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# Integrated management of Harmful Algal Blooms (HABs) along the French Channel area. A system approach to assess and manage socio-economic impacts of HABs

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## Abstract

HABs occur naturally, but human activities that disturb ecosystems seem to play a role in their more frequent occurrence, intensity and spatial extent (Hallegraeff et al., 2004). Increased nutrient loadings and pollution, food web alterations, non-native species, current modifications and climate change all play a role (NOAA, 2018). Regarding impacted economic activities, HAB events are managed on a crisis basis, leading to closures of contaminated areas and/or ban commercial products based on *in situ* monitoring and alert systems. Developments in remote sensing science can bring a significant added value to existing monitoring systems. For instance, remote sensing can support the development of an alert system that could result in much faster response times. To assess to which extent it can mitigate the socio-economic impacts of HABs (monitoring and management costs, avoided economic losses, risk management by stakeholders), but also to understand the adaptation dynamics of economic activities to HAB events and the way they are managed, a system approach has been implemented to describe the HAB socio-ecosystem of the French-administrated part of the English Channel. It will help to address the intrinsic complexity of HABs and their impacts.

**Keywords:** marine toxins, system approach, economic impact, French part of English Channel, scallop fishery

## Introduction

Economic and human health impacts of HABs increased over the last decades in relation with increased nutrient loadings and pollution, food web alterations, non-native species, current modifications and climate change. Growth of economic activities attached to the exploitation of coastal and marine resources (fisheries, aquaculture, tourism and recreational activities are most important ones) have also contributed to increasing impacts.

At the same time, research and knowledge about HABs and especially factors that contribute to HABs, have developed strongly, following the development of monitoring systems. Still, how these factors come together to create a bloom of algae is not well understood (NOAA, 2018). As a consequence, HAB events are managed on a crisis basis, leading to administrative closures of impacted areas to human activities relying on the use of contaminated resources. Existing monitoring and systems are often costly, spatially limited and not very responsive due to time constraints for toxicological analyses.

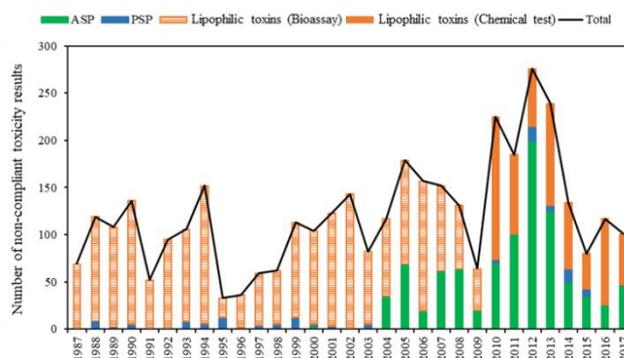


Fig. 1. Evolution of non-compliant results of toxicity/toxin testing over the 3 last decades (1987 – 2017) along the French Channel (data extracted from REPHYTOX monitoring network).

Remote sensing can thus bring a significant added value to existing monitoring systems. Using material from the Copernicus S-3 satellite, the Interreg France (Channel) England S-3 EUROHAB project is tracking the growth and spread of HABs in the Channel. These data will then be used to create a web-based system to alert

marine managers and fishing industries to the growth of potentially damaging algal blooms. The alert system should result in much faster response times. Data gathered will also help to better understand why, how and when HABs occur.

Facing HAB complexity, a system approach is implemented as a holistic and integrated approach to better assess and map HAB impacts over the Channel socio-ecosystem and their management, to address how far the proposed Web based alert system is able to mitigate these socio-economic impacts, and how economic activities are able to adapt to occurrences of HABs. Results will be used to feed and calibrate a regional economic model (I/O model) that will quantitatively assess the socio-economic costs of HABs along the French part of the English Channel for all potential affected activities. It will be also later used to explore scenarios for alternative management and refine the design of the web-based alert system.

## Materials and Methods

### *Mapping of management processes, activities and impacts of HABs along the French Channel*

An identification of economic activities impacted by HAB events was implemented in order to better understand HAB process from a monitoring and socio-economic point of view. This allows for mapping a first draft of the HAB system along the French part of the English Channel.

A DPSIR (Driver, Pressure, State, Impact, Response) framework was used to help building and mapping the system. It allows for an exhaustive and holistic view of HAB issues. Updates of mapping were made according to feedbacks from participative stakeholder workshops and interviews based on a shared and common view of the HAB system. Stakeholders were representatives of all potentially affected users as well as stakeholders in charge of the management of HAB events.

### *A system approach to address socioeconomic dimensions of HABs: beyond the assessments of impacts*

The socio-economic dimensions of HABs go beyond the assessment of economic impacts. There is a lack of detailed information on human activities, especially regarding recreational ones. There are still ongoing debate and controversy about methods used for the assessments of economic impacts (mainly for non-market use). Sector-based assessments do not take in account cascade effects to other sectors. There is an important heterogeneity of individuals and companies rendering global evaluation complex.

There are different sensibilities to risk exposure and then different coping capacities and adaptation strategies. This results in different vulnerability profiles. There is also the need to take into account feed-back mechanisms and dynamics through adaptation strategies (individual and collective actions) and changes in regulation. To address this complexity and integrate the different socio-economic dimensions of HABs, a system approach is then applied (Bertalanffy 1968, Checkland 1999, Forrester 1961).

### *Application of the System Approach to the scallop fishery in the eastern Channel*

The scallop fishery in the eastern Channel is the most important shellfish fishery in France. It counts for more than 250 fishing vessels, operating from October to May (legal fishing season). The annual production in 2017 was about 22,000 tons for a turnover of € 70 million. The fishery is strongly regulated in terms of fishing calendar, production areas, quotas, fishing trips and a minimum legal size of catch (11 cm). Due to the occurrences of HAB events, production areas can be closed leading to losses in production or additional cost to reach other remote and open production areas. The application of the System Approach to the scallop fishery proceeds with the characterisation of the monitoring subsystem and its spatial confrontation to the characterisation of the fishery subsystem (Figure 2).

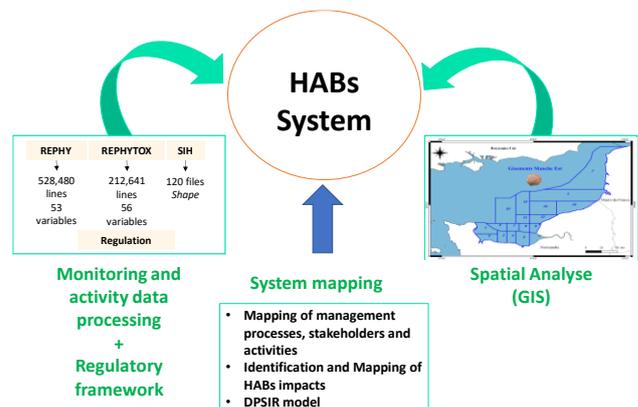


Fig. 2. Spatial confrontation of scallop fishery to HAB occurrences and the regulatory framework.

Data used for the spatial analysis are Phytoplankton cells count per litre and Phycotoxins concentration in shellfish from the REPHY and REPHYTOX monitoring networks managed by Ifremer, and production and value of scallops from the fisheries information system of Ifremer (SIH).

### Assessment protocol of HAB risks over the fishing activity

The confrontation of monitoring data to the regulatory framework leads to the definition and construction of a protocol to derive a theoretical number of bans from HAB events integrating all toxins relevant to scallops. Using the R software, an algorithm was built to convert the abundance of toxic phytoplankton into a number of bans and duration of ban for each production areas (18 production areas). The script relies on a logical framework integrating regulatory information for each toxin and exploited species. A calendar of closures/openings was generated based on the results of the REPHYTOX monitoring network analysis. This calendar was then crossed with the fishing calendar, which is used for resource management purposes. Results from this cross-checking was finally used to generate the duration of bans expressed in days (Chenouf et al. 2020). This was later expressed through an indicator of loss rate of access days to fishing areas (Figure 3).

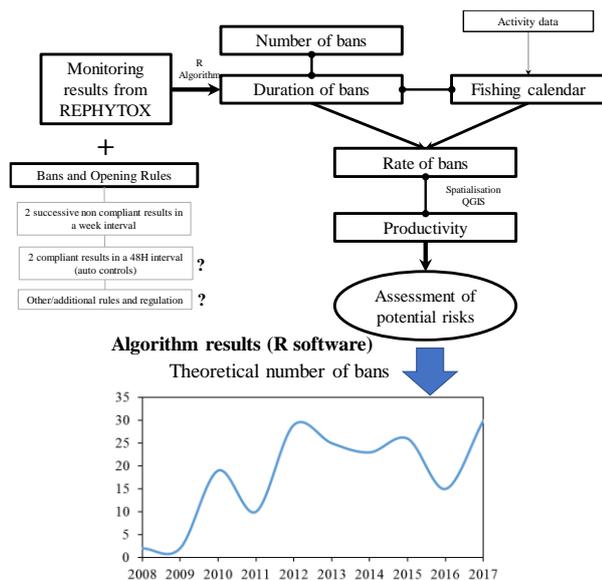


Fig. 3. Assessment protocol of HAB risks over the fishing activity

From 1988 to 2017, data used were:

- the abundance of toxic phytoplankton
- the number of alerts (evidence of phycotoxins impacting scallop species)
- the number of non-compliant results (results above the legal threshold)
- the number of bans and duration of bans per production area obtained from the R Algorithm.

The processed loss rate of access days to production areas was then confronted to the inter-annual production of scallop per production area to assess the risk exposure of the scallop fishery to HAB events. From the superposition of the two pieces of information a map of exposure to the HAB risk, based on the previous observation decade (2008-2017), was produced for each month of the fishing season (8).

### Results and Discussion

The 8 monthly maps of exposure to the HAB risk form an atlas of HAB risk for the scallop fishery (Figure 4).

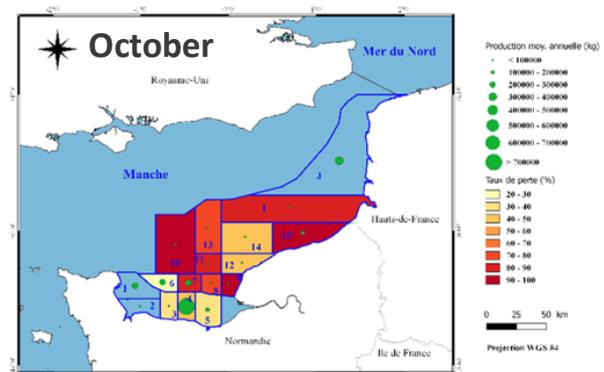


Fig. 4. Exposure map to the HAB risk for the October month.

The maps underline a strong exposure risk for the most important fishing period (from October to December) when production and prices are the most important. The potential for a web-based alert system seems to be quite important for this key period of the fishing season. The maps could be provided at a lower time scale, e.g. to assess the risk on a weekly basis, allowing fishermen to avoid risky areas. The web-based alert system would support fishermen by providing them with more detailed spatial information and almost real-time information to reduce potential losses of production due to contaminated areas.

But if threats in terms of HABs are naturally expressed in terms of negative impacts, the maps can also underline or question other impacts that could be positive. First when a HAB event occurs leading to a ban of one or several production areas, there are often no real losses of production for fishermen as they can redeploy their fishing effort to other production areas as underlined by the maps. This is particularly true for the eastern Channel where production areas are numerous (18). As a number of alternatives, some neighbouring production areas can remain opened

and accessible, fishing vessels can also be polyvalent and switch to other gears and species.

Reallocation of fishing effort over other production areas following occurrences of HAB events may then have consequences. Some of them could be either positive or negative. For instance, the closure of a production area can act as a biological rest and support stock dynamics. When the area is reopened after a long period, catches can also reach a premium market size with a significant added value for fishermen. Similarly, a more limited production due to HAB events can also be balanced by increasing prices at auctions for a scarce resource. But at the same time, the reallocation of fishing effort to other areas can lead to an overexploitation in these areas and to potential conflicts with other fishermen. The increase in production due to alternatives can also lead to decreasing prices.

There could be a balance between negative and positive impacts of HABs and they may act as a regulator of the scallop fishery in the eastern Channel.

There is thus a need to take into account the dynamics induced by the reallocation of fishing effort. This would require to work at a daily time scale and at the fishing vessel unit, to couple bio-economic models to HAB occurrences in order to assess the threshold above which HABs act as regulators or destructors of economic activities.

This potential regulator role of HABs can significantly impact the support from remote sensing through the proposed web-based alert system. Such an alert system can be positive if it contributes to alleviate the HAB constraints and the monitoring and control costs: mitigation of bans and associated costs, optimizing own checks, storage... But it questions the operational time scale of the tool (adverse effects for management purpose) and alleviating HAB constraints could also contribute to increase the fishing effort over the stocks.

The HAB system is a complex and dynamic system with a multivariate risk level. The System

Approach to HABs is a useful, holistic and shared representation of HABs, allowing to reveal hidden impacts of HABs. The definition and construction of an analysis protocol to translate monitoring and surveillance data into a risk exposure atlas through management measures can be replicated to other species, activities and areas. This a first use of data from the REPHY/REPHYTOX networks to a management purpose.

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