

to-end digital services can optimize feed use, reduce waste, improve profitability, and empower small-scale shrimp farmers when innovation is built around stakeholder partnerships rather than technology alone (Izharuddin, 2025).

8 Conclusions

Across the reviewed studies, shrimp performance was consistently linked to core environmental variables, especially dissolved oxygen, temperature, salinity, and nitrogenous wastes. In semi-intensive farms, dissolved oxygen was positively associated with body weight, while higher temperature was negatively associated with survival and average daily growth, and parallel pond studies likewise concluded that temperature, pH, salinity, ammonia, and dissolved oxygen must be kept within favorable ranges through routine management. These findings support the broader conclusion that shrimp growth and survival are regulated by the combined stability of multiple environmental parameters rather than by any single variable alone.

Experimental evidence also shows that environmental effects are often nonlinear and interactive. Response-surface analysis in biofloc nursery production found that survival remained above 84.5% at 24°C–28°C but declined as temperature increased from 28 to 32°C, while growth and survival were jointly optimized near 27.25°C and 25.5 g/L salinity. Salinity effects were further confirmed in hatchery-stage experiments, although the apparent optimum varied by developmental stage and system, with one study reporting the highest post-larval performance at 26 ppt and another reporting the best survival at 33 ppt, indicating that salinity targets should be interpreted in relation to age class and culture context.

Statistical analysis has contributed most clearly by converting routine environmental measurements into decision-relevant estimates of production risk and performance. Pond-scale studies used variance analysis, correlation analysis, and simple linear regression to identify which environmental variables differed significantly among ponds and which ones most strongly predicted final weight and survival, with dissolved oxygen emerging as one of the most influential drivers of production. Even relatively simple multiple linear regression frameworks have shown that temperature, salinity, pH, and dissolved oxygen can jointly explain shrimp-age-related variation in intensive ponds, supporting the practical value of statistical screening before more advanced modeling is applied.

More recent work extends these contributions from interpretation to automation, prediction, and farm-level intervention. Real-time IoT systems coupled with regression and classification models predicted next-day pond conditions with $R^2 = 0.94$ and classified shrimp production levels with 97.84% accuracy, while integrated IoT–machine learning systems in aquaculture more broadly achieved high predictive accuracy and supported over 6000 corrective interventions while maintaining survival above 90%. Statistical and machine-learning approaches therefore now function not only as analytical tools for understanding environmental effects, but also as operational tools for continuous monitoring, rapid response, and improved management efficiency.

Future research should move toward more integrated, high-frequency, and spatially explicit environmental assessment. Recent reviews indicate that deep learning models such as LSTM, GRU, and CNN perform well for predicting dissolved oxygen, pH, and temperature from streaming data, but they also emphasize unresolved needs for benchmarking, hybrid edge-cloud architectures, and long-term validation across shrimp systems. In parallel, ecosystem-modeling work recommends stronger adoption of autonomous monitoring and three-dimensional modeling, because current simulations still struggle to reproduce sudden dissolved oxygen drops and other fast fluctuations that increase production risk.

A second priority is to connect pond-level environmental statistics with broader sustainability and management outcomes. Meta-analytic evidence suggests that survival rate, pH, and dissolved oxygen all influence the comprehensive benefits of different farming models, and that future work should incorporate dynamic models to simulate long-term benefit trends under changing production strategies. Life-cycle assessment reviews further show that future environmental analysis should extend beyond pond water quality alone to include feed formulation, farm energy use, feed conversion, nutrient discharges, and renewable energy integration, so that shrimp production can be optimized for both biological performance and environmental sustainability.