

fish health (Yang et al., 2024). For large yellow croaker, farm-level comparisons indicate that cage-reared fish can experience prolonged summer temperatures above the optimal range, accompanied by lower dissolved oxygen, higher mortality and poorer growth than fish maintained in mobile offshore ship systems that can track more favorable environmental conditions. International experience further shows that marine heatwaves and elevated temperatures can intensify harmful algal blooms and secondary infections, leading to geographically extensive fish kills and revealing the vulnerability of shallow, warm-water ecosystems where cultured fish often live near their upper thermal limits.

Within this climatic and environmental context, infectious diseases have become a major limiting factor for large yellow croaker aquaculture. Ciliate parasites such as *Cryptocaryon irritans* and scuticociliates are capable of causing rapid outbreaks, abnormal behavior, severe tissue damage and high cumulative mortalities in farmed stocks, with infection dynamics strongly influenced by stocking density and mariculture conditions. Recent investigations in large yellow croaker have documented mass-mortality events linked to scuticociliate infection, with experimental challenges producing over 70% cumulative mortality within one week, and transcriptomic analyses revealing extensive immune and metabolic disruption at the peak of mortality. Coinfections with blood-borne and myxosporean parasites have also been associated with mass mortalities in offshore net-cage systems, with year-round feeding and seasonal fish movements likely facilitating parasite circulation and transmission (Zhang et al., 2025). At the same time, bacterial pathogens such as *Vibrio* spp. and *Pseudomonas plecoglossicida* remain economically important, with outbreaks occurring across temperature ranges and sometimes outside previously recognized seasonal windows, underscoring the dynamic interaction between pathogens, host susceptibility, and changing environmental conditions. More broadly, infectious disease is recognized as a leading global constraint in aquaculture, causing multibillion-dollar losses annually, with disease emergence and antimicrobial resistance making traditional, treatment-focused approaches increasingly unsustainable (Wright et al., 2023).

These converging pressures make health management during high-temperature seasons a strategic priority for the large yellow croaker industry. General aquaculture experience emphasizes that the most predictable consequence of stress is immune suppression, leading to increased disease susceptibility and mortality, and therefore highlights the importance of controlling environmental stressors such as temperature, dissolved oxygen and stocking density through good husbandry and biosecurity practices rather than relying solely on therapeutic interventions. Preventive health strategies—combining optimized culture systems that avoid peak thermal stress, farm-level biosecurity, vaccination where available, functional feeds and probiotics, and microbiome-informed early-warning tools—are increasingly viewed as essential components of sustainable disease control frameworks that align with One Health principles. For large yellow croaker specifically, research on probiotics capable of inhibiting key bacterial pathogens, breeding for enhanced stress and temperature tolerance, and alternative farming systems that maintain fish within optimal thermal and oxygen ranges illustrate emerging pathways to strengthen resilience under warming scenarios. Systematically synthesizing these strands into health management strategies tailored to high-temperature seasons is therefore of great significance for safeguarding fish welfare, stabilizing production, and securing the long-term sustainability of large yellow croaker aquaculture.

2 Research Background and Mechanisms of High-Temperature Stress

2.1 Climate warming and marine heatwave ecological context

In recent decades, global ocean warming has driven a marked rise in the frequency, duration and intensity of marine heatwaves (MHWs), with the number of MHW days roughly doubling between 1982 and 2016. These extreme warm events are projected to intensify strongly under continued warming, greatly increasing the probability that coastal farming areas experience prolonged high-temperature anomalies. MHWs already cause broad ecological impacts, restructuring marine ecosystems and threatening biodiversity and ecosystem services that support fisheries. For exploited fish and invertebrates, annual high temperature extremes typically reduce biomass for most stocks and lower maximum catch potential, adding to long-term climate impacts (Cheung et al., 2021).