COMPLETED PROJECT CASE STUDY

NAMAQI: A NOVEL APPROACH TO MONITORING AQUACULTURE IMPACTS

PARTNERS

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PROJECT LEADS

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BACKGROUND

The sector's ongoing drive toward increasingly sustainable fish farming methods has led many aquaculture companies to move their operations over the years to dispersive or off-shore locations, such as the Orkney and Shetland islands in the north of Scotland and off the coast of Nova Scotia in eastern Canada. These sites have the potential to support higher output at an environmentally sustainable level, while also being more cost-effective and reducing the risk of disease transmission between farmed and wild fish.

Due to the nature of these sites, areas with strong water currents or high water flow rates are presented with unique challenges. For example, these types of sites are prone to scattering organic waste materials from fish farms. Sulphides, including hydrogen sulphide, are by-products of the decomposition process of organic waste materials, and may have negative effects aquatic life.

Secondly, predictions of the environmental footprint of dispersive sites can be limited and inaccurate, by nature. Current environmental monitoring methods rely heavily on depositional modelling and macrofaunal ITI (Infaunal Trophic Index) analysis to determine fish farming's impact on the environment, as well as on the health of the benthic community. These are both costly and time intensive. The release of NewDEPOMOD in 2017 marked a significant advancement in predicting the impact of fish farms on the benthic environment. However, even though NewDEPOMOD led to important improvements for dispersive sites, challenges have persisted in efficiently collecting and analysing benthic samples and correlating them to NewDEPOMOD predictions, a requirement of Scottish Environment Protection Agency (SEPA) regulations.*

Other continued, SAIC-funded research – through the comprehensive ExPAND and ExPAND2 projects – has resulted in enhanced understanding of depositional modelling, including a comprehensive software user guide and improved user interface.

To help meet these challenges, analysis of total dissolved free sulphides (TFS) in sediments could be a suitable and cost-effective addition to environmental monitoring and may reduce the need for frequent macrofaunal (ITI) analysis.

This project builds on existing relationships between academic and industry partners. Collaborators for this work include the University of Stirling's Institute of Aquaculture with commercial partner Cooke Aquaculture. Fieldwork and data gathering took place at Cooke Aquaculture sites in both Scotland and Canada. This project also brings together regulators from both countries, SEPA and Fisheries and Oceans Canada (DFO). The work builds on expertise gained through existing projects, including INCREASE, as well as established networks, including the Scottish Association for Marine Science (SAMS) at the University of Highlands and Islands (UHI). Analysis of samples collected in Canada was performed by Dalhousie University, while sample analysis in Scotland was performed by SAMS.

AIMS

The main objective of this project was to demonstrate whether integrating measurement of sulphide levels in benthic samples has the potential to be an effective environmental monitoring tool in dispersive areas. Furthermore, the project aimed to build on existing technical and methodological knowledge in order to improve environmental monitoring techniques for measuring the impact of organic enrichment activities.

The successful outcomes of this study would have direct economic implications, both through creating jobs and by supporting the sustainable expansion of the sector, including enhanced environmental monitoring.

ORGANIC ENRICHMENT

Natural processes of decomposition within aquatic settings are important and contribute to nutrient cycling. However, in all human activities, such as fish farming, it is important to ensure that this does not lead to ecological imbalances. These organic enrichment activities include the release of uneaten feed, faeces, and decaying organisms, and can lead to excessive concentrations of sulphides.

In extreme cases not normally seen in high-energy conditions, highly elevated levels of dissolved sulphides – particularly hydrogen sulphide (H_2S) – can have several adverse impacts on fish and aquaculture systems. For instance, sulphides:

- interfere with fish respiration and can damage gill tissue in fish, leading to hypoxia and causing stress, reduced growth and mortality in aquatic organisms;
- alter the behaviour of fish;
- disrupt the food system, particularly by destroying aquatic invertebrates, a crucial food source for many fish.

Aquaculture operations may experience economic losses due to reduced fish growth, increased mortality and the need to introduce additional management practices to mitigate sulphide exposure.

More recently, measurement of TFS in sediment as an indicator of benthic health under organic enrichment conditions has become increasingly widespread, including within Canadian environmental monitoring programmes. Additionally, WWF has recognised TFS measurement as a component of a credible global aquaculture standard.

> *This project will enhance the work already underway in Scotland to enhance our understanding of how aquaculture affects the organisms living on the seabed and what can be done in response. Ultimately, we hope it will provide us with the best way forward for monitoring the marine environment in highly dispersive waters – a crucial issue for the industry as it looks to find suitable new locations and potentially increase production at existing sites with spare capacity. It is also another example of the ways in which we are looking to support aquaculture's long-term ambition to grow sustainably, ensuring the environment is being monitored and the industry is complying to strict environmental guidelines.*

MEASURING SULPHIDE LEVELS IN DISPERSIVE SITES

The project followed a comprehensive methodology involving fieldwork, sample analysis, model outputs, and workshops. Fieldwork campaigns were undertaken at six Cooke Aquaculture farms, three in the Orkney Islands and three in Nova Scotia. These took place in spring and summer to ensure sampling while the farms were fully stocked and close to peak biomass. The geographical spread of this project was of particular value, given the learnings and advances that could be shared between Nova Scotia and Scotland.

Following the fieldwork, sample analysis was performed, including sulphide measurements, total carbon measurements and macrofaunal (ITI) analysis, and studied for predictive relationships between these variables, as well as site characteristics like water flow rate and fish biomass. Furthermore, in order to correlate sample analysis with model outputs, as required by SEPA regulation, NewDEPOMOD was performed at each site.

A threshold of 1500 µM of total dissolved free sulphides (TFS) has been established as the level at which aquatic organisms transition from healthy oxic to hypoxic conditions. Patterns in sulphide concentrations were in alignment with infaunal impacts, with mid-range sulphide levels (200 – 1500 µM) showing diverse ecological states. Sulphide measurements proved to be a rapid indicator of "High" Infaunal Quality Index (IQI) status, correlating with low sulphide concentrations, while levels above 1500 µM suggested a "Poor" or "Bad" IQI status. However, this conclusion is based on a limited number of highly impacted samples.

Comparisons between Scottish and Canadian site data revealed potential differences in sulphide tolerance based on energy levels, impacting IQI responses. Among data from two sites in Nova Scotia, "High" IQI status was observed even with high sulphide concentrations. Differences in sulphide tolerance between biological communities (e.g. between low-energy vs high-energy sites) may explain the differences in IQI responses to sulphides.

IMPACT

The objectives of this study were achieved to the extent that it provided further evidence to the limited data available on the use of sulphides as an analytical tool, as well as to how benthic biological response relates to sulphide concentration in sediment.

However, although sulphide measurements may serve as a quick indicator of ecological status, the study suggests limitations at intermediate concentrations. Therefore, the method is unlikely to provide a replacement for macrofaunal analyses. Nonetheless, the study recommends that sulphide measurement could be a useful screening tool.

The ion-specific electrode (ISE) approach to measuring sulphide levels in sediment demonstrated feasibility but faced accuracy concerns, prompting consideration of alternative methods for evaluating benthic community status on Scottish fish farms. Recent analytical advances (e.g. spectrophotometric) might give more accurate sulphide measurements, although the overall patterns with biological community response are likely to remain similar.

Cooke Aquaculture will continue to develop and investigate alternative methods of identifying impacts to help with model calibration and site management.

ADDITIONAL INFORMATION

- Measuring and modelling the dispersal of salmon farm organic waste over sandy sediments, Clive James Fox et al
- Hydrogen sulfide toxic but manageable, Claude E. Boyd
- A revised classification system describing the ecological quality status of organically enriched marine sediments based on total dissolved sulfides, Peter Cranford et al