26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Qualitative network modelling to assess climate-sensitive vibrio and antimicrobial resistance in Tasmanian oyster supply chain

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Abstract: Climate change is reshaping the ecology of foodborne pathogens, with implications for human, animal, and environmental health. In Australia, emerging risks associated with rising temperatures, *Vibrio parahaemolyticus* and antimicrobial resistance (AMR) in aquaculture present a growing concern for seafood safety. Vibrio can grow at any point in the seafood supply chain if temperature is not adequately controlled. This poses a food safety risk for oysters in particular, as they are typically consumed raw. Despite this, integrative risk assessment approaches that align with One Health principles remain limited. This study aimed to characterise the climate-sensitive dynamics of Vibrio and AMR risks in the Tasmanian oyster industry as a case study using a participatory systems modelling approach grounded in One Health principles.

We applied a qualitative network modelling (QNM) framework to capture key interactions across environmental, microbial, seafood industry, and policy domains. The initial model was developed through a literature synthesis and refined through expert elicitation workshops. The final model included 25 nodes and 47 directional linkages and was used to simulate system responses to press perturbations. Climate-related perturbation scenarios included increases in air temperature, water temperature, and extreme rainfall, as well as the effects of positive policy actions such as cross-sector collaboration and improved food safety awareness.

A simulated increase in air temperature amplified post-harvest Vibrio risks along the cold chain and increased consumer mishandling, thereby elevating the risk of *V. parahaemolyticus* outbreaks. Due in part to the relationship between antibiotic use in salmon aquaculture and temperature stress, perturbing air temperature produced the highest proportion of human Vibriosis with AMR. Increased water temperature primarily affected Vibrio abundance in seawater and the potential for that increased concentration to accumulate in oysters that are harvested for consumption. We were able to identify that through wastewater treatment plant overflows and contaminated runoff, extreme rainfall had a pronounced effect on pollution, antibiotic resistant aquatic microbes, and consequently, the potential for antibiotic resistance genes to be acquired by Vibrio via mechanisms such as horizontal gene transfer. However, our interpretation of AMR impacts was limited due to high uncertainty, knowledge gaps in the Australian context and few feedback loops. We suggest this as a focus area for future work. Combined climate perturbations did not act synergistically but reinforced known vulnerabilities. Policy interventions consistently improved system responses, with co-benefits for human health, oyster demand, and operational resilience.

This study demonstrates how systems modelling can operationalise One Health approaches in climate-sensitive food systems. The QNM provided a mechanism to identify key variables influencing Vibrio and AMR risks along the oyster supply chain, identify leverage points, and explore trade-offs in a data-limited context. Our findings highlight the critical role of intersectoral collaboration and regulatory action in mitigating climate-driven Vibrio and AMR risks. This integrative approach offers a scalable tool for informing and testing public health preparedness, food safety governance, and climate adaptation strategies.

Keywords: *Qualitative network modelling, Vibrio and Antimicrobial resistance, Systems thinking, One Health*

