BLUE ECONOMY
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Effect of fish-farm waste on animal–sediment interactions

Ecosystem understanding for sustainable offshore aquaculture

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In a nutshell

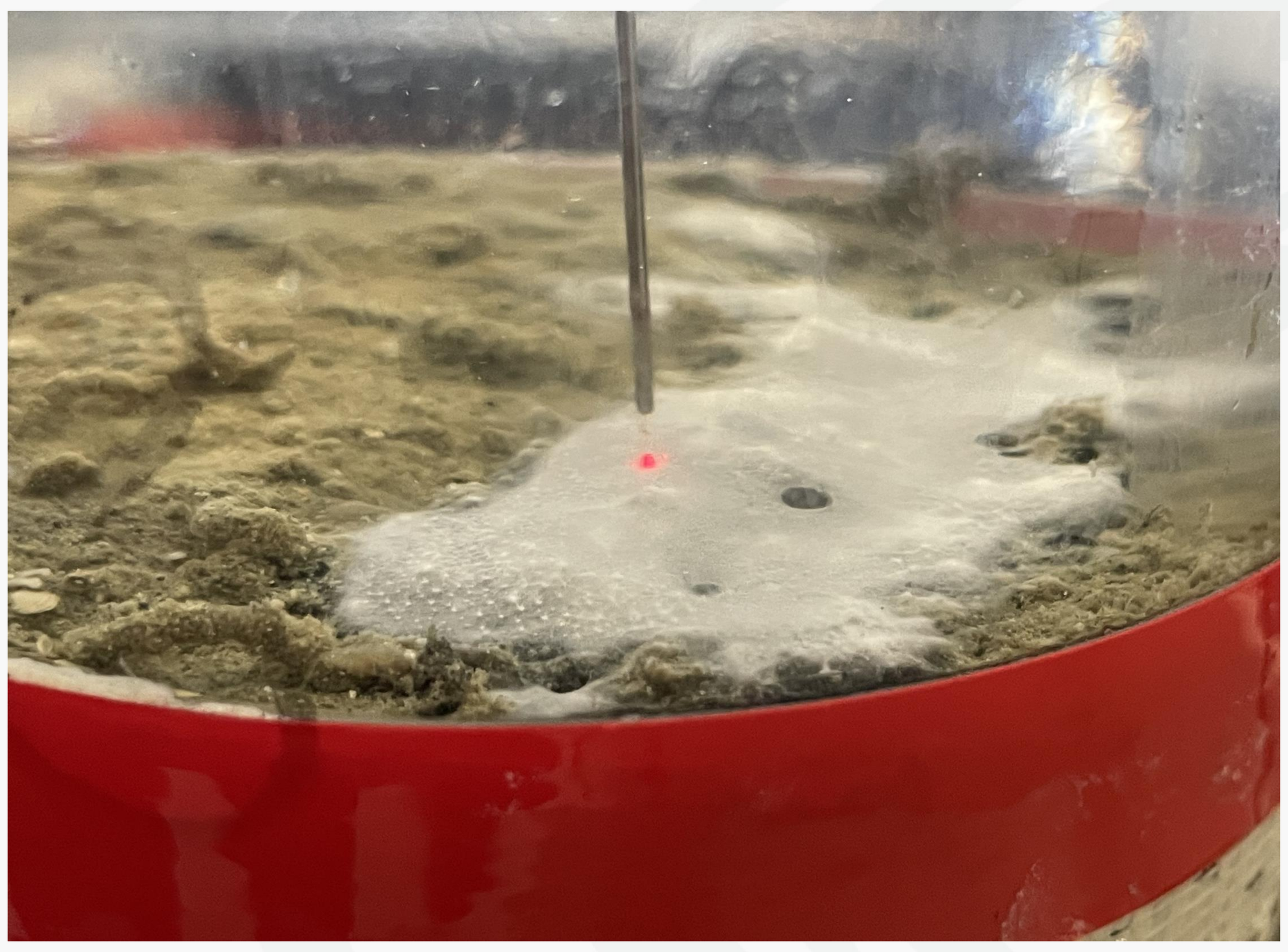
Bioturbation, the irrigation and mixing of seafloor sediment by fauna, profoundly increases the capacity of the seafloor microbes to mineralise organic matter with oxygen. Understanding this capacity is crucial because it determines how the seafloor ecosystem responds to the deposition of organic waste by fish farms. If the waste deposition exceeds this capacity, microbial sulfate reduction will dominate leading to the production and accumulation of hydrogen sulphide. This in turn will exclude invertebrates from the sediment, thus reducing the intensity of bioturbation, which further increases sulphate reduction.

While this positive feedback loop is well understood, its effects on important seafloor ecosystem functions, such as the transformation and removal of nitrogen, are not well known. The offshore environment introduces additional uncertainties: the greater water depths and currents prolong the suspension of settling fish waste in oxygenated seawater, which may decrease the reactivity of the deposit, and benthic faunal assemblages may exhibit greater sensitivity to organic enrichment than those in coastal sediment.

Here, we introduce a series of laboratory experiments to (i) assess how the reactivity of fish farm waste changes during settling, (ii) evaluate how waste deposition affects animal–sediment interactions, and (iii) investigate how changes in the intensity of bioturbation affect the sediment–seawater inorganic nitrogen exchange. The goal of these experiments is to support the development of sustainable offshore aquaculture by improving our ability to predict ecosystem responses.

The heart urchin *Echinocardium cordatum* is a key bioturbator ploughing seafloor sediment worldwide. When moving below the sediment surface, the urchin displaces sediment particles while maintaining two connections to the surface: One small channel draws oxygenated seawater around the outer surface of the urchin (respiration). The second larger funnel, which is in front of the urchin and indicates the direction of its movement, guides particles to the mouth (feeding). Respiration, feeding and movement effectively irrigate and mix the top five centimetre of the sediment, enhancing the decomposition.

With **Experiment 1** we will investigate how the elemental composition and reactivity of fish waste changes during extended suspension in oxygenated seawater. To do so, we will suspend waste generated by fish raised in a land-based facility (NIWA, Bream Bay, New Zealand) in agitated seawater and then conduct analyses of the waste's C:N ratio and biological oxygen demand at regular intervals over the duration of the experiment.



Experiment 2 will address the role of benthic fauna in the mineralisation of organic matter deposits. We will investigate how the contribution fauna to the total sediment oxygen uptake, the so-called fauna-mediated sediment oxygen demand, changes as the loading of the sediment with fish waste increases. Two techniques will provide this insight, laboratory incubation of intact sediment cores, and modelling of measured porewater oxygen concentration micro-profiles.

Experiment 3 will address the influence of bioturbation on an important seafloor ecosystem function, the transformation and removal of nitrogen. We will ask how the sediment–seawater exchange of inorganic nitrogen (ammonia, nitrate, nitrite, nitrogen gas) changes as a function of bioturbation intensity. To derive nitrogen exchange rates, we will enclose intact sediment cores in the laboratory and measure how the nitrogen content of the enclosed sediment-overlying seawater changes over the duration of the incubation. For seawater nitrogen analyses, we will use a micro-segmented flow analyser (nitrate, nitrite, ammonium) and a membrane inlet mass spectrometer (MIMS).

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