COMPLETED PROJECT CASE STUDY

INCREASE: ENHANCING PREDICTIVE MODELS FOR ORGANIC WASTE DISPERSAL

PARTNERS

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BACKGROUND

Scotland, a nation with deep maritime roots, has long recognised the importance of its waterways and the sea in shaping its national identity, heritage and economy. The marine environment has played a critical role in the country's economic vitality, notably through fishing and aquaculture. Consequently, environmental protection agencies in Scotland have implemented rigorous measures to safeguard these valuable assets, encouraging sustainable practices to minimise ecological impact.

One of the primary methods employed to protect Scotland's marine environment is the regulation of waste and pollutants released into the water. The amount of settling organic waste is a key factor in determining the maximum allowable biomass at a fish farm, as part of the stringent regulations applied to the aquaculture sector. The primary tool used in Scotland to model the dispersal of organic waste is NewDEPOMOD, a sophisticated model initially developed for sheltered, low-dispersal sea lochs with muddy seabeds. However, the expansion into more dispersive sites has revealed limitations to the model's ability to accurately predict the benthic footprint of organic waste in these environments. This challenge prompted the initiation of the INCREASE project, which aimed to investigate the discrepancies in the model's predictions and propose solutions to address the identified issues.

This project formed an international collaboration between Cooke Aquaculture Scotland (CAS), which acted as the main industry partner and hosted the fieldwork, the Scottish Association for Marine Science (SAMS), responsible for carrying out the laboratory analysis and modelling, and Dalhousie University, which houses Canada's largest university aquatic research facility. The University of Essex also contributed to preparatory work and the deployment of sediment traps.

AIMS

The INCREASE project focussed on two main objectives:

1. To investigate the fate and effects of organic matter deposition and resuspension from dispersive salmon farms in the Northern Isles (Orkney) concerning benthic habitats and sediment organic matter during the period of peak biomass;
2. To use the new insights gained to improve the parameterisation of NewDEPOMOD, enhancing its ability to predict sustainable carrying capacities under the proposed Deposit Zone Regulation (DZR) guidelines by the Scottish Environment Protection Agency (SEPA) and ultimately supporting increased production.

SEDIMENT SAMPLING AND ANALYSIS

The project began with a comprehensive literature review, which revealed that the challenges of modelling waste dispersal at high-energy sites have been documented in several previous studies. Additionally, limited flume experiments indicated that the critical erosion threshold for organic waste is significantly influenced by the coarseness of the sediments and the level of organic loading.

Fieldwork took place at three sites in the Orkney Islands. The research team carried out extensive sampling to characterise the benthic habitat, including particulate size analysis (PSA), sediment particulate organic carbon (POC) measurements, sediment sulphide analysis (at Quanterness and Bay of Meil) and infaunal analyses using Infernal Trophic Index (ITI) and Infaunal Quality Index (IQI). A novel design of sediment traps was also deployed along four transects at each site during spring and neap tides. These traps support organic carbon deposit estimates while allowing the resuspension of settled organic material. The estimated deposition rates were then compared with the site characteristics, IQI patterns, and results from the NewDEPOMOD model.

RESULTS

The results from the study were revealing. The estimated patterns and quantities of carbon deposition were generally consistent with expectations and IQI data, suggesting that the novel sediment traps effectively captured realistic patterns of organic waste deposition around fish farms with high spatial resolution. However, when modelling with NewDEPOMOD using its default parameter settings, nearly all simulated particles were moved out of the model domain, preventing the capture of any benthic footprint. To obtain a footprint, researchers increased the critical shear stress within the model to a level where resuspension was almost entirely disabled. However, this adjustment caused the rapid decline of waste deposition estimates at growing distances from the fish cages, indicating that waste resuspension and dispersal were underestimated by the model.

These findings, supported by other published studies on fish farm waste resuspension, suggest that NewDEPOMOD does not fully capture the resuspension and redistribution processes occurring in more dispersive environments. This limitation is likely due to the use of a spatially invariant critical shear stress, which does not account for the variability in organic waste erosion and resuspension across different sediment types. Organic waste seems more easily eroded from heavily enriched areas and more difficult to resuspend when dispersed onto less enriched areas. This behaviour is more pronounced in coarser sediments, such as sands and gravels, compared to mud.

IMPACT

The introduction of sediment box traps offers a new method for directly testing NewDEPOMOD predictions in more dispersive, shallow sites, and this technique may prove valuable in future studies. Furthermore, the findings suggest that NewDEPOMOD's code should be reviewed to evaluate the feasibility of allowing critical bed shear stress to vary based on the degree of organic enrichment and sediment type. Implementing such changes could significantly improve the model's predictive capability in dispersive environments.

The project's outcomes have enabled Cooke Aquaculture Scotland to re-evaluate the parameterisation process for more dispersive sites, ensuring that the model calibrations better reflect benthic results. Furthermore, the findings have led to the development of specialist modelling job roles within the organisation. Current staff and researchers have acquired invaluable skills and knowledge that will have a lasting impact on their fields and organisations.

Additionally, insights gained from the project were disseminated more widely among external stakeholders, including SEPA and industry colleagues in Scotland and Canada. This improved approach will lead to more accurate predictions of waste deposition footprints, supporting the sustainable planning and development of fish farming sites in Scotland's dynamic marine environments, and possibly benefiting international stakeholders.

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