

managed more effectively. Current knowledge shows that oyster disease expression is influenced by a suite of interacting host, pathogen and environmental factors-such as oyster age and genetics, temperature, food availability and microbiota-but the mechanisms by which these variables jointly control outbreaks remain poorly resolved. The present study therefore focuses on describing the characteristics of disease occurrence in oyster farming-across space, time, production stages and environmental gradients-with the dual objectives of identifying key risk factors and providing an empirical basis for improved surveillance and management strategies (Petton et al., 2021).

2 Biological and Ecological Basis of Oyster Disease Susceptibility

2.1 Oyster physiological characteristics and immune defense systems

Oysters rely entirely on a sophisticated innate immune system to survive in pathogen-rich estuarine environments, compensating for the absence of adaptive immunity. Hemocytes circulating in the hemolymph execute core defenses including immune recognition, signal transduction, synthesis of antimicrobial peptides, phagocytosis and encapsulation, supported by apoptosis and autophagy as important immune mechanisms (Wang et al., 2018). Single-cell transcriptomic analyses have revealed at least seven functionally distinct hemocyte types and multiple hematopoietic lineages, with specialized roles such as phagocytosis, reactive oxygen species production, copper accumulation and antimicrobial peptide expression, underscoring the cellular complexity behind disease resistance (De La Forest Divonne et al., 2025). Oyster immunity also shows plasticity and memory-like features that shape disease outcomes in farming. Immune priming and maternal immune transfer have been reported, suggesting that prior exposure can modulate subsequent responses, and neuroendocrine systems (catecholaminergic, cholinergic, neuropeptide and GABAergic) further regulate these defenses (Wang et al., 2018). Experimental work shows that inactivated Ostreid herpesvirus-1 and related viral antigens can rapidly stimulate hemocyte functions (e.g. ROS production, immune-related gene expression) without cytotoxicity, highlighting the potential to exploit innate “immune memory” and hemocyte responsiveness to reduce mortality from Pacific oyster mortality syndrome (Delisle et al., 2023).

2.2 Filter-feeding ecological habits and environmental exposure characteristics

As sessile filter feeders, oysters continuously pump large volumes of water, concentrating microorganisms and particles from their environment. An individual can retain up to 75% of microorganisms present in surrounding water, so naturally occurring bacterial communities, including potentially pathogenic taxa, accumulate in tissues and can pose health risks, particularly when animals originate from poor-quality environments (Mendes et al., 2023). Long-term monitoring at a commercial Pacific oyster area showed that, while oysters exhibited good depurating capacity for fecal bacteria (*E. coli*, enterococci) compared with surrounding waters, norovirus persisted seasonally in digestive glands, illustrating that filter feeding exposes oysters to diverse microbes and that clearance efficiency is pathogen-dependent (Rodrigues et al., 2023). Filter feeding also structures host-microbiota-pathogen interactions that influence disease susceptibility and food safety. Comparative analyses of water and oyster microbiota found that environmental conditions strongly shaped water communities and pathogen levels, whereas oyster digestive gland communities were more stable and showed “hot oyster” patterns, where individual oysters accumulated much higher *Vibrio* or fecal indicator loads than neighbors (Diner et al., 2023). In estuarine culture sites, surveys of *Crassostrea gasar* and surrounding waters have repeatedly detected human-pathogenic bacteria such as *Escherichia coli*, *Salmonella*, *Vibrio* spp. and others in both oysters and environment, confirming that filter-feeding oysters mirror-and can amplify-microbial risks associated with degraded water quality (Mendes et al., 2023).

2.3 Mechanisms linking environmental stress to disease susceptibility

Environmental stressors modulate both pathogens and host defenses, creating windows of high disease susceptibility in oyster farming. Large-scale field and modeling studies demonstrate that seawater temperature is a dominant driver of disease-induced mortality in Pacific oysters, with mortality risk sharply increasing between about 16 °C-24 °C and specific mean temperature thresholds (around 19 °C-24 °C over 12-21 days) corresponding to high probabilities of OsHV-1 outbreaks and substantial stock losses (Shi et al., 2024). A four-year, multi-site survival analysis similarly identified seawater temperature as the strongest predictor of mortality, with additional modulation by wind speed and humidity, and showed that spat were far more vulnerable than juveniles or adults, indicating that