

northern Chinese farming areas, with cumulative mortality reaching 85%-90% in some sites, and medium- and high-density groups showing faster early mortality and reduced growth. Earlier analyses likewise argued that long-term continuous high stocking density can worsen environmental aging, food shortage, self-pollution, and pathogen proliferation during summer, thereby reducing the tolerance of cultured scallops. More recent studies in other cultured scallops also indicate that overcrowding can suppress immune function and increase bacterial vulnerability, suggesting that density affects not only space competition but also health resilience (Feng et al., 2023).

The aquaculture industry of *C. farreri* has developed from a seed-dependent coastal practice into a large and regionally dominant mariculture sector. Once abundant and reliable seed supply became available, *C. farreri* culture expanded rapidly, and by 1985 cultured yield had already exceeded the wild fishery in Shandong Province. Nursery and grow-out technologies based on nets, cages, and other suspended devices enabled large-scale farming, with conventional cages holding 30-50 scallops per compartment and 450-600 cages per hectare. In Sungo Bay, one of the representative production centers, scallop longline culture has been estimated to exceed 50,000 tonnes annually, making site selection and suitable rearing density key management issues. Over the past decades, however, the industry has faced a transition from simple expansion toward quality-oriented and sustainability-oriented development, because overexploitation has been associated with reduced shellfish growth and increased disease incidence. Field trials have shown that culture location matters as much as density: in Sungo Bay, offshore longline systems produced higher survival than inshore systems, and offshore densities of 20-30 individuals per disc achieved better shell and tissue growth than denser treatments, likely because stronger currents improved food delivery. Seasonal culture performance also remains uneven, as *C. farreri* in deep water of Haizhou Bay grew rapidly except in summer, while most mortality occurred during the first summer and autumn. These production challenges have stimulated broader interest in improved farming modes, including offshore culture, integrated multi-trophic aquaculture, and germplasm improvement. Offshore studies indicate that *C. farreri* can maintain continuous growth in new farming spaces such as offshore wind farm areas, although growth may remain below that observed in more favorable reference sites and temperature appears to be a key determinant (Lee et al., 2023). Integrated culture with *Gracilaria lemaneiformis* has shown strong nutrient removal capacity, with ammonium and phosphorus reduction efficiencies reaching 83.7% and 70.4%, respectively, indicating that system optimization can improve environmental performance around scallop farming. At the same time, the industry is paying closer attention to product quality, food safety, and genetic improvement: recent surveys across the Shandong Peninsula evaluated nearly 70 hazard indicators and 90 nutritional and flavor substances in cultured *C. farreri* (Song et al., 2023), while genomic analyses found high genetic diversity in natural populations and identified selected strains with growth- and stress-resistance-related signatures that could support future breeding programs. Seasonal monitoring has also shown that some metal-related consumer risks, especially cadmium and arsenic, still require attention in risk assessment even when seawater concentrations remain below regulatory limits.

Against this background, the present study focuses on a central practical and scientific question: what stocking density best balances growth performance and survival in cultured Zhikong scallop under suspended farming conditions? This question is important because prior studies consistently show that low density tends to favor individual growth, but the optimal density for production depends on species, life stage, environment, and management objectives. Even larval and hatchery studies in other scallops show that density effects are not biologically trivial and can shift according to water exchange, developmental stage, and the trade-off between growth, survival, and space efficiency. Therefore, evaluating density responses in *C. farreri* under explicit farming conditions is necessary for converting broad principles into species-specific recommendations. The objective of this study is to compare the growth performance and survival of *C. farreri* cultured at different stocking densities, and to identify a density range that can improve biological performance while supporting efficient farm management. Its innovation lies first in linking a classic husbandry variable to the current needs of the *C. farreri* industry, which now requires not only high output but also lower mortality, better environmental matching, and more stable product quality. Its second significance is that density optimization can provide a simple and directly applicable management tool for reducing food competition, minimizing stress accumulation, and lowering summer mortality risk in commercial culture. Its third significance is that the results can contribute to site-specific and system-specific