BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE

Australian Government
Department of Industry, Science and Resources

Cooperative Research Centres Program

SHORT SUMMARY

4.20.004 - A novel approach to measuring the depositional footprint of the Blue Economy

KEY POINTS

- A team of eight researchers from six organisations demonstrated a proof-of-concept for a seafloor monitoring method that enables proactive management of the ecological impact of wastes released by fish farms in deep and energetic offshore waters.
- This concept is based on transect deployments of a chamber lander to measure the seafloor's O_2 demand - a proxy of ecosystem function. The measurement is simple, data are instantly available, and the required sensors are robust.
- We present a measurement protocol, including secure deployment routines, methods for determining site-specific lander configurations, notes on technological constraints and remedies, and the results of a measurement trial.
- Furthermore, we developed and tested the design of a laboratory experiment that can reveal how and at which waste deposition rate the resulting organic enrichment alters the microbial cycling of nitrogen - a critical seafloor ecosystem function.
- We discuss the implementation of this monitoring approach in regulatory frameworks, suggest a management decision tree, and recommend technology development to further simplify routines for deployment at exposed farm sites.

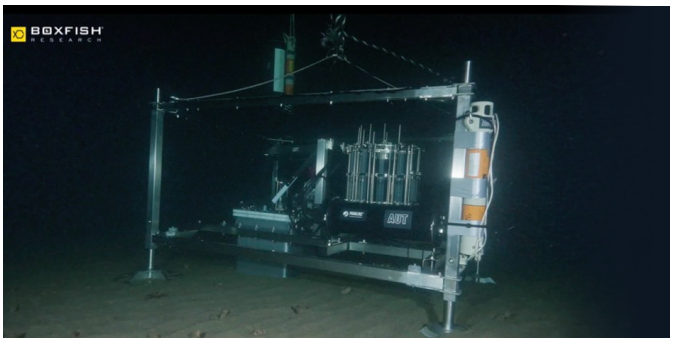

Figure A1: A benthic chamber lander deployed at ~49 m water depth in the D'Entrecasteaux Channel in Tasmania, Australia

THE CHALLENGE

To produce fish sustainably offshore, in deep and energetic waters, farmers should proactively manage the environmental impact of their farms, which discharge organic-rich solid wastes (faeces, uneaten feed) into the open sea, leaving their mineralisation to the receiving ecosystem.

Proactive environmental management, which can generate a social license for such farming, requires farmers to regularly quantify the effects of waste deposition on seafloor ecosystem functioning, so that they can adjust their operations in a timely manner—before, not after, this deposition exceeds the ecosystem's capacity for waste mineralisation.

To achieve this, farmers will need the knowledge, tools, and motivation to regularly measure the mineralisation of their wastes by the seafloor ecosystem. The technology and know-how for this are currently not available.

THE OPPORTUNITY

We explored the feasibility of using lander-based measurements of the seafloor O_2 demand as a tool to describe and manage a fish farm's organic enrichment footprint in the seafloor ecosystem.

Seafloor monitoring based on such measurements would be applicable in any area where soft sediment accumulates on the seafloor, regardless of the water depth.

The Blue Economy CRC is funded in part under the Australian Government's CRC program administered by the Department of Industry, Science, Energy and Resources.

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OUR RESEARCH

Voyages

We completed five voyages including over 100 lander deployments in depths of up to 125 m to test and systematically improve the performance of our seafloor landers under various sea and seafloor conditions, and to refine lander configurations and deployment protocols.

The first voyage in the **Queen Charlotte Sound**, New Zealand, generated a set of lander deployment and recovery protocols, a draft measurement routine for the chamber lander, and configurations suitable for the eddy-covariance lander.

These protocols, routines, and configurations were put to a test under a variety of sea and seafloor conditions during the following **Hauraki Gulf Voyage**. The main purpose of this voyage, however, was to collect cores of offshore sediment for laboratory enrichment experiments.

During the following voyage to the **Blue Endeavour** farm site in Cook Strait, the team tested the performance of their landers in strong currents at 80 m water depth, including deployments and recoveries under conditions of large swell. We discovered a critical flaw in the design of the chamber sensor port and developed requirements for a future autonomous lander version.

The aim of the subsequent **Onapua Bay Voyage** (Bay of Many Coves, Queen Charlotte Sound) was to test the performance of the improved sensor ports and to reveal the influences of chamber stirrer settings and sediment resuspension on the measurements of the sediment O_2 demand.

Our final **Tassal Voyage** (East of Lippies salmon farm in the D'Entrecasteaux Channel in Tasmania, Australia) successfully generated the desired proof-of-concept for a lander-based monitoring of seafloor organic enrichment by open ocean fish farms.

Monitoring concept

Our monitoring concept consists of a series of chamber lander deployments at seafloor sites placed along a straight-line transect leading away from an open-ocean fish farm. Such measurements will reveal the presence of a spatial gradient in the seafloor O_2 demand which describes the size and intensity of the organic enrichment footprint in the seafloor ecosystem.

Proof of concept: Our trial in the D'Entrecasteaux Channel, Tasmania, Australia, revealed the size and intensity of a fish farm's organic enrichment footprint in the seafloor ecosystem.

The graph in Figure A2 shows a gradient in the sediment O_2 demand, which increased from a background level of 220–560 to 1,922 µmol m^{-2} h^{-1} about 5 m next to the boundary of the farm.

The data revealed that the organic waste released by this farm created a footprint in the seafloor ecosystem that, in June 2023, extended beyond the farm boundary by about 500 m.

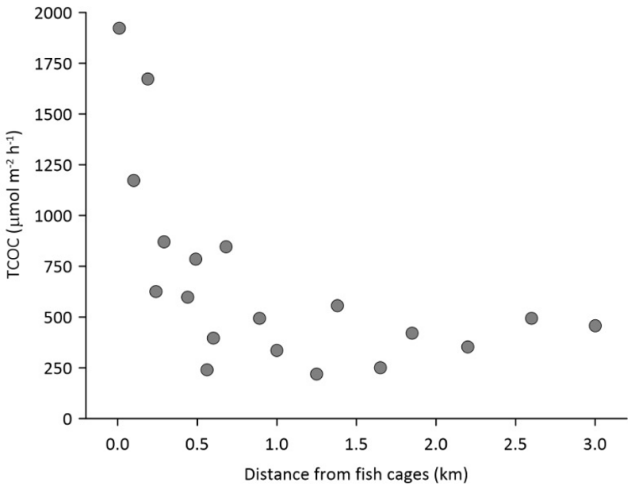

Figure A2. A spatial gradient in the seafloor O_2 demand derived from consecutive three-hour lander deployments along a transect starting 3 km South of the East of Lippies salmon farm and heading towards the southern pen of this farm. TCOC, total chamber O_2 consumption.

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Implementation

Because of waste dispersion, the rate at which organic wastes settle at the seafloor will decrease with increasing distance from the farm resulting in the spatial gradient shown in Figure A2. Changes over time in this gradient can be used as a farm management tool as indicated in Figure A3.

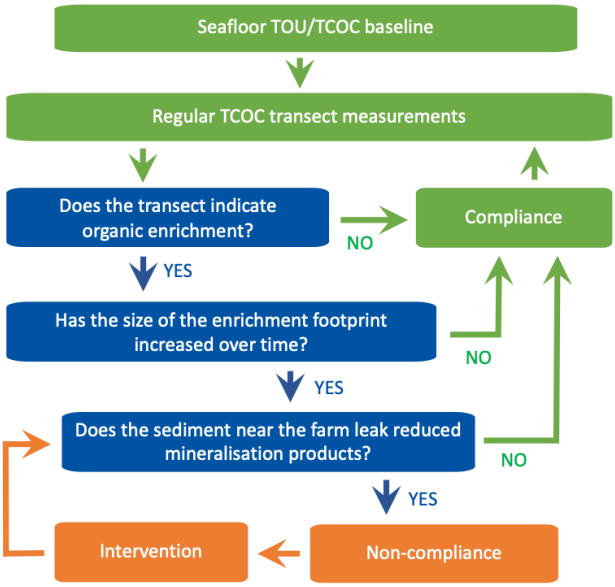

Figure A3. Example of an environmental management decision tree based on regular monitoring of the seafloor O_2 demand (measured as TCOC).

NEXT STEPS

To implement this monitoring approach in regulatory frameworks, lander deployments in deep and energetic waters must be simple, safe, and cost-effective. That is, non-experts must be able to complete a transect measurement rapidly in a safe manner.

The technology that meets these requirements is currently not available. Therefore, we recommend drawing upon this project's experience from over 100 lander deployments to design, build and test a fully autonomous lander that makes this possible.

PROJECT TEAM

Kay Vopel, AUT; Michelle Simone, AUT; Iana Gritcan, AUT; Chris Frid, Griffith University; Raymond Bannister, DPIPWE; Jeff Ross, IMAS UTAS; Scott Hadley, IMAS UTAS; Andrew Pender, UTAS; Ben Quigley, UTAS; James Hortle, UTAS; Karen Wild-Allen, CSIRO; Lumin Wang, ECSFRI; David Plew, NIWA; Mark Preece, NZKS; Brad Evans, Tassal; Matt Barrenger, Tassal.

PROJECT REPORTS/PUBLICATIONS

Vopel K, Plew D, Simone MN, Ross J, Hadley S, Bannister R, Wild-Allen K, Frid CLJ (2024) *A novel approach to measuring the depositional footprint of the Blue Economy, 4.20.004 – Final Project Report*. Prepared for the Australian Blue Economy Cooperative Research Centre, 46 pp.

Vopel K, Plew S, Simone M, Hadley S, Ross J, Bannister R, Wild-Allen K, Frid CLJ: Environmental impact of a coastal salmon farm: line transect reveals consistent gradients in seafloor ecosystem structure and function. In preparation for *Scientific Reports.*

Simone MN, Hermans S, Plew D, Vopel K: From nitrogen loss to retention: The intensity and duration of fish farm loading alters the fate of nitrogen in cohesive surface sediment. *ACS Environmental Science & Technology Water* (under review).

Simone MN, Hibberd A, Plew D, Vopel K: Patchy organic deposition from fish farms enhances cohesive sediment heterogeneity. *Aquaculture Environment Interaction* (under review).

Simone MN, Vopel K (2023) The need for proactive environmental management of offshore aquaculture. *Reviews in Aquaculture* 16(2):603–607.

Simone M, Plew D, Vopel K (2021) Towards sustainable offshore aquaculture. *Coastal News* 75:8–9.

SHORT SUMMARY AUTHOR

Associate Professor Kay Vopel

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