

2 Biological Characteristics and Culture Systems of Manila Clam

2.1 Ecological habits and growth characteristics of manila clam

Manila clam (*Ruditapes philippinarum*) is a dominant intertidal bivalve widely distributed in coastal sediments, especially on tidal flats where exposure at ebb tide and sediment properties strongly shape its habitat use. Its survival and growth depend heavily on benthic behaviors such as burrowing, which improves resistance to currents and predation, and this behavior is affected by substrate particle size, temperature, and salinity (Li et al., 2025).

Growth performance of Manila clam is typically rapid under favorable coastal conditions, helping explain its high fishery and aquaculture value. In Portugal, *R. philippinarum* showed a high growth coefficient, early maturation at about 20.0 mm shell length, and a longer spawning season than the native *R. decussatus*, indicating strong reproductive capacity and fast population turnover (Maia et al., 2025). On the Korean west coast, spat settlement timing and subsequent growth also varied markedly by site, and juveniles settling in autumn at the more favorable site continued growing to adult size by the following May (Kim et al., 2017).

2.2 Major culture systems and their technical features

Current Manila clam farming mainly includes bottom-sowing or on-bottom culture on tidal flats and suspended or caged systems in the water column. Bottom-sowing is widely used because, after seed is released, clams can move, disperse, or aggregate within habitat patches under relatively low direct human interference (Hou et al., 2023). In contrast, suspended systems confine seed in containers or cages and therefore allow tighter control over substrate, depth, and maintenance conditions.

The technical performance of these systems differs in predictable ways. Suspended culture often enhances shell and somatic growth because feeding time is extended compared with intertidal bottom culture, and juvenile clams in subtidal suspended cages grew significantly faster than bottom-cultured controls (Lee et al., 2020). Similarly, suspended containers with deeper substrate improved growth and nutritional condition relative to on-bottom mesh bags, although suspended systems can also experience higher losses if enclosure design allows escape or if fouling is not controlled through regular maintenance.

2.3 Interactions between environmental factors and stocking density

The effects of stocking density cannot be separated from surrounding environmental conditions, because clam performance responds to temperature, salinity, food supply, sediment properties, and oxygen conditions simultaneously. Field evidence shows that adult density can depress individual condition index, while high spat density can reduce recruitment success, indicating that density-dependent competition emerges at different life stages. Sediment grain size, organic carbon, and clam biomass also jointly structure benthic communities in culture areas, showing that density effects propagate through habitat modification as well as direct crowding.

Environmental stress can further amplify density effects by narrowing the range of conditions under which clams maintain growth and survival. Experimental work on other cultured bivalves shows that growth advantages at lower stocking density become especially pronounced at warmer temperatures, with scallops in low-density nets growing 75% faster in summer and performing best within a defined thermal window (Coleman et al., 2021). Likewise, hatchery and larval studies in clams indicate that intermediate or low culture densities generally support better growth and survival when temperature, salinity, food ration, and water exchange are kept within suitable ranges, underscoring that optimal stocking density is always conditional rather than fixed (Guete-Salazar et al., 2025). Manila clam biology and farming strategy are closely linked: the species' rapid growth, sediment-dependent behavior, and flexible culture options make it highly productive, but the outcomes of stocking density depend on how well density is matched to habitat quality, culture method, and environmental stress (Figure 1).

3 Effects of Stocking Density on Growth Performance of Manila Clam

3.1 Growth rate responses under different stocking densities

Across culture stages, Manila clam growth rate generally declines as stocking density increases. In early pre-fattening under controlled upwelling conditions, specific growth rate ranged from 2.3% to 5.0% per day and fell