extend beyond fixed timers by using behavioral or environmental feedback to decide when to continue, slow, or stop feeding. Conventional automatic feeders generally deliver feed

at preset times and quantities, but such fixed programs can still cause underfeeding or overfeeding because they do not respond to real-time appetite changes (Zhang et al., 2023). This limitation is important for mud crab aquaculture, where feeding demand varies with molt stage, as postmolt juveniles show much higher growth rate and feed conversion efficiency than intermolt individuals.

Recent intelligent aquaculture systems attempt to solve this limitation by combining sensors with machine vision or deep learning. A computer-vision-based feeding system detected wave patterns generated by feeding activity and integrated water-quality sensing, reaching 93.2% accuracy in feeding decisions under aquaculture conditions. Likewise, a dynamic feeding method based on a multi-task neural network achieved 95.44% accuracy in classifying feeding activity while also estimating uneaten pellets, allowing real-time adjustment of feeding intervals and feeding endpoint (Wang et al., 2022). Although these systems were developed mainly for fish rather than mud crabs, they provide a strong technical model for future crab farming because they address the central weakness of fixed quantitative feeding: poor responsiveness to actual feeding demand. Scheduled and quantitative feeding currently has the strongest direct evidence base in mud crab culture, restricted feeding appears to improve efficiency but usually reduces growth, and automated intelligent feeding remains promising but still largely extrapolated from broader aquaculture systems.

4 Effects of Different Feeding Frequencies on Mud Crab Growth Performance

4.1 Weight gain and specific growth rate

Feeding frequency influences weight gain and specific growth rate, but the effect is not uniform across life stage and production system. In grow-out or fattening conditions, several studies found that changing frequency from once to multiple meals per day did not significantly change growth, even when one schedule still produced numerically better results. In a 60-day RAS trial with *Scylla serrata*, feeding frequency did not significantly affect growth or survival, although feeding once daily at 10 pm produced the highest mean weight gain and SGR, reaching 52.00 ± 21.17 g and 5.04 ± 0.14, respectively (Mayzuri et al., 2025). A second RAS apartment-system study likewise reported no significant effect of feeding once, twice, or three times daily on growth parameters, suggesting that within controlled fattening systems, crabs can maintain similar growth across moderate feeding schedules (Diatin et al., 2026).

Other evidence indicates that more frequent feeding can improve growth when animals are at earlier or physiologically more sensitive stages. In *Scylla olivacea* larvae, feeding rotifers three times daily produced greater absolute growth by day 6 than one or two daily feedings, showing that high-frequency feeding better supports early larval growth. A separate study on mud crabs maintained under different feeding frequencies reported weight growth of 108 g and a daily growth rate of 1.55% with trash fish, indicating that frequency treatment can coincide with measurable growth differences under basket-based maintenance conditions. More broadly, inadequate feed availability suppresses SGR because growth depends on retained energy exceeding maintenance costs, a pattern also observed in juvenile crablets under lower prey availability (Sulaeman et al., 2024).

4.2 Feed utilization efficiency

The effect of feeding frequency on feed utilization efficiency appears weaker and less consistent than its effect on growth. In the RAS apartment-system study, feeding once, twice, or three times daily had no significant effect on feed utilization efficiency or FCR, indicating that increasing meal frequency alone does not guarantee better conversion of feed into biomass (Diatin et al., 2026). This interpretation is consistent with broader nutrition trials showing that mud crab feed efficiency often responds more strongly to diet composition than to feeding schedule. For example, changing carbohydrate and lipid ratios in 35% isoprotein diets did not significantly alter FCR or other feed-efficiency indicators over 60 days (Al., 2024).

At the same time, the wider mud crab literature suggests that efficient feed use depends on matching feeding regime to dietary quality and physiological demand. Juvenile *S. serrata* achieved their best growth and feed efficiency at about 40% crude protein, with improvements in FCR, protein efficiency, and nutrient retention over higher- or lower-protein diets. Feed utilization also shifts strongly across the molt cycle: feed conversion, protein retention,

and energy retention are four to five times higher during postmolt than intermolt stages, showing that the biological timing of intake may be as important as feeding frequency itself (Nguyen et al., 2022). Practical feeding management should therefore consider not only how often crabs are fed, but also whether feed quality and feeding time align with the periods of highest assimilation efficiency.

4.3 Survival rate and molting rate

Survival rate is generally less sensitive to feeding frequency than molting or short-term growth. In the 2025 RAS study, feeding frequency had no significant effect on survival, and the once-daily treatment still achieved 100% survival with a molting rate of 0.67 ± 0.58. Similarly, the 2026 RAS apartment-system trial found no significant differences in survival rate or molting performance among crabs fed one, two, or three times per day (Diatin et al., 2026). These findings suggest that under controlled fattening conditions with acceptable water quality, moderate changes in frequency alone are unlikely to alter survival substantially.

Molting responses appear more context dependent and can improve with higher feeding frequency when crabs are younger or when nutritional stimulation is stronger. In mud crab larvae, feeding rotifers three times daily increased survival above one- and two-time feeding schedules by day 3 and day 4, indicating that frequent food supply is especially important during early developmental stages. In crablets and instars, better feeding conditions are also linked to higher cumulative molting and improved survival, as shown when higher prey density increased cumulative molting and when a more efficiently utilized formulated diet produced both higher survival and higher moulting frequency than minced fish (Thien et al., 2022). Overall, feeding frequency alone does not consistently drive survival and molting in grow-out mud crabs, but it becomes more influential when combined with vulnerable life stages, limited feed access, or nutritionally superior diets. Across these three outcomes, feeding frequency in mud crab culture appears to have stage-dependent effects: it is often neutral in grow-out RAS systems, but more important for larvae, crablets, and periods of high postmolt nutrient demand.

5 Effects of Different Feeding Times on Mud Crab Growth Performance

5.1 Comparison between daytime and nighttime feeding

The evidence on mud crab feeding regimes centers on day-night timing, feeding frequency, and the link between feeding behavior and culture performance. Across the available studies, outcomes differ by life stage and culture system, so the strongest conclusion is not a single universal schedule but a stage-specific feeding strategy. Mud crabs generally show stronger feeding activity under darkness or during the night at juvenile and grow-out stages, which helps explain why many culture protocols include evening meals. Field observations likewise indicate that *Scylla serrata* remains in its burrow until sunset and then spends the night actively feeding, supporting the view that nocturnal behavior is a core ecological trait in older crabs.

This behavioral pattern can translate into culture performance, although the effect depends on lighting regime and developmental stage. In a recirculating system, once-daily feeding at 10 p.m. produced the best numerical growth, molting, and survival values even though feeding frequency overall was not statistically significant (Mayzuri et al., 2025). However, constant darkness is not uniformly beneficial, because juvenile *S. paramamosain* achieved lower final weight and specific growth rate under 0L:24D than under 12L:12D or 18L:6D, indicating that complete darkness can impair grow-out despite the species' nocturnal tendencies.

5.2 Effects of single feeding versus multiple feeding events

The effect of single versus multiple feeding events is mixed, with larval studies tending to favor more frequent feeding, while juvenile and fattening studies often find little difference in growth across schedules. In S. olivacea larvae, feeding rotifers three times daily improved survival on days 3 and 4 and produced greater absolute growth by day 6 than one or two feedings per day (Pattirane et al., 2022). This pattern is biologically plausible because larval feeding strategy is constrained by short gut evacuation and digestion times, making repeated feed delivery more compatible with continuous energy demand during early development.

By contrast, for larger crabs the benefits of more frequent feeding are less consistent. In *S. serrata* reared in RAS, feeding once, twice, or three times daily did not significantly affect growth or survival, and the best numerical performance occurred in the once-daily 10 p.m. treatment (Mayzuri et al., 2025). A separate RAS apartment study also found no significant biological advantage of increasing frequency, although feeding twice daily gave the highest profit and labor efficiency, suggesting that operational optimization may favor moderate frequency even when growth responses are similar (Diatin et al., 2026).

5.3 Relationship between feeding time and feeding behavior

Feeding time is closely tied to mud crab behavior because activity rhythm, prey detection, and digestive physiology shape when feed is most effectively consumed. Juvenile S. olivacea respond rapidly to attractive diets, and pellet or natural feed choice appears to be mediated partly by chemosensory cues released into the water, which trigger approach and feeding behavior. Broader evidence also shows that feeding rhythm is related to circadian organization and digestive enzyme activity, so synchronizing feed delivery with active periods can improve feed utilization and reduce waste (Wang et al., 2024).

Importantly, this relationship changes with ontogeny. Zoea of *S. paramamosain* showed a strong diurnal feeding rhythm, with significantly higher feeding rates at 10:00-14:00 from ZI to ZIV, and newly hatched larvae required immediate feeding because they do not retain yolk reserves. In contrast, adult and juvenile field studies show continuous night feeding and only limited daytime feeding, often associated with high tide, indicating a shift from larval daytime peaks to predominantly nocturnal feeding later in life. Overall, the literature indicates that mud crab growth performance is influenced less by a single fixed schedule than by matching feeding time and frequency to developmental stage, behavior, and production system. Night-oriented schedules appear more suitable for juveniles and adults, whereas larvae often benefit from more frequent and partly daytime feeding windows.

6 Effects of Different Feeding Levels on Mud Crab Growth Performance

6.1 Growth rate

Feeding level strongly affects mud crab growth because ration size determines whether enough nutrients remain after maintenance needs are met for tissue accretion and molting (Mayzuri et al., 2025). In a dose-response fattening trial with raw fish, different feeding levels significantly changed absolute weight gain and specific growth rate, showing that ration is not a neutral management variable in *Scylla serrata* culture (Annisa et al., 2024). Evidence from a broader review likewise indicates that trash fish offered at 15% of body weight yields optimal growth and feed efficiency under fattening conditions. At the same time, growth response is not determined by quantity alone, because some studies found that feed formulation differences produced little improvement when protein levels were modest or water conditions fluctuated strongly.

The growth advantage of appropriate feeding also reflects stage-specific metabolic demand. Juvenile *S. serrata* in postmolt stages showed average growth rates of 2.064% initial body weight per day, far above intermolt crabs at 0.492%, while feed intake and nutrient demand for growth were also higher in postmolt animals. This helps explain why stable and appropriately timed feeding tends to improve specific growth rate by maintaining nutrient availability for metabolism and reducing energy loss to stress. Experimental work further shows that once a biologically adequate intake is reached, increasing feeding frequency alone does not necessarily improve growth, since feeding one, two, or three times daily in RAS produced no significant difference in growth parameters, even though one daily feeding gave the best numerical result in that trial (Figure 2) (Diatin et al., 2026).

6.2 Feed conversion efficiency and economic benefits

Feeding level influences production economics primarily through feed conversion ratio (FCR), because lower FCR means less feed is required to produce each unit of crab biomass (Andal et al., 2025). In mud crab polyculture, the treatment with the lower FCR also produced higher absolute growth, reinforcing the general pattern that efficient feed use translates directly into better production output. Evidence from feeding-dose trials is more nuanced, however: one 45-day fattening study found that different ration levels significantly altered growth but did not significantly affect FCR, even though observed FCR values remained relatively high at 1.7-3.8 (Annisa et al., 2024).

This suggests that raising feed input can stimulate growth without always improving conversion efficiency proportionally.

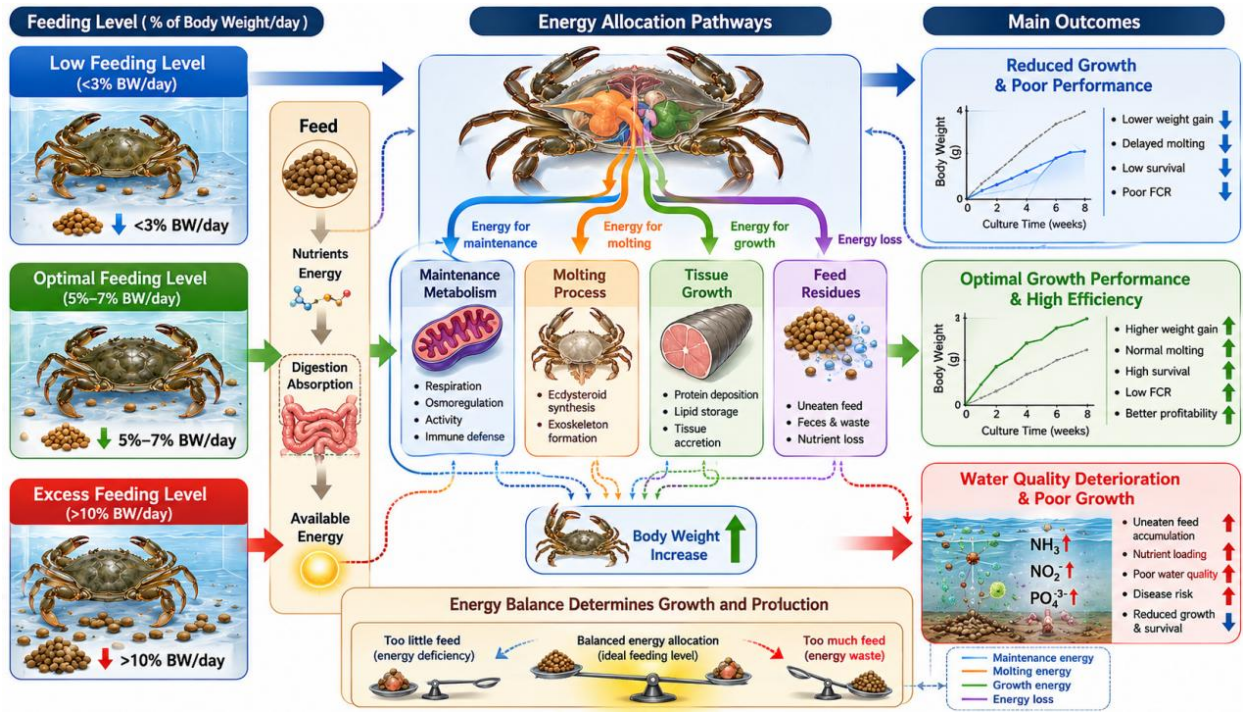

Figure 2 Conceptual model illustrating the effects of feeding level on nutrient allocation, molting activity, and growth performance in mud crab culture

Economic return therefore depends on matching feeding level with feed type and management system rather than simply maximizing ration. In a natural-feed comparison, African land snail produced the best FCR and the highest return on investment, reaching 96.8%, which indicates that biologically efficient feeding can also be financially superior. Another fattening study reported that trash fish achieved the lowest FCR among tested natural feeds and generated a positive ROI of 33.26%, supporting its continued use where supply is reliable (Andal et al., 2025). Operational studies in RAS add that feeding frequency affects labor economics even when biological performance is similar, since feeding twice daily produced the highest profit in one business analysis (Diatin et al., 2026). Feed cost remains the dominant expense in mud crab farming, so inefficient feeding regimes quickly erode margins even when survival is acceptable.

6.3 Risks associated with overfeeding and underfeeding

Both overfeeding and underfeeding impose clear risks on mud crab culture. Underfeeding suppresses growth and molting, while overfeeding promotes feed residue accumulation that can pollute the culture water. The same concern appears in RAS-based work, where inappropriate feeding is linked to slow growth, higher mortality, and declining water quality (Mayzuri et al., 2025). These outcomes are biologically plausible because mud crabs require sufficient digestible energy not only for maintenance but also for molting and tissue recovery; when intake is inadequate, available energy is diverted away from growth.

The practical consequences extend beyond growth depression to broader production instability. Excess residual feed can degrade the rearing environment, and the sustainability literature identifies water-quality deterioration as a recurring constraint that interacts with disease risk and survival across mud crab production systems. By contrast, several feeding studies reported acceptable survival when feeding was paired with water conditions kept within suitable ranges, indicating that feeding risk is partly mediated through environmental management rather than ration alone. Overall, the literature supports a moderate-feeding strategy: enough feed to sustain molting and growth, but not so much that unused feed accumulates, wastes money, and destabilizes culture conditions.

7 Synergistic Effects of Feed Types and Feeding Strategies

7.1 Fresh versus formulated feed

Fresh trash fish remains the dominant feed in mud crab fattening because it is familiar to farmers, protein-rich, and often profitable under short production cycles. Several studies nevertheless identify clear operational weaknesses of this strategy, including unstable supply, seasonality, short shelf life, disease-transfer concerns, and deterioration of water quality when wet feeds are poorly handled (Hadi et al., 2024). In direct fattening comparisons, trash fish also does not consistently produce the best biological response, since alternative fresh feeds such as chicken intestine or African land snail sometimes generated better growth or feed conversion than low-value fish controls.

Formulated feeds, by contrast, are being developed to improve storage stability, handling convenience, and nutritional control, even though their growth advantage over trash fish is still inconsistent. A 30-day fattening trial using dry pellets made from fishery and seafood by-products found that one formulation improved growth response and meat protein content, whereas the trash fish control still achieved better feed and protein efficiency and remained more profitable overall (Senarathna et al., 2021). Other formulation studies similarly reported that artificial diets did not significantly improve growth, molting, or feed efficiency when dietary protein was moderate or when water quality fluctuated strongly, indicating that formulation quality and culture conditions jointly determine whether pellets can replace fresh feeds effectively.

7.2 Mixed feeding and health outcomes

Mixed feeding modes appear promising because they can compensate for the nutritional limits of any single feed source while reducing dependence on trash fish alone. In silvofishery culture of *Scylla olivacea*, combining tilapia with blood clams produced much higher absolute growth and better production than single tilapia feeding, although survival remained similarly high across treatments at 93.33%-96.67% (Wahida et al., 2022). Broodstock evidence points in the same direction: mixed diets combining natural and artificial feeds generally improved spawning output, hatching success, survival, and final body weight relative to either diet alone.

The health value of mixed or diversified feeding lies not only in growth promotion but also in its effects on molting, tissue quality, and system stability. Feed diversification can lower nutritional gaps and reduce overreliance on a single raw material, which is important because mud crab performance depends on feed, rearing system, and environmental management as an integrated package (Diamahesa and Rahmadani, 2024). Related feeding trials also show that improved diet design can raise meat quality or functional performance even when gross growth differences are small, as seen in iso-protein diets where growth was unchanged but meat quality tended to improve in one carbohydrate-lipid ratio, and in formulated feeds supplemented with herbal extracts that increased feed utilization, growth, and molting response (Figure 3).

7.3 Feed quality and strategy matching

Optimizing feeding regimes therefore requires matching feed quality to biological stage, farming objective, and delivery method rather than searching for one universally superior diet. Evidence from formulated-feed studies suggests that mud crabs respond to relatively narrow nutritional windows: feeds around 32%-40% protein and roughly 6%-12% lipid have been associated with favorable growth, while a semi-moist broodstock diet containing 42% protein and 12% lipid produced the strongest somatic and reproductive gains in female mud crabs. At the same time, ingredient quality and physical form matter, because mangrove clam showed strong nutritional suitability as a basal ingredient and high-lipid semi-moist feeds were readily accepted with positive weight gain across treatments (Aaqillah-Amr et al., 2022).

Feeding strategy must also fit ration size, frequency, and pellet stability to the rearing environment. Review evidence indicates that trash fish at about 15% of body weight often gives strong growth and feed efficiency, whereas a raw-fish dosing trial found significant effects of ration level on absolute weight gain and specific growth rate (Annisa et al., 2024). However, feeding frequency in RAS did not significantly alter growth or survival in two recent studies, even though once-daily feeding maximized biological performance in one case and twice-daily feeding gave the best economic return in another, showing that strategy optimization should balance growth, labor, water quality, and

cost rather than weight gain alone (Mayzuri et al., 2025). Across these studies, fresh trash fish remains effective but operationally limited, mixed feeding often improves overall performance, and the best regime is the one that aligns nutrient profile, feed form, ration, and culture system with the specific production goal.

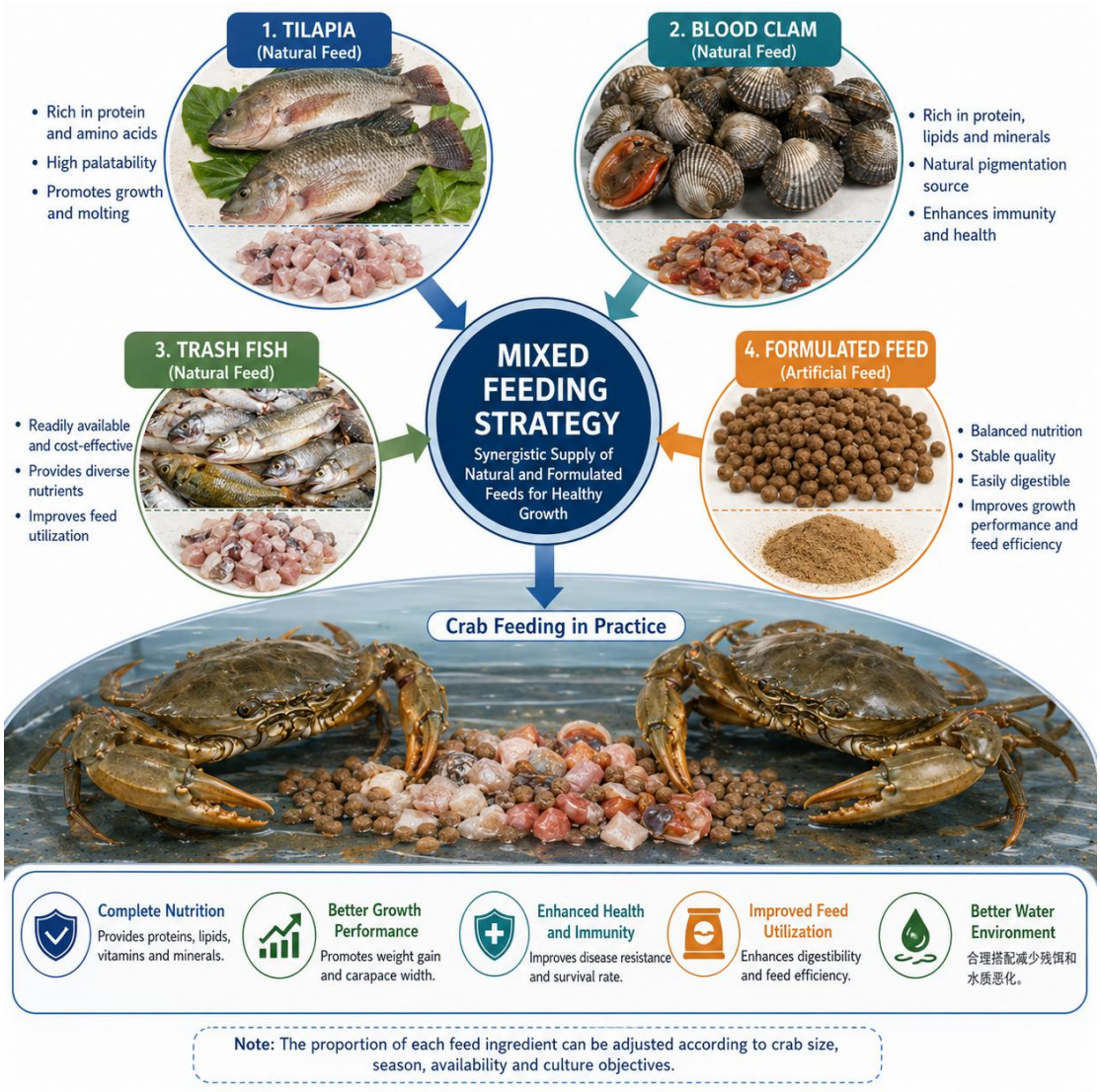

Figure 3 Major feed sources used in mixed feeding strategies for mud crab aquaculture

8 Case Study: Application Effects of Different Feeding Modes in Mud Crab Culture

8.1 Scheduled and quantitative feeding

Scheduled and quantitative feeding in mud crab culture is designed to match ration size and feeding time with the animal's metabolic demand while limiting waste. In fattening systems, this approach often uses fixed percentages of body weight and set feeding times rather than continuously increasing meal frequency. Recent RAS work on *Scylla serrata* found that changing feeding frequency from once to three times daily did not significantly alter survival, growth, molting, or feed utilization, indicating that a stable schedule can maintain performance without requiring more frequent manual feeding (Diatin et al., 2026). Similarly, another RAS experiment reported no significant growth or survival advantage from increasing feeding frequency, and the once-daily treatment still produced 100% survival with 52.00 ± 21.17 g weight gain and 5.04 ± 0.14% day^{-1} specific growth rate.

The quantitative component appears especially important when feed allowance, rather than feeding frequency alone, is manipulated. In a crab-box fattening study using raw fish, different feed doses significantly affected absolute weight gain and specific growth rate, while survival and FCR remained statistically similar among treatments,

showing that underfeeding constrains growth more clearly than modest changes in schedule (Annisa et al., 2024). Comparable practical regimes have been used in grow-out studies where mud crabs were fed fixed daily proportions such as 5% or 7% of body weight once or twice daily, and growth outcomes then depended strongly on feed type and efficiency, including FCR values of 1.38 for African snail and 6.90 for trash fish in separate trials.

8.2 High-frequency, small-amount feeding

High-frequency, small-amount feeding is based on the idea that dividing the same daily ration into more meals can improve nutrient capture, reduce competition, and better fit gut evacuation dynamics. This mechanism is particularly plausible in crustaceans because feeding pattern is linked to digestive turnover, and in mud crab larvae, rotifer delivery three times per day improved both survival and growth relative to one or two feedings per day (Pattirane et al., 2022). In *Scylla olivacea* zoeae, the three-times-daily treatment raised survival by 58% on day 3 and by 22% on day 4 over lower-frequency treatments, while also producing higher absolute larval growth by day 6.

Evidence from juvenile and grow-out crustaceans suggests that the benefit of frequent small meals depends on life stage and feeding context. In juvenile *Litopenaeus vannamei*, increasing feeding frequency from three to six and twelve times per day improved final weight, yield, feed conversion, and digestive enzyme activity when the total daily ration was controlled, supporting the physiological rationale for meal splitting (Xu et al., 2020). A factorial study in *Penaeus monodon* likewise showed clear growth benefits of feeding six rather than two times daily, especially when ration size was restricted, suggesting that higher meal frequency can partly compensate for lower per-meal delivery. However, mud crab grow-out results are less uniform than larval data, since RAS fattening studies in *S. serrata* found little or no significant advantage of moving from one or two meals to three meals per day under otherwise stable conditions (Mayzuri et al., 2025).

8.3 Intelligent precision feeding

Intelligent precision feeding extends scheduled feeding by using automation, behavioral feedback, or environmental data to adjust ration and timing in real time. In aquaculture more broadly, intelligent feeding control systems combine models, acoustic tools, or computer vision to determine feeding demand automatically, although current systems still require better accuracy for routine farm deployment. A more integrated precision-feeding framework has also been demonstrated through multi-factor control, where predicted feed requirement is corrected using dissolved oxygen and feeding-activity signals, allowing dynamic adjustment of feed amount instead of relying only on fixed farmer experience (Liu et al., 2023).

Direct mud crab studies on intelligent precision feeding remain limited, but adjacent evidence suggests strong practical relevance for future crab farming. Automatic feeders can improve sustainability by reducing feed waste and enabling feeding schedules to respond to real-time water quality, which is important because overfeeding elevates cost and deteriorates culture conditions (Thornburg, 2025). In intensive shrimp systems, automatic feeding at 6-8 times per day improved body weight, specific growth rate, feed conversion ratio, and profitability relative to manual feeding, indicating that precision delivery can convert the concept of “small, frequent meals” into an operationally feasible strategy. For mud crab, the most defensible conclusion is that intelligent precision feeding is a promising next step, but its value still needs direct validation in species-specific trials that link sensors and automated ration control to molting, survival, and growth performance.

9 Conclusions and Future Perspectives

Different feeding modes affect mud crab growth mainly through feed type, nutrient balance, feeding frequency, and their interaction with culture conditions. Across fattening studies, several natural and wet feeds outperformed conventional low-value fish, but the best option was not identical across experiments because species, size class, culture system, and environmental stability differed. Trash fish performed strongly in some systems and was associated with high growth, efficient feed use, and favorable economic return in fattening. In another trial, trash fish produced the highest weight increment and protein content, with an FCR of 6.90 and positive return on investment. However, African land snail gave the best weight gain, condition factor, feed efficiency, and ROI in a separate grow-out study. Processed chicken intestine also produced better growth and economic performance than

low-value fish, shrimp head waste, and oyster meat in cage fattening, and it gave the best weight gain and molting response among fresh feeds in a single-room system. Formulated diets show promise, but current evidence indicates that formulation quality matters more than formulation alone. Some artificial diet studies found no significant differences in growth, molting, or feed efficiency across tested formulations, suggesting that diets with inadequate protein levels or unstable water conditions can mask treatment effects. Similarly, varying carbohydrate-to-lipid ratios within a 35% isoprotein diet did not significantly affect growth or feed efficiency, although the 31% carbohydrate and 10% lipid treatment showed a favorable trend. More targeted nutrient manipulation appears more effective when aligned with crab physiology: a diet containing 20% starch improved growth and nutrient utilization in juvenile *Scylla paramamosain*, while krill oil supported higher weight gain, specific growth rate, and feed efficiency than linseed oil, with performance similar to fish oil. Feeding frequency appears less influential than feed quality under stable conditions, because RAS culture showed no significant growth differences among once-, twice-, and thrice-daily feeding, although once-daily feeding produced the best overall values. At early life stages, feed choice remains critical, with Lansy pellet feed and frozen Artemia producing better growth than pureed shrimp meat and NRD pellets from megalopa to crablet-1.

Precision feeding technologies for mud crab aquaculture are developing toward automated, sensor-linked, and data-driven control of feed delivery. The underlying rationale is strong because feed is a major production cost, and manual feeding often causes waste, labor inefficiency, and inconsistent feeding intensity across ponds. Broader aquaculture research defines precision nutrition as matching dietary composition and feeding strategy to the animal's requirements while minimizing waste. This framework extends beyond simple ration control by integrating genetic background, metabolism, environmental conditions, and production goals. In practical terms, mud crab farming is moving from labor-dependent feeding toward automated and computer-assisted systems, a transition already recognized across aquaculture sectors but still uneven in developing regions. Recent engineering studies show how this transition may occur in crab farming. An IoT-based indoor mud crab system combined automatic feeding with continuous monitoring of pH, salinity, temperature, and water level, and it reported improved growth, reduced mortality, and lower labor demand. Machine-vision monitoring platforms now allow real-time detection of crabs and bait on feeding platforms, with bait detection rates above 90%, offering a basis for adaptive ration adjustment. At the pond scale, RTK-GPS-guided bait casting systems have been designed to achieve variable and spatially uniform feed distribution, with positioning accuracy below 30 cm and continuous feeding speeds up to 240 m^2 per minute. More advanced feeding boats now incorporate multi-voyage path planning to improve complete bait coverage while reducing repeated paths, turning frequency, and energy consumption. Together, these technologies indicate that precision mud crab feeding will likely combine automated delivery, environmental sensing, machine vision, and algorithmic navigation rather than relying on fixed schedules alone.

Future research should focus on stage-specific feeding strategies, nutritionally optimized formulated diets, and stronger integration between feed management and rearing environment. Current evidence shows that mud crabs do not respond uniformly across life stages or systems. Juvenile and nursery stages appear especially sensitive to feed suitability, salinity, and rearing conditions, with Artemia, Lansy pellets, and favorable salinity ranges improving growth or shortening the molting cycle in early-stage *Scylla paramamosain*. By contrast, several grow-out and fattening studies found limited differences among feed treatments when water quality fluctuated or when diets were broadly adequate, indicating that environmental control is often necessary to reveal true nutritional effects. This means future experiments should use better-controlled systems, longer feeding periods, and standardized performance metrics so that dietary effects can be separated from salinity and water-quality noise. Industrial prospects are strongest for feeding systems that reduce dependence on seasonal trash fish while improving feed conversion, labor efficiency, and production consistency. Reviews of mud crab culture already emphasize that sustainable expansion depends on combining suitable feed, rearing system, stocking density, and environmental management rather than optimizing feed in isolation. At the industry level, aquaculture nutrition research points toward more precise requirement estimates, wider ingredient diversification, and greater use of sustainable protein and lipid sources. That direction is directly relevant to mud crab farming, where trash fish remains common but is constrained by seasonality, storage limits, variable quality, and sustainability concerns. Novel ingredient

combinations and processing methods in crab aquaculture more broadly also suggest that performance and product quality can improve together when diets are designed around both biology and sustainability. Overall, the most promising commercial pathway is an integrated model in which balanced formulated feeds, precision delivery systems, and real-time environmental monitoring are deployed together to improve mud crab growth performance reliably and at scale.

Acknowledgments

I extend my sincere gratitude to the anonymous reviewers for their valuable and insightful comments, which have greatly strengthened this paper.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Aaqillah-Amr M.A., Hidir A., David M., Ahmad-Ideris A.R., Muhammad-Zulhilmi R., Julius Y.F.S., Noordiyana M.N., Abualreesh M.H., Peng T.H., Ma H., and Ikhwanuddin M., 2022, Development of semi-moist formulated feed for female orange mud crabs, *Scylla olivacea* (Herbst, 1796) broodstocks with graded lipid levels, Animal Feed Science and Technology, 290: 115365.
https://doi.org/10.1016/j.anifeedsci.2022.115365

Andal K.A.D., Loreno B.C., Flavier R.L.R., Castillo E.A., and Alano J.C.M., 2025, Effects of various natural feeds on growth performance and protein content of mud crabs (*Scylla serrata*), Agricultural Development, 10(4): 49-56.
https://doi.org/10.55220/25766740.v10i4.383

Annisa K.N., Marzuki M., and Cokrowati N., 2024, Impact of different small fish feeds on the growth and survival of mangrove crabs (*Scylla serrata*), Asian Journal of Fisheries and Aquatic Research, 26(10): 122-133.
https://doi.org/10.9734/ajfar/2024/v26i10825

Diamahesa W.A., and Rahmadani T.B.C., 2024, Natural feed administration during fattening stage for the growth of mud crabs (*Scylla* sp.) under different rearing systems, Journal of Fish Health, 4(4): 215-223.
https://doi.org/10.29303/jfh.v4i4.5930

Diatin I., Sianturi M.O., Effendi I., and Astari B., 2026, Operational efficiency of feeding in mud crab fattening culture *Scylla serrata* in recirculating aquaculture system (RAS) apartment system, BIO Web of Conferences, 221: 01004.
https://doi.org/10.1051/bioconf/202622101004

Gabito P.P., and Baltar C., 2023, Evaluating different diets on the growth performance of mud crab (*Scylla serrata*), Can Tho University Journal of Science, 15(1): 58-63.
https://doi.org/10.22144/ctu.jen.2023.007

Gong J., Huang C., Yu K., Li S., Zeng C., and Ye H., 2022, The effects of feeding ration and cheliped autotomy on the growth and expression of ecdysteroid receptor in early juvenile mud crabs, *Scylla paramamosain*, Aquaculture Reports, 25: 101206.
https://doi.org/10.1016/j.aqrep.2022.101206

Hadi A.N., Wisnu R., Chilmamawati D., Yuniarti T., Windarto S., and Herawati V.E., 2024, The effect of different fresh feeds on the growth and molting period of mud crab (*Scylla serrata*) cultivated in a single room system, International Journal of Fisheries and Aquatic Studies, 12(4): 161-166.
https://doi.org/10.22271/fish.2024.v12.i4b.2959

Liu X., Du K., Zhang C., Luo Y., Sha Z., and Wang C., 2023, Precision feeding system for largemouth bass (*Micropterus salmoides*) based on multi-factor comprehensive control, Biosystems Engineering, 227: 195-216.
https://doi.org/10.1016/j.biosystemseng.2023.02.005

Ly T.H., Vu L.H., and Diep D.X., 2024, Effects of different feeds and stocking densities on growth and survival rates of mud crab (*Scylla paramamosain*) at the stage from megalopa to crablet-1, Israeli Journal of Aquaculture - Bamidgeh, 76(1): 10-21.
https://doi.org/10.46989/001c.91128

Mayzuri Z., Lubis A.S., and Kamal E., 2025, Effect of feeding frequency on the growth of mud crabs (*Scylla serrata*) in the recirculating aquaculture system, Jurnal Perikanan Unram, 15(3): 471-482.
https://doi.org/10.29303/jp.v15i3.1474

Nguyen N.T.B., Wantiez L., Lemaire P., and Chim L., 2022, Feed efficiency, tissue growth and energy budget changes during the molting cycle of juvenile mud crab, *Scylla serrata*: effects of dietary proteins, fishmeal versus soy protein concentrate, Fishes, 7(6): 334.
https://doi.org/10.3390/fishes7060334

Paran B.C., Jeyagobi B., Kizhakedath V.K., Antony J., Francis B., Anand P.S.S., Radhakrishnapillai A., Lalramchhani C., Kannappan S., Marimuthu R.D., and Paulpandi S., 2022, Production of juvenile mud crabs, *Scylla serrata*: Captive breeding, larviculture and nursery production, Aquaculture Reports, 22: 101003.
https://doi.org/10.1016/j.aqrep.2021.101003

Pattirane C.P., Pattiasina B.J., and Sangkia F.D., 2022, Effects of rotifer feeding frequency on growth and survival rate of early larval stages of mud crab, *Scylla olivacea*, Omni-Akuatika, 17(2): 127-134.
https://doi.org/10.20884/1.oa.2021.17.2.915

Senarathna D.D.T.T.D., Thangarajah V., Kumari A.H.M.L.N., and Abeysooriya K.H.D.N., 2021, Effect of dietary protein level of feed formulated using fishery and seafood processing by-products on mud crab (*Scylla serrata*) fattening, Journal of Agriculture and Environmental Sciences, 10(2): 16-28.
https://doi.org/10.15640/jaes.v10n2a3

Sulaeman S., Herlinah H., Gunarto G., Nurfadila N., and Rosmiati R., 2024, The preying capacity of mud crab (*Scylla tranquebarica* Fabricius, 1798) on live amphipods (*Grandidierella megnae* Giles, 1888), Fisheries and Aquatic Sciences, 27(3): 195-205.
https://doi.org/10.47853/fas.2024.e19

Thien F.Y., Sanudin N., and Yong A.S.K., 2022, Survival and growth performance of the purple mud crab (*Scylla tranquebarica*) instar fed with commercial formulated feed and minced fish diets, Borneo Journal of Marine Science and Aquaculture, 15(3): 1499-1506.

Thornburg J., 2025, Feed the fish: A review of aquaculture feeders and their strategic implementation, Journal of the World Aquaculture Society, 56(2): e70016.
https://doi.org/10.1111/jwas.70016

Wahida N., Karim M.Y., Zainuddin, Amri K., Nurfadilah, and Alimuddin, 2022, The effect of fresh feed combinations on survival rate, growth, and production of mud crab (*Scylla olivacea*) cultured by silvofishery model, International Journal of Scientific and Research Publications, 12(6): 311-318.
https://doi.org/10.29322/IJSRP.12.06.2022.p12639

Wang W., Liu Z.Q., Wang X.Y., Zhang F.Y., Ma C.Y., Zhao M., Ma K.Y., and Ma L.B., 2024, Feeding rhythm of the zoea larvae of *Scylla paramamosain*: The dynamic feeding rhythm is not completely synchronized with photoperiod, Heliyon, 10(8): e29826.
https://doi.org/10.1016/j.heliyon.2024.e29826

Wang Y.Q., Yu X.N., Liu J.C., An D., and Wei Y., 2022, Dynamic feeding method for aquaculture fish using multi-task neural network, Aquaculture, 551: 737913.
https://doi.org/10.1016/j.aquaculture.2022.737913

Xu W.J., Yu X., Su H.C., Hu X.J., Xu Y.N., Li Z.J., Wen G.L., and Cao Y., 2020, Effects of feeding frequency on growth, feed utilization, digestive enzyme activity and body composition of *Litopenaeus vannamei* in biofloc-based zero-exchange intensive systems, Aquaculture, 522: 735079.
https://doi.org/10.1016/j.aquaculture.2020.735079

Zhang L., Li B., Sun X.Y., Hong Q.Q., and Duan Q., 2023, Intelligent fish feeding based on machine vision: a review, Biosystems Engineering, 231: 133-164.
https://doi.org/10.1016/j.biosystemseng.2023.05.010

Zhang Y., Gao W.F., Yuan Y., Cui W., Xiang Z.H., Ye Y., Ikhwanuddin M., and Ma H., 2024, Impact and accumulation of calcium on soft-shell mud crab *Scylla paramamosain* in recirculating aquaculture system, Aquaculture, 593: 741323.
https://doi.org/10.1016/j.aquaculture.2024.741323