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Assessment of Genetic Diversity in Germplasm Resources of Cultured Marine Groupers

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Abstract This study explores the classification characteristics, geographic distribution, and utilization status of grouper germplasm resources, and elaborates on the theoretical basis and major evaluation indices of genetic diversity. It focuses on summarizing the application progress of molecular techniques—such as microsatellite markers (SSR), single nucleotide polymorphisms (SNP), mitochondrial DNA, and high-throughput sequencing—in population genetic analyses, and analyzes the genetic structural differences between cultured and wild populations through representative case studies. The results indicate that wild grouper populations generally maintain relatively high genetic diversity, whereas cultured populations commonly exhibit reduced allelic richness, decreased heterozygosity, and increased genetic differentiation, mainly due to founder effects, genetic drift, and artificial selection. Meanwhile, genetic bottlenecks and inbreeding effects have gradually emerged in some cultured populations. Current research still faces limitations, including insufficient sample coverage, lack of a unified evaluation system, and inadequate integration of multi-omics approaches. Based on these findings, this study proposes strengthening genetic monitoring, optimizing broodstock management, establishing germplasm conservation systems, and promoting the application of high-throughput genomic technologies in genetic evaluation and molecular breeding. The results provide a theoretical basis for the conservation of grouper germplasm resources, genetic improvement, and the high-quality development of the aquaculture industry.
Keywords Grouper; Germplasm resources; Genetic diversity; Molecular markers; Population genetic structure

1 Introduction

Groupers (*Epinephelus* spp.), as one of the most important marine economic fish species, occupy a significant position in global mariculture due to their rapid growth, high flesh quality, and high market value. This group is mainly distributed and farmed in tropical and subtropical regions, with Asia—particularly China, Taiwan, and Indonesia—contributing over 90% of global production. Driven by market demand, the grouper industry has expanded rapidly, with global production increasing from approximately 60,000 tons in 1990 to nearly 200,000 tons in 2007. In China, coastal regions in the south have developed grouper aquaculture into a dominant specialty industry, supported by continuous advancements in farming technologies. Artificial breeding techniques have gradually matured, and superior varieties such as orange-spotted grouper, giant grouper, and their hybrids have been widely applied. However, the rapid expansion of the industry has, to some extent, outpaced the development of technology and management. Current farming systems still face challenges such as insufficient seed supply, high dependence on wild-caught juveniles, unbalanced feed structures, and frequent disease outbreaks (Ybanez and Gonzales, 2023). Meanwhile, long-term artificial selection and closed breeding practices have led to issues such as germplasm degradation, reduced growth performance, and weakened disease resistance, posing significant constraints on the sustainable development of the industry.

Germplasm resources constitute the fundamental basis for the sustainable development of aquaculture, and their level of genetic diversity directly determines a population's adaptability to environmental changes and resistance to pathogenic stress (Yang et al., 2024). High genetic diversity not only helps maintain population vitality but also provides potential resources for the genetic improvement of desirable traits. However, under the combined pressures of overfishing, habitat destruction, and aquaculture practices reliant on wild resources, the genetic diversity of wild grouper populations is declining. At the same time, non-standardized seed production processes