

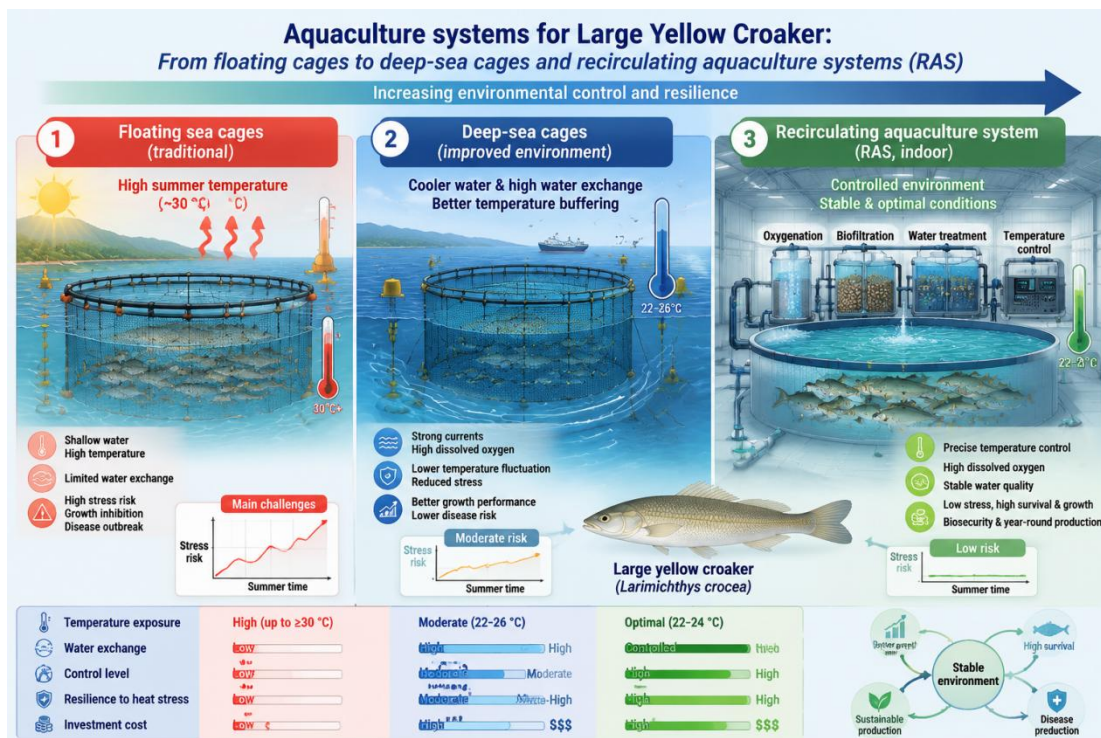


Figure 3 Comparison of farming systems for large yellow croaker, illustrating traditional floating cages, deep-sea cages, and recirculating aquaculture systems (RAS) as adaptive responses to environmental stress

7.3 Comparative analysis of success and failure cases and experience summary

Comparisons across culture modes and regions reveal clear patterns distinguishing successful high-temperature management from failure. Offshore ship aquaculture, operating within moderate temperature and high oxygen ranges and maintaining low nitrogen and bacterial levels, achieved near-complete survival and superior flesh composition, whereas static nearshore cages exposed to heat and hypoxia suffered slower growth and higher mortality, illustrating the cost of inadequate environmental buffering. Regionally, heavily eutrophic areas with low pH and dissolved oxygen, such as one major cage region where nutrients and heavy metals were highest, present higher ecological risk and poorer fish quality than better-managed sites, emphasizing that pollution control is integral to heat-season health management (Chen et al., 2025).

Experience from thermal biology and breeding research further refines these practical lessons. Large yellow croaker show appreciable thermal plasticity and high formal thermal safety margins, yet prolonged exposure to 30 °C still causes energy reallocation, growth depression and oxidative stress, warning against relying solely on nominal tolerance when designing summer strategies. At the same time, genetic and seed selection work stresses the need to integrate traits such as disease resistance and environmental stress adaptation into breeding and to pair improved strains with intelligent environmental control, precision feeding and disease prevention, forming a comprehensive package for robust performance under future hotter summers.

8 Health Monitoring and Early Warning Technologies

8.1 Physiological indicators and behavioral monitoring techniques

High-temperature seasons demand noninvasive techniques that track physiological stress in large yellow croaker without adding further injury risk. A high-temperature stress study showed that cortisol in serum, skin mucus, and surrounding water followed a similar “rise then fall” pattern, peaking at 1.5 h, and that cortisol levels in these three media were highly correlated, supporting skin mucus and tank water as practical substitutes for blood sampling. Parallel measurement of MDA, IgM, and AKP in serum and skin mucus further indicates that oxidative damage and immune status can also be followed through mucus, enabling repeated monitoring during heatwaves without sacrificing fish.