

Evidence from commercial and pond-based studies shows that environmental variability can explain meaningful differences in shrimp performance among ponds exposed to otherwise similar production regimes. In semi-intensive *Litopenaeus vannamei* farming, temperature and dissolved oxygen showed significant variation among ponds and were associated with production outcomes, while sensitivity analysis indicated that dissolved oxygen variability affected final production more than the other variables considered (Ruiz-Velazco et al., 2022). In inland low-salinity ponds, wide temporal and spatial variation in water quality was also documented, and survival and production were positively correlated with alkalinity and calcium hardness, suggesting that suboptimal but nonlethal conditions can still reduce performance through chronic stress pathways. Environmental effects also extend beyond growth alone, because changes in temperature, salinity, oxygenation, and pH can increase physiological stress and disease susceptibility, particularly in intensive pond systems where animals are reared at high densities. Accordingly, growth and survival should be treated as integrative indicators of the cumulative environmental quality experienced during the production cycle.

Given this complexity, statistical analysis provides an essential framework for identifying which environmental factors are most strongly associated with shrimp growth and survival and for translating farm observations into decision-relevant evidence. Regression-based approaches have already been used to relate water temperature, salinity, dissolved oxygen, stocking density, pond size, cultivation duration, and feed inputs to final weight and survival in commercial farms, showing how quantitative models can support production improvement (Ruiz-Velazco et al., 2022). More advanced predictive approaches, such as artificial neural networks, have also outperformed conventional regression forms under complex commercial conditions, indicating that shrimp growth patterns may reflect nonlinear and interacting effects that simple models do not always capture fully. Against this background, the present study aims to statistically evaluate the environmental effects on shrimp growth and survival rate by examining key water-quality and production variables, quantifying their relationships with biological outcomes, and establishing an analytical framework that can help improve interpretation, prediction, and management in shrimp aquaculture.

2 Environmental Variables and Their Biological Effects on Shrimp Performance

2.1 Water temperature effects

Water temperature is a primary environmental determinant of shrimp metabolism, feeding, and growth because it directly regulates physiological process rates in ectothermic animals. In *Litopenaeus vannamei*, higher temperatures generally increase metabolic activity and feeding, but performance declines once thermal conditions move beyond the optimal range or remain unfavorable for extended periods. Experimental evidence further shows that growth response is size-dependent: smaller shrimp can tolerate and benefit from slightly higher temperatures, whereas larger shrimp perform better at lower thermal optima, indicating that temperature management should account for developmental stage as well as mean pond conditions.

Controlled studies converge on an optimal production window centered near 25°C–30°C, although exact values vary with salinity, shrimp size, and culture system. Juvenile white shrimp showed best combined growth and survival around 28°C–30°C and moderate-to-high salinity, while thermal acclimation work also identified 25°C–30°C as the most effective range for production based on standard metabolic performance. By contrast, exposure to excessively warm conditions can suppress performance: pond observations found impaired production when shrimp experienced more hours above 33°C, and nursery trials reported survival declines as temperature increased from 28°C to 32°C.

2.2 Water quality parameters

Shrimp survival and physiological stability depend not only on temperature but also on dissolved oxygen, pH, salinity, alkalinity, hardness, and nitrogenous wastes. In commercial and pond systems, these variables often remain below lethal thresholds yet still move outside optimal ranges often enough to impose chronic stress, which can reduce survival and productivity without causing immediate mortality. Field evidence indicates that dissolved oxygen tends to support growth, while water chemistry linked to buffering and ionic balance, especially alkalinity and calcium hardness, is positively associated with survival and production outcomes (Srinivasan et al., 2025).