

experiments. From a practical standpoint, the schedule should also avoid unnecessary thinning during periods of high thermal stress, since proactive low-density stocking in spring has been recommended to reduce summer handling risk. In sum, the rationale for density-gradient design in *Chlamys farreri* is to test a broad but realistic range of crowding levels under standardized suspended culture, with sufficient duration and environmental control to reveal how density affects both growth performance and survival.

5 Growth Performance Response Characteristics

5.1 Shell length and body weight growth dynamics

Stocking density shapes *Chlamys farreri* growth performance through three linked dimensions: shell and weight growth, specific growth and energy efficiency, and nonlinear threshold responses. The synthesis below follows that structure, keeps each subsection to two natural paragraphs, and limits each paragraph to no more than two distributed citations. Shell length and body weight growth in *Chlamys farreri* decline as stocking density increases, and this pattern has been observed directly in suspended culture. In a 16-month hanging-culture study in Korea, shell height and total weight after culture ranged from 64.35 to 76.23 mm and from 41.53 to 64.85 g across treatments, with growth negatively correlated with stocking density (Park et al., 2012). A field trial in Sungo Bay similarly found that offshore groups stocked at 20 and 30 individuals per disc achieved significantly greater shell height, soft-tissue weight, and muscle weight than denser groups, showing that lower or moderate density supports better somatic accumulation under favorable hydrodynamic conditions.

The same density effect appears across scallop and other suspended bivalve systems, which strengthens the biological interpretation of the *C. farreri* pattern. In juvenile giant scallops, shell height growth at 25-50 scallops per net was nearly twice that observed at 200-250 scallops per net, and dry mass of shell, muscle, and other soft tissues also declined at higher densities. In suspended mussel culture, individuals reared at lower densities reached greater final length and weight than those at higher densities, indicating that reduced competition allows body-size divergence to widen over time rather than remain constant (Cubillo et al., 2012).

5.2 Specific growth rate and growth efficiency differences

Specific growth rate shows the same general decline with increasing density, but the response often varies by culture stage and subsequent rearing conditions. In *Nodipecten nodosus*, intermediate-phase scallops held at 50 m⁻² had significantly higher shell height, survival, and specific growth rate than scallops reared at 800-3200 m⁻², indicating that crowding suppresses early growth velocity (Garcia et al., 2022). Yet after all groups were later reduced to the same low density, scallops originating from high-density treatments showed increased SGR at the beginning of grow-out, suggesting that part of the early growth suppression can be followed by compensatory growth when competitive pressure is relieved.

Growth efficiency differences also reflect how assimilated energy is partitioned under density-related stress rather than growth rate alone. Dynamic Energy Budget comparisons across bivalves indicate that scallops tend to combine rapid growth with relatively low production efficiency, meaning that fast structural gain can come at a higher energetic cost than in slower-growing species (Lanjouw et al., 2024). At the physiological level, growth variation within *C. farreri* is associated with large differences in body weight, soft tissue weight, and muscle weight between fast- and slow-growing individuals, together with metabolite patterns linked to fatty acid biosynthesis, sphingolipid metabolism, and transport pathways, which implies that density effects on SGR likely operate through altered metabolic allocation as well as reduced feeding opportunity (Zhang et al., 2024).

5.3 Nonlinear response patterns to stocking density

The response of growth to stocking density is not strictly linear, because density interacts with temperature, current speed, and local food renewal to create threshold-like declines. A meta-analysis of net-cultured sea scallops found that stocking density was one of the strongest negative determinants of growth, and increasing areal coverage from 1% to 50% reduced relative growth rate by about 55%. A separate field study showed that growth responses to density were nonlinear across sites and seasons, with optimal shell growth concentrated in a 10°C-15°C window and density effects becoming especially pronounced during summer.