

Feature Review

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Characteristics of Water Quality Changes in Cage-Cultured Grouper

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International Journal of Marine Science, 2026, Vol.16, No.2 doi: [10.5376/ijms.2026.16.0010](https://doi.org/10.5376/ijms.2026.16.0010)

Received: 28 Feb., 2026

Accepted: 05 Apr., 2026

Published: 20 Apr., 2026

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Preferred citation for this article:

Li X., Wang Y.L., and Chen J., 2026, Characteristics of water quality changes in cage-cultured grouper, International Journal of Marine Science, 16(2): 127-140 (doi: [10.5376/ijms.2026.16.0010](https://doi.org/10.5376/ijms.2026.16.0010))

Abstract This study investigates the water quality dynamics in grouper (*Epinephelus* spp.) cage aquaculture systems, with a focus on identifying spatiotemporal variation patterns, driving mechanisms, and their ecological implications. Based on field monitoring and systematic analysis, key water quality parameters-including temperature, salinity, dissolved oxygen, pH, nutrients, and organic matter-were evaluated to characterize environmental variability within and around cage farming areas. The results indicate that water quality exhibits pronounced diurnal, seasonal, and spatial heterogeneity, primarily driven by tidal exchange, hydrodynamic conditions, and meteorological forcing. Aquaculture activities, particularly feed input and metabolic waste release, significantly contribute to nutrient enrichment and organic load accumulation, which may further alter microbial community structure and ecosystem stability. External environmental factors, such as rainfall events, wind-driven mixing, and adjacent coastal pollution inputs, also play important roles in modulating water quality fluctuations. A case study from a representative aquaculture region further demonstrates the interaction between farming intensity and environmental response. Finally, the study discusses the impacts of deteriorating water quality on grouper physiological stress, disease susceptibility, and growth performance, and proposes integrated management strategies including ecological carrying capacity control, real-time monitoring systems, and sustainable aquaculture practices. These findings provide scientific support for optimizing cage aquaculture management and improving coastal water environmental sustainability.

Keywords Grouper aquaculture; Cage culture; Water quality dynamics; Spatiotemporal variation; Environmental management

1 Introduction

Grouper cage aquaculture has expanded rapidly in tropical and subtropical coastal waters and is now a major marine fish farming sector in Asia, supplying high-value protein and income for coastal communities. This growth coincides with broader global expansion of marine cage culture, where waste discharge, nutrient loading, and associated changes in water quality are recognized as key limiting factors for sustainable development (Zhang et al., 2020). Water quality shapes fish physiology, behavior, health, and welfare; changes in temperature, turbidity, dissolved oxygen, salinity, pH, inorganic nitrogen, and emerging pollutants can produce profound effects on metabolism, organs, and behavior that ultimately determine growth and survival in culture systems (Zhang et al., 2024). Against this backdrop, clarifying the characteristics of water quality changes in cage-cultured grouper has both scientific and practical significance for optimizing production, safeguarding fish welfare, and protecting surrounding coastal ecosystems.

Grouper production now involves at least dozens of species and hybrids, with Asia dominating global output and many small-scale farmers depending on this activity for employment and income. Hybrid groupers, such as crosses between tiger grouper (*Epinephelus fuscoguttatus*) and giant grouper (*E. lanceolatus*), have been widely adopted because of high growth potential, production efficiency, and resilience, supporting commercial-scale farming across the Asia-Pacific region. Grouper culture is now recognized as one of the highest-yielding marine aquaculture sectors in China, where hypoxia and other environmental stresses associated with intensified production, elevated temperatures, and high-density transport have become major constraints (Wang et al., 2026). At the same time, eco-friendly aquaculture management technologies are being promoted to increase grouper output per unit area while reducing water and energy use, showing that management innovations can enhance both economic returns and resource efficiency (Cheng et al., 2024).