

shows that continuous monitoring of temperature, pH, dissolved oxygen, and ammonia improves growth and reduces mortality by enabling rapid detection of abnormal water-quality events, which is particularly relevant during summer heat periods (Zein et al., 2023; Flores-Iwasaki et al., 2025).

## 2.2 Impact of high temperature on farming production performance

High temperature can accelerate some developmental processes in swimming crab, but this does not translate into uniformly better production outcomes. In off-season breeding, embryonic development became faster as temperature increased, with total development time shortening from 9.43 d at 27°C to 6.88 d at 33°C; however, development at 31°C became asynchronous and embryo mortality increased, showing that excessive warming trades faster development for poorer developmental quality (He et al., 2022). A similar pattern appears during larval culture: development from zoea to megalopa was fastest at 31°C, but survival declined progressively with increasing temperature, and megalopa survival at 33°C dropped to only 2% (Wu et al., 2024).

For juveniles and crablets, production performance generally follows a unimodal temperature response, with moderate warmth supporting growth and thermal excess suppressing feeding efficiency and survival. In juvenile mud crabs, specific growth rate was optimized around 28.5°C–29.7°C, whereas 35°C reduced survival, feed intake, and feed conversion efficiency and increased oxidative stress (Liu et al., 2022). The same tendency has now been reported for *P. trituberculatus* crablets, in which 30°C produced the highest growth, while 34°C reduced ecdysis frequency, slowed growth, and lowered food intake (Macario et al., 2025).

## 2.3 Farming risks and mortality events induced by high temperature

High temperature raises farming risk not only through direct thermal injury but also by amplifying energetic disturbance during routine culture operations such as handling, grading, and transport. In *P. trituberculatus*, high temperature increased lactate, ADP, AMP, and the ratios ADP/ATP and AMP/ATP, while decreasing ATP and adenylate energy charge, indicating a mismatch between energy demand and supply under thermal stress. When crabs were exposed to air, mortality increased with higher air temperature and longer emersion time, confirming that hot-weather handling can convert routine operational stress into acute survival loss (Lu et al., 2020).

Heat-related farming risk also includes biological losses that emerge when stressed crabs become less resilient to environmental and pathological challenges. Natural farm mortality events in swimming crab have been linked to Decapod iridescent virus 1, with diseased crabs showing slow movement, anorexia, and very high viral loads in gill tissue, illustrating how severe losses can occur once health status collapses in culture populations (Qiu et al., 2023). In parallel, recent crab-behavior synthesis indicates that temperature, dissolved oxygen, ammonia, pH, conspecific interactions, and pathogens jointly shape feeding, sheltering, aggression, and cannibalism, so high-temperature episodes are likely to increase mortality risk through both physiological stress and behavior-mediated system instability (Zhu et al., 2025).

# 3 Physiological Responses of Swimming Crab to Heat Stress

## 3.1 Metabolic regulation

High temperature disrupts metabolic homeostasis in *Portunus trituberculatus* by increasing maintenance energy demand and shifting energy use toward short-term survival rather than growth or storage. Under thermal variation, swimming crabs show increased lactate, elevated ADP/ATP and AMP/ATP ratios, and reduced ATP and adenylate energy charge, indicating a mismatch between energy demand and aerobic supply at high temperature. A similar pattern appears behaviorally, because crabs held at warmer temperatures exhibit higher hemolymph glucose and lactate concentrations together with more intense agonistic activity, showing that heat exposure is coupled to accelerated substrate mobilization and greater energetic expenditure (Su et al., 2020).

Heat stress also appears to reallocate energy among metabolic pathways and physiological functions. Multi-omics evidence indicates that elevated temperature activates lipid and amino acid metabolism at moderate warming and then strengthens glycolysis, gluconeogenesis, and neural-related pathways at higher temperature, supporting rapid energy provision for stress-related behavior (He et al., 2025). Evidence from other stress models in the same species