

Feature Review

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Computational Analysis of Growth Performance and Feeding Efficiency in Aquaculture Species

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International Journal of Marine Science, 2026, Vol.16, No.4 doi: [10.5376/ijms.2026.16.0018](https://doi.org/10.5376/ijms.2026.16.0018)

Received: 25 Jun., 2026

Accepted: 31 Jul., 2026

Published: 12 Aug., 2026

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Preferred citation for this article:

Chen L., and Mai R.D., 2026, Computational analysis of growth performance and feeding efficiency in aquaculture species, International Journal of Marine Science, 16(4): 231-242 (doi: [10.5376/ijms.2026.16.0018](https://doi.org/10.5376/ijms.2026.16.0018))

Abstract The rapid expansion of aquaculture production has increased the demand for efficient approaches to optimize growth performance and feeding management. Computational analysis provides powerful tools for understanding complex interactions among biological traits, nutritional factors, and environmental conditions in cultured aquatic species. This review summarizes recent advances in mathematical modeling, statistical analysis, machine learning, and artificial intelligence applications for evaluating growth dynamics and feeding efficiency in aquaculture systems. Key production indicators, including weight gain, specific growth rate, feed conversion ratio, and nutrient utilization efficiency, are analyzed through computational frameworks integrating feeding records, environmental monitoring, and physiological responses. Growth prediction models, nonlinear growth simulations, and machine learning algorithms are discussed for their ability to identify critical factors affecting production outcomes and improve management decisions. A case study of Pacific white shrimp (*Litopenaeus vannamei*) demonstrates the application of computational models in predicting growth performance and optimizing feeding strategies under different culture conditions. Furthermore, the integration of computational technologies with IoT-based monitoring and precision aquaculture systems provides new opportunities for reducing feed waste, enhancing production efficiency, and promoting sustainable aquaculture development. Future research should focus on developing more accurate, interpretable, and adaptive models that integrate multi-source biological and environmental data.

Keywords Computational analysis; Aquaculture species; Growth performance; Feeding efficiency; Machine learning models

1 Introduction

Aquaculture has become a central component of the global food system and is now expected to shoulder much of the future increase in aquatic food supply. Over the past two decades, the sector has expanded through intensification, improved feeds, stronger production management, and better biosecurity, while inland aquaculture in Asia has contributed especially strongly to global food security (Naylor et al., 2021). This growth has been driven in part by the limits of capture fisheries and by rising demand for nutrient-dense aquatic foods, making aquaculture one of the fastest-growing food production sectors worldwide and a key pathway for narrowing the global protein supply gap. Yet expansion alone is not sufficient. As fed aquaculture becomes a larger share of production, improving growth performance and feeding efficiency has become one of the industry's most important technical and economic priorities. Feed commonly represents the largest operating cost in many fish production systems, and inefficient feed use increases waste outputs, raises environmental burdens, and reduces profitability. For this reason, indicators such as growth rate, feed conversion ratio, and feed efficiency are no longer viewed simply as farm-level performance measures, but as strategic indicators linking biological productivity with sustainability, resource use, and the long-term resilience of aquaculture systems.

The biological basis of growth performance and feeding efficiency in aquaculture species is complex because these traits emerge from interactions among genetics, physiology, nutrition, environment, and behavior. At the molecular level, fish growth is strongly regulated by the hypothalamic-pituitary-somatotropic axis, particularly through growth hormone and insulin-like growth factor-I, while external variables such as diet, temperature, salinity, photoperiod, pollutants, and stocking density can alter gene expression within this pathway and thereby modify growth outcomes. Growth regulation also depends on broader integrated networks that include epigenetic mechanisms, developmental plasticity, and signaling pathways beyond GH-IGF, which helps explain why growth responses differ across species