COMPLETED PROJECT CASE STUDY

FROM DETECTION TO FORECAST: TACKLING HARMFUL ALGAL BLOOMS IN SCOTTISH AQUACULTURE

PARTNERS

Scottish Sea Farms | Scottish Association for Marine Science (SAMS) | Mowi Scotland, with the later addition of UHI Shetland | Scotland's Rural College (SRUC) | Bakkafrost Scotland | The University of Aberdeen

BACKGROUND

In recent years, the Scottish salmon sector has faced increasing challenges from harmful algal blooms (HABs), which can compromise gill health in farmed salmon. Blooms can cause physical damage or toxin exposure, sometimes leading to acute mortality, chronic gill pathology, or – when combined with other pathogens – the development of complex gill disease (CGD).

Seasonal conditions, including higher sea temperatures and reduced dissolved oxygen, further increase the risks to fish health, particularly when farms must also carry out interventions for issues such as amoebic gill disease (AGD) or sea lice. Recognising these pressures, the Scottish Government's Farmed Fish Health Framework highlights gill health as a priority for the industry.

Because most HABs are natural offshore events transported to the coast, they cannot be prevented. However, early warning and timely husbandry strategies can reduce their impact. This case study follows a programme of work that began with the development of predictive models and expanded through a follow-up project. A third project in the series, focusing on extending the domain of the high-resolution model from the Scottish west coast to include the Orkney and Shetland islands, is covered in a separate case study.

AIMS

The main objective of the original project was to provide early-warning alerts for HABs affecting Scottish aquaculture. These alerts would be generated from mathematical models to predict the timing and location of blooms and delivered through an online portal.

The extension work focused on demonstrating and evaluating the Imaging FlowCytoBot (IFCB) as a tool for rapid HAB detection at a Scottish aquaculture site.

Specific aims included assessing the classifier's ability to identify and count potentially fish-killing organisms, comparing results with farm-based counts at the deployment site and nearby farms, and establishing a real-time IFCB data feed to HABreports.org. The extension also aimed to use IFCB data to trigger model runs forecasting bloom development and transport, enhancing early-warning capability.

OVERVIEW

This initiative brought together Scottish Sea Farms, Mowi Scotland, SAMS, UHI Shetland, and SRUC. It was delivered through six work packages covering the original project and its extension, followed by the 'High-Resolution modelling for Shetland' project.

The first four work packages (WP1–WP4) established the foundation of the early-warning system. Farm staff undertook phytoplankton monitoring, supported by new training materials to improve taxonomy skills. Participating partners agreed on a reporting methodology and defined 16 harmful taxa along with their threshold concentrations, which would trigger a run of the WeStCOMS HAB prediction model once exceeded. This stage also focused on developing and validating the predictive models, as well as building out the user interface of the reporting platform, HABreports.org.

The extension project (WP5) introduced the IFCB at a Shetland farm. This is the first deployment of such an instrument at a working aquaculture site worldwide. It was initially deployed at a depth of five metres, and subsequently on a remotely operable winch that can profile the top 20 meters of the water column, in parallel to a CTD system that can provide real-time environmental information such as water temperature and dissolved oxygen concentration Over its operation, the instrument has already captured more than 76 million images of phytoplankton and other particles.

Using AI-based classification, the IFCB provided automated, near-real-time identification of harmful taxa. A bespoke dashboard was developed to display results, allowing users to track the appearance and density of phytoplankton, and providing an early indication of bloom development (https://ifcb-portal.sams.ac.uk/).

The sixth work package was covered by the third project in the series ('High-Resolution modelling for Shetland'), the main aim of which was to establish and develop the North Scotland Coast Ocean Modelling System (NORSCOMS-WRF-FVCOM), extending the existing west coast WeStCOMS model. The resulting system is capable of providing near-real-time operational hindcasts and short-term forecasts of the hydrodynamic field states of the seas between the northern Scotland mainland (from Cape Wrath to Pentland Firth) and the Orkney and Shetland islands. Through the introduction of virtual algal cells, the model can predict the development and movement of a harmful bloom in the subsequent week. A full case study of this project can be found here. The project also developed prototype statistical models potentially capable of providing true site-specific forecasts of HAB risk for the week ahead.

RESULTS

The project delivered a fully operational early-warning system for HABs. Key achievements included five-day forecasting, a web-based portal for farm data and model predictions, a successful proof-of-concept for automated real-time HAB detection, enhanced forecasting capacity for Shetland through new modelling tools, and training of farm staff in phytoplankton monitoring and identification.

As part of the original study, the project's hydrodynamic models were updated. The system now uses WeStCOMS2 for the West Coast and NORSCOMS for northern waters, and can be triggered automatically when new data becomes available.

The hydrodynamic models were validated through sea glider surveys and comparisons with buoy data, showing strong accuracy. Their outputs are now available online and used by HABreports.org to give short-term forecasts of how blooms may move and develop.

HABreports itself was expanded from an open-access site for shellfish data into a secure platform for salmon farms. A login system protects sensitive information, while clearer visual displays and risk thresholds make results easier to interpret. Site managers now have access, and the system can also run on data from other sources, such as shellfish monitoring or satellites. Since May 2023, the portal and its alert system have been fully operational.

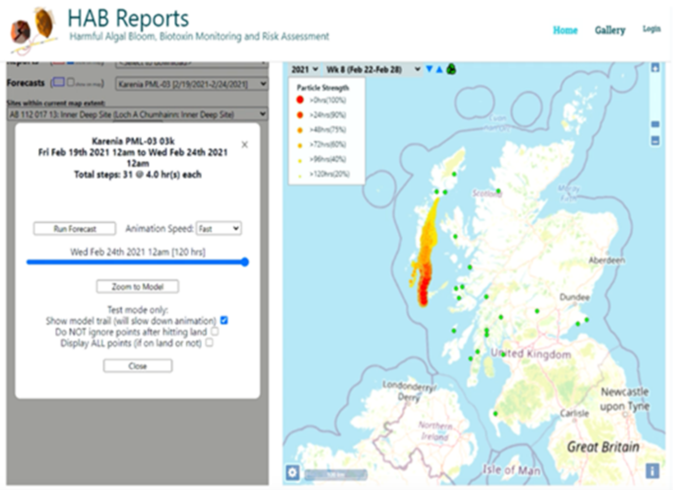

Figure 1: Evolution of a HAB event originating near the Isle of Tiree and progressing over time northwards into the Minch. Points change colour and size with time, to demonstrate the evolution of the bloom.

The IFCB instrument introduced in WP5 performed well in long-term deployment at sea, demonstrating reliable high-frequency monitoring despite minor issues such as occasional blockages and data transfer interruptions, which were successfully resolved. The classifier was able to enumerate potentially fish-killing organisms and provided valuable comparisons between sites.

The dashboard created for the IFCB (Figure 2) allows interrogation of phytoplankton data in near real-time.

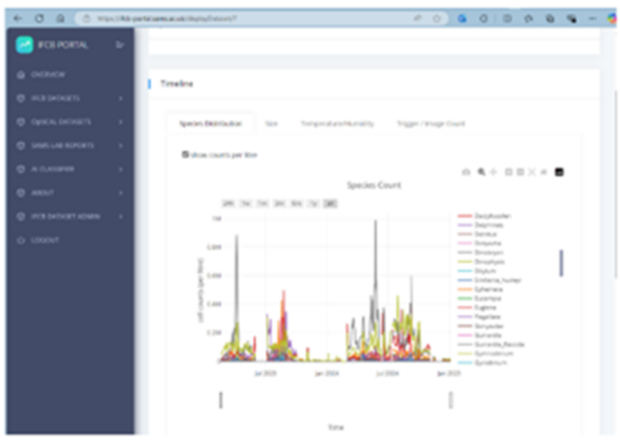

Figure 2. IFCB bespoke dashboard, with AI-classified and enumerated phytoplankton species.

For example, it has tracked changes in the abundance of the harmful diatom *Pseudo-nitzschia* both over long timescales and in short, high-resolution timeframes. These data, now publicly accessible, provide a valuable resource both for aquaculture and marine science more broadly.

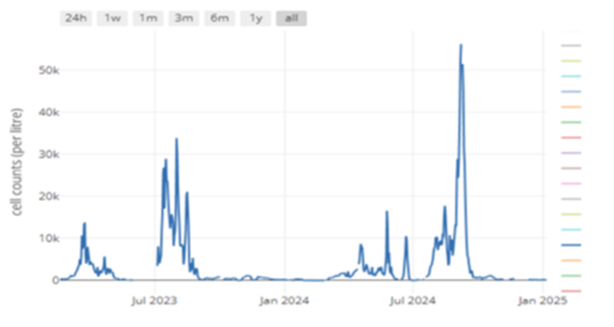

Figure 3a (above) and 3b (below). Pseudo-nitzschia abundance at Cole Deep a) from Feb 2023 - Jan 2025 and b) over a 12-day period in August and September 2024. Taxa identified from images generated by IFCB and reported to the graphing tools in the IFCB Dashboard.

Importantly, IFCB alerts proved effective in triggering model runs, directly linking real-time monitoring with forecasting capability. This integration significantly strengthens the robustness of the early-warning system.

IMPACT

The project delivered a practical, integrated early-warning system for HABs that combines farm-based monitoring, predictive modelling, and automated high-frequency detection. It has improved data sharing between companies, raised awareness of bloom risks, and supported earlier implementation of mitigation strategies such as aeration systems and bubble curtains.

Although HAB frequency was relatively low during the project period, the system is fully operational and ready to respond to future events. The work has also encouraged wider industry investment in monitoring, training, and technology.

Publicly available IFCB datasets extend the project's benefits to other aquaculture sectors and marine stakeholders. The project has also strengthened collaboration between industry and academia and created lasting infrastructure to support fish health and welfare.

The follow-up research that was commissioned to develop a flexible-structure, high-resolution coastal ocean modelling system to enhance forecasting of hydrodynamic conditions in the seas of northern Scotland, Orkney and Shetland has significantly improved HAB early-warning applications for the region, alongside a range of wider benefits outside of aquaculture, and is discussed in a separate case study. Digicat model output is freely available at the SAMS thredds server.

Future development will refine IFCB deployment further and expand monitoring to include other plankton groups, such as micro-jellyfish. Together, these advances ensure Scotland's aquaculture sector is better prepared to manage the risks posed by harmful algal blooms.