

frequency and duration rising as temperature increases, indicating that thermal stress management must include both physiological and behavioral regulation.

Mechanistic work has further expanded this framework from phenotype to molecular regulation. Multi-omics evidence indicates that warming enhances aggressiveness through coordinated activation of energy metabolism and neural signaling pathways, while recent gene-level studies suggest that temperature perception in swimming crab involves broad induction of transient receptor potential channel genes under acute thermal stress. Together, these advances show that high-temperature health management is no longer limited to maintaining survival, but increasingly targets early stress recognition, metabolic stabilization, and the reduction of secondary risks such as injury, hypoxia, and immune imbalance.

The next stage of technology development should prioritize real-time, data-driven monitoring systems that can detect environmental deterioration and disease risk before mass losses occur. Recent aquaculture studies show that integrated IoT platforms can continuously track key variables such as pH, dissolved oxygen, and redox conditions, while machine-learning models can convert these data into disease prediction and automated warning outputs for farm management. More broadly, intelligent aquaculture frameworks that combine sensors, big-data processing, and AI-based decision systems appear well suited for swimming crab farming under heat stress, because they can shift management from experience-based reaction to evidence-based prevention.

A second development direction is rapid and field-deployable health diagnostics linked with stress biomarkers and epidemiological forecasting. Emerging aquamedicine tools, including biosensors, sequencing, CRISPR-based assays, drones, and AI-assisted monitoring, have already improved the speed of pathogen detection and farm surveillance, but broader adoption still requires lower-cost kits and better farmer training. In parallel, predictive systems that integrate surveillance with environmental drivers are becoming increasingly feasible; machine learning models using real-time or near-real-time environmental data now provide scalable outbreak forecasting frameworks that could be adapted to swimming crab pathogens under high-temperature conditions.

In the context of climate change, sustainable swimming crab aquaculture will depend on combining farm-level health management with broader adaptation planning. Reviews across aquaculture systems show that rising temperature alters physiology, feeding, immunity, and disease dynamics, while prolonged warming increasingly threatens productivity and sustainability, making adaptation an immediate rather than future requirement. For crustacean farming specifically, resilience pathways increasingly center on selective breeding, species or system diversification, dietary intervention, and technological upgrading, because thermal sensitivity affects growth, moulting, immune response, and survival across cultured taxa.

Long-term sustainability also requires climate-resilient production models supported by governance, forecasting, and ecological safeguards. Recirculating or integrated systems, environmental control strategies, and planned adaptation measures can reduce exposure to climate stressors, but their success depends on timely environmental information, regional planning, and policy support rather than farm-level action alone. At the same time, future development should avoid a narrow focus on productivity, because intelligent and genetic technologies can create ecological or animal-health tradeoffs if they are applied without localization, biodiversity protection, and sustainability oversight.

Reference

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