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Editorial: Current challenges in providing early warning of harmful algal and microbiological risk to aquaculture

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Editorial on the research topic

Current Challenges in Providing Early Warning of Harmful Algal and Microbiological Risk to Aquaculture

The aquaculture sector is a major industry in Europe's Atlantic Arc. Its continued sustainable growth is required to meet the increasing demand for farmed fish and shellfish. However, such expansion faces several microbiological challenges, with harmful algal blooms (HABs) being prominent among these.

A few species of naturally occurring marine microalgae can produce biotoxins. When conditions are favourable, these organisms can rapidly increase in abundance generating a HAB event. Farmed shellfish feed on these microalgae and can concentrate the biotoxins within their flesh. While the shellfish themselves are not harmed, their consumption poses a risk to human consumers. The impact of shellfish poisoning can range from mild gastrointestinal symptoms to neurological issues and, in extreme cases, may even lead to death.

Blooms of other harmful phytoplankton species have a damaging effect on farmed fish through deoxygenation, toxicity, or damage to the gills. In most cases, consumption of these fish would not be harmful to humans, but the associated production losses can be economically significant for the industry.

HAB and pathogen events are spatially and temporally variable. The aquaculture industry, therefore, relies on early warning indicators of these events to allow for the best possible mitigation measures to be put in place.

The Interreg Atlantic Area funded project PRIMROSE built on the existing HAB forecasting systems developed within the award-winning EU FP7 funded project ASIMUTH (Maguire et al., 2016). The project PRIMROSE delivered improved forecasts of HABs, microbial risks and climate impacts in aquaculture locations encompassing the length of Europe's Atlantic Arc, from the Shetland Islands in the north to the Canary Islands in the South.

The transnational cooperation within PRIMROSE allowed for the generation of best practices and methodologies for HAB, biotoxin and microbial early warning indicators to be shared among the partner countries, allowing enhanced risk assessment.

This special issue summarises the developments in HAB early warning indicators through PRIMROSE in the European Atlantic Arc, while also showcasing similar developments in other geographical regions.

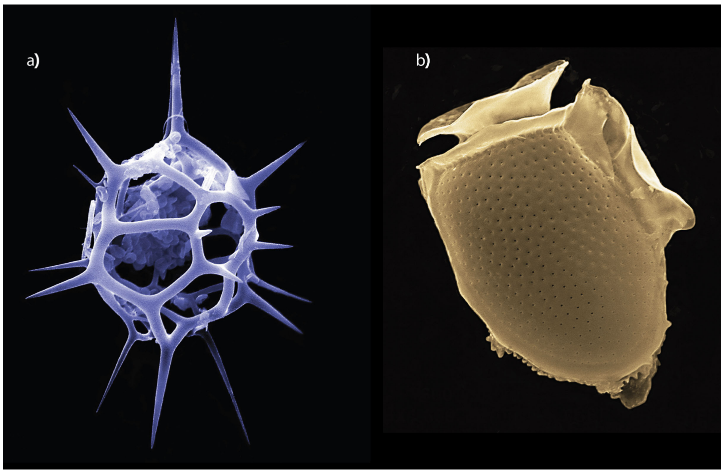
Early detection of HABs is key to providing the aquaculture industry with sufficient time to undertake mitigative measures. Several authors highlighted the role of remote sensing in this process. Martinez-Vicente et al. presented results from laboratory experiments that were conducted to improve existing algorithms for the satellite detection of the important fish killing dinoflagellate *Karenia mikimotoi*. The application of the laboratory-derived training dataset improved the ability of the algorithm to distinguish between high turbidity and high chlorophyll (phytoplankton) concentrations.

A different approach to the use of remote sensing for the detection of *K. mikimotoi* was undertaken by Jordan et al., who demonstrated the potential use of the "red band difference" algorithm, that was originally developed to monitor a different harmful species of the same genus (*Karenia brevis*) in the US. The study found success with this approach in European waters, with the potential to couple the remote sensing to a Lagrangian particle tracking model to then predict the future progression of the bloom as it advects across the shelf. Lin et al. also addressed satellite-derived ocean colour measurements and Lagrangian particle tracking. In this work the authors developed a prediction scheme to merge the satellite observations and the model data, thus enhancing the capability to interpret HAB risk.

The use of Lagrangian modelling approaches was prominent in other studies in this issue. Beddington et al. reviewed the performance of three different modelling systems against historical bloom events, confirming that such particle tracking tools can be usefully integrated operationally into HAB early warning systems. Hariri et al. discuss the combination of Lagrangian modelling with molecular analyses that can provide more information on the species composition of the taxa of interest. In another case, the role of molecular approaches combined with flow cytometry was evaluated by Mirasbekov et al. as a means for better identification of HAB taxa.

Operational early warning indication using a FVCOM based high-resolution unstructured grid mathematical model for Scottish waters was demonstrated by Davidson et al. This contribution also summarised the Scottish HAB early warning system and its use by the aquaculture industry. The need for such reactive early warning approaches was confirmed by Gianella et al. who used PCA and K-means to statistically demonstrate the spatial and temporal variability of HABs in Scottish waters.

The status of HAB and shellfish biotoxin EWS approaches Europe-wide, and an evaluation of the similarities and differences in separate regions was summarised by Fernandes-Salvador et al. Their paper considered the potential to further improve these EWS through multi-disciplinary approaches combining heterogeneous sources of information.



GRAPHICAL ABSTRACT
Enhanced colour image scanning electron microscope of two harmful phytoplankton **(A)** *Dictyocha* sp. and **(B)** *Dinophysis acuminata*.

Mitigation of HABs is problematic and was not ignored within this Research Topic, being addressed by Zhang et al., who examined the effects of natural extracts of the edible brown algae *Sargassum fusiforme* on the growth of some important HAB species as one possible method of intervention.

Microbial pathogens such as *Vibrio* or *Ecoli* can also accumulate in shellfish. Occurrences of these pathogens can lead to gastrointestinal health implications for anyone who consumes contaminated shellfish. But novel microbial challenges may also pose a risk to aquaculture. In this issue, for instance, Mateus et al. discuss the potential for shellfish to be a reservoir for the SARS-CoV-2 virus and the potential need to consider the incorporation of SARS-CoV-2 detection strategies within regulatory shellfish monitoring programmes.

The development of new technologies for harmful algal blooms is likely to be key to the enhancement of early warning systems for HABs to protect aquaculture. A range of novel technologies applied within PRIMORE are described by Ruiz-Villarreal et al.

The articles of this Research Topic demonstrate the 'state of the art' in HAB early warning systems in European waters. Remote sensing and molecular approaches continue to develop to supplement the "core" microscope-based methods for HAB detection. Early warning systems are targeted to the specific challenges in different countries and regions but utilise similar approaches with data sharing in different countries. The issue demonstrates the considerable developments and success in the application of Lagrangian mathematical model-based alerts for the HAB taxa that are transported advectively on oceanographic currents.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Reference

Maguire, J., Cusack, C., Ruiz-Villarreal, M., Silk, J., McElligott, D., and Davidson, K. (2016). Applied simulations and integrated modelling for the understanding of toxic and harmful algal blooms (ASIMUTH): Integrated HAB forecast systems for europe's Atlantic arc. *Harmful Algae* 53, 160–165. doi: 10.1016/j.hal.2015.11.006.