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Effects of Temperature Variations on Growth and Survival of Abalone

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Abstract Temperature variation is a critical environmental factor influencing the physiological performance, growth, and survival of abalone in aquaculture systems. This study systematically reviews and analyzes the effects of temperature fluctuations on abalone culture by integrating biological characteristics, environmental temperature dynamics, growth performance responses, survival outcomes, and underlying metabolic mechanisms. Results indicate that abalone exhibits a relatively narrow optimal temperature range, within which growth rate, feeding efficiency, and energy allocation are maximized. Deviations from this optimal range, particularly under elevated temperature conditions, significantly reduce growth performance and increase mortality risk due to intensified metabolic demand, oxygen limitation, and physiological stress. Low-temperature stress similarly suppresses metabolic activity and feeding behavior, leading to reduced growth and delayed development. At the molecular level, temperature fluctuations influence enzyme activity, respiratory metabolism, and gene expression associated with stress response pathways. Seasonal and climate-driven temperature variability further exacerbates these effects in intensive aquaculture systems. A case study of commercial abalone farms demonstrates that extreme temperature events can cause substantial production losses, while effective temperature regulation strategies such as water cooling, depth adjustment, and environmental monitoring can mitigate adverse impacts. Overall, this study highlights the importance of precise temperature management for maintaining abalone health, improving production efficiency, and ensuring the sustainability of aquaculture operations.

Keywords Abalone; Temperature variation; Growth performance; Survival rate; Aquaculture management

1 Introduction

Global warming and more frequent marine heatwaves are intensifying temperature variability in coastal waters, directly challenging aquaculture species such as abalone. Abalone farms, which typically rely on ambient coastal water with limited control over temperature and other variables, already experience mass summer mortalities and reduced growth when thermal conditions exceed species' tolerance ranges (Morash and Alter, 2016). As a result, temperature sensitivity has emerged as one of the key bottlenecks for the sustainable expansion and economic stability of the abalone farming industry worldwide (Liu et al., 2022). Abalone are poikilothermic marine invertebrates whose physiological performance, including growth, reproduction and survival, is tightly constrained by water temperature regimes. Elevated temperatures can compromise multiple life stages, suppressing larval development, stunting growth and increasing susceptibility to disease, with documented mass mortalities during anomalously warm summers and marine heatwaves (Barkan et al., 2025). In abalone culture regions such as southern China, seasonal peaks approaching 30 °C now regularly drive severe summer mortality events, highlighting a narrowing safety margin between optimal and lethal conditions for farmed stocks. From a broader physiological perspective, temperature fluctuations alter core processes in marine invertebrates, including metabolism, cardio-respiratory function, mitochondrial performance and cellular protective mechanisms (Whiteley and Mackenzie, 2016; Kazmi et al., 2022).

In abalone specifically, both rapid and chronic thermal stress can drive increased metabolic rates, oxidative stress, altered enzyme activities, and changes in gene expression that influence growth efficiency and survival probabilities (Kang et al., 2019). Yet, some exposure regimes, such as naturally fluctuating temperatures, may allow physiological adjustment that buffers animals against lethal extremes (Xu et al., 2020). Despite growing recognition of temperature as a critical constraint for abalone aquaculture, key questions remain regarding how specific patterns