

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