

single technical rule but a context-dependent management strategy. For *Chlamys farreri*, the strongest case supports moderate offshore grow-out densities, staged control of early-life high density, and environment-specific adjustment based on hydrodynamics, seasonal temperature, and ecological carrying capacity.

9 Conclusions and Prospects for Practical Application

The central conclusion is that increasing stocking density generally reduces the growth performance of *Chlamys farreri*. In hanging culture, shell growth was negatively correlated with density and survival was highest at 20 individuals per compartment. Offshore longline culture in Sungo Bay likewise showed that scallops stocked at 20-30 individuals per disc achieved better shell and tissue growth than denser treatments, indicating that moderate density improves individual performance under commercially relevant conditions. The effect of density on survival is more conditional than its effect on growth, but the risk becomes pronounced when density stress overlaps with summer warming, reproduction, and poor circulation. Mass mortality studies in northern China found that most *C. farreri* deaths occurred in July and August at 23°C-26°C, and medium- and high-density groups showed faster initial mortality than low-density groups. This pattern is consistent with broader scallop evidence that density-related mortality and growth losses become strongest during warm seasons, when low-density culture is most protective.

In aquaculture practice, density optimization should begin with seasonal risk avoidance rather than with maximal short-term yield. Evidence from Jiaozhou Bay indicates that scallop culture density exceeded carrying capacity and should be reduced to 280 individuals per cage, while earlier field observations cited in that analysis reported low mortality at no more than 50 individuals per layer and improved ecological conditions when density in nearby Sungo Bay was reduced to 20 individuals per layer. These results support a management principle of keeping spring stocking low enough that thinning is unnecessary during summer stress periods. Site selection should be treated as part of density management, because the same nominal density can perform very differently across environments. A depletion model developed for Sungo Bay showed that at 50 ind m⁻³, density reduced growth from 0% to 100% depending on current velocity below 20 cm/s, showing that hydrodynamics directly determine whether crowding translates into food limitation. More generally, ecological carrying-capacity modeling across embayments has shown that local water circulation controls whether stocked biomass remains within precautionary limits, so lease placement in well-flushed areas should accompany density regulation.

The long-term prospect for sustainable bivalve aquaculture is favorable, but only if density control is integrated with ecosystem-based management. Ecological carrying capacity is best understood as the upper stocking level beyond which unacceptable environmental impacts appear, and its practical assessment must consider both production potential and ecological feedbacks. Recent indicator reviews further emphasize that carrying capacity differs among farm types and locations, so standardized but operational indicators are needed for management rather than relying on universal thresholds. Future development should therefore combine farm-scale optimization with bay-scale ecological planning, climate sensitivity, and habitat protection. In Sanggou Bay, aquaculture was modeled to reduce water-exchange ability substantially, and scallop carrying capacity was lowest in spring and summer, with mean-size density recommended not to exceed 59 ind m⁻². At the same time, sustainable expansion remains possible in some regions when ecosystem limits are respected, as shown by Yellow River Estuary modeling that found room for cautious future growth under current environmental conditions. Overall, the practical outlook for *Chlamys farreri* culture is strongest where moderate density, strong circulation, seasonal adjustment, and ecological carrying-capacity assessment are managed together.

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Conflict of Interest Disclosure

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