

ecosystem stability, while also increasing the likelihood of disease outbreaks (Daunde et al., 2025). More generally across aquaculture species, temperatures above thermal thresholds tend to reduce performance, health, and productivity, showing that heat stress is not only an environmental issue but also a direct production constraint (Mugwanya et al., 2022). In crustaceans, prolonged thermal stress also forces trade-offs between survival, growth, and reproduction, meaning that even animals capable of short-term acclimation may still suffer reduced farming performance under sustained warming. These patterns make high-temperature episodes, including marine heat waves and seasonal extremes, a central risk factor for the stability and profitability of crustacean farming systems.

Evidence from physiological and immunological studies further shows that heat stress can undermine crustacean health well before visible mortality occurs, which is particularly important for intensive farming. In decapod crustaceans exposed to simulated heat waves, thermal stress increased protective chaperones, antioxidant biomarkers, and integrated stress indices, indicating poorer health status even when mortality did not immediately rise. In Chinese mitten crab, exposure to 32°C altered haemolymph metabolism, suppressed total antioxidant capacity during later stages of stress, and shifted the intestinal microbiota toward lower abundance of beneficial bacteria and higher abundance of pathogenic taxa (Li et al., 2022). In *P. trituberculatus*, rapid temperature stress significantly altered serum non-specific immune factors, including hemocyanin and multiple antioxidant and hydrolase enzymes, showing that acute temperature increase can cause metabolic maladjustment and profound changes in physiological and immune function. More broadly in shellfish, chronic stress combined with microbial or abiotic pressures increases infectious disease risk and reduces recovery capacity, reinforcing the view that thermal stress acts through a stress-immunity axis rather than through temperature alone (Coates and Söderhäll, 2020).

Against this background, research on health management techniques for swimming crab under high-temperature conditions is both scientifically necessary and practically urgent. Because heat stress affects metabolism, immunity, microbial balance, and survival-related trade-offs, effective management must move beyond simple temperature observation and instead target resilience mechanisms at the organism and farm levels (Wang et al., 2025). Recent reviews indicate that adaptation options for crustacean aquaculture include nutritional regulation, selective breeding, biotechnology, and husbandry optimization, all of which are relevant for developing high-temperature health management programs in swimming crab culture (Mugwanya et al., 2022; Daunde et al., 2025). Cellular stress proteins are also increasingly recognized as useful tools in crustacean health management, because heat shock proteins maintain protein homeostasis under stress and appear to enhance disease resistance and protective immunity when properly induced (Kumar et al., 2022). In addition, work on *P. trituberculatus* broodstock suggests that culture performance can be improved through nutritional optimization, supporting the broader idea that targeted physiological management is feasible in this species. Therefore, studying health management techniques for swimming crab under high-temperature conditions is essential for reducing thermal injury, stabilizing production, and supporting the sustainable development of the swimming crab farming industry in a warming climate (Daunde et al., 2025).

2 Effects of High Temperature on Swimming Crab Farming Systems

2.1 Impact of high temperature on the culture water environment

High temperature alters the physical and chemical stability of culture water, with the strongest effects appearing in dissolved oxygen dynamics and nitrogen metabolism. In crab ponds, dissolved oxygen fluctuates markedly over a 24 h cycle, and bottom waters are more prone to hypoxia because vertical diffusion weakens with depth (Yin et al., 2021). At the same time, higher temperature increases oxygen consumption and ammonia excretion in crabs, which raises the metabolic burden placed on the pond environment and accelerates deterioration of water quality under intensive culture (Liu et al., 2022).

High temperature also interacts with existing pond management constraints, making environmental instability more difficult to control in commercial systems. Survey data from pond aquaculture show that pH commonly remains within a moderate range, whereas ammonia can exceed the national standard across culture systems, indicating that nitrogen accumulation is already a chronic pressure before heat stress is added. Broader aquaculture evidence further