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, introduced species, water flow modifications and climate change all play a role (NOAA, 2018). Regarding impacted economic activities, HABs events are managed on a crisis basis, leading to close 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 HABs events and the way they are managed, a system approach has been implemented to describe the French Channel HABs socio-ecosystem. It will help to address the intrinsic complexity of HABs and their impacts.

Keywords: marine biotoxins, system approach, economic impacts, French 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, introduced species, water flow modifications and climate change. Growth of economic activities attached to the exploitation of coastal and marine resources (fisheries, aquaculture, tourism and recreational activities for the 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, has developed strongly, following the development of monitoring systems. But how these factors come together to create a bloom of algae is not well understood (NOAA, 2018). As a consequence, HABs events are managed on a crisis basis, leading to close impacted areas to human activities relying on the uses of contaminated resources. Existing monitoring and systems are often costly, spatially limited and not very responsive due to time constraints for toxicological analyses.

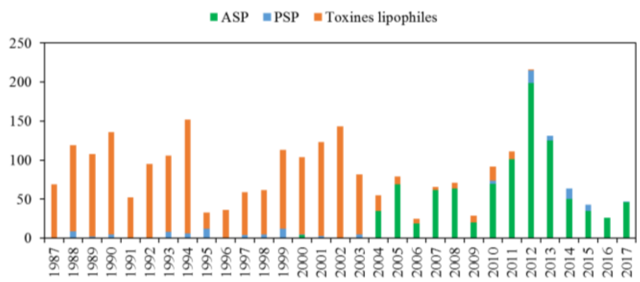

Fig. 1. Toxicity events in the Channel area. Evolution of non-compliant results of phycotoxins (shellfish poisoning) analyses over the 3 last decades (1987 – 2017) along the French Channel.

Remote sensing can then 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. This data will then be used to create a web based alert system to alert marine managers and fishing industries of the growth of potentially damaging algal blooms.

The alert system should result in much faster response times. Data gathered will also help better understand why, how and when HABs occur.
Facing HABs' complexity, a system approach is implemented as a holistic and integrated approach to better assess and map HABs' 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 Channel. It will be also later use to explore scenarios for alternative management and refine the design of the web based alert system.

Material and Methods

Mapping of management processes, activities and impacts of HABs along the French Channel
An identification of economic activities impacted by HABs events as well as stakeholders impacted or in charge of management of HABs events was implemented in order to better understand HABs process from a monitoring and socio-economic point of view. This allows for mapping a first draft of the HABs system along the French 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 HABs issues. Updates of mapping were made according to feedbacks from participative stakeholder workshops and interviews based on a shared and common view of the HABs system.

A system approach to address socioeconomic dimensions of HABs: beyond the assessments of impacts
The socioeconomic dimensions of HABs go beyond of the assessment of economic impacts. There is a lack of detailed information about human activities, especially regarding recreational ones. There are still ongoing debates and controversies about methods used for the assessments of economic impacts (mainly for non-market uses). Sector-based assessments don't take in account cascade effects to other sectors. There is an important heterogeneity of individuals and companies that makes complex a global evaluation. There are different sensibilities to risks exposure and then different coping capacities and adaptation strategies. This results in different vulnerability profiles. There is also the need to take in account feed-back mechanisms and dynamics through adaptation strategies (individual and collective action) and changes in regulation. To address this complexity and integrate the different socioeconomic 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 of 250 fishing vessels, operating from October to May (legal fishing season). The annual production in 2017was 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 HABs 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).

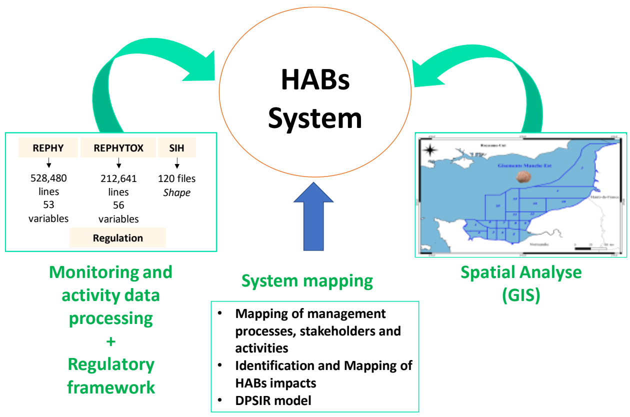

Fig. 2. Spatial confrontation of scallop fishery to HABs' occurrences and the regulatory framework.

Data used for the spatial analyse 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 HABs 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 HABs 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). This was later expressed through an indicator of loss rate of access days to fishing areas (Figure 3).

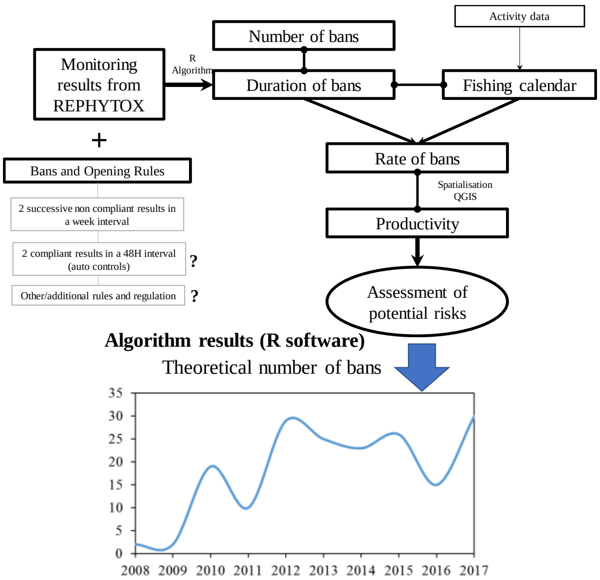

Fig. 3. Assessment protocol of HABs risks over the fishing activity

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 HABs events. From the superposition of the two information a map of exposure to the HABs risk, based on the previous observation decade (2008-2017) is produced for each month of the fishing season (8).

Results and Discussion

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

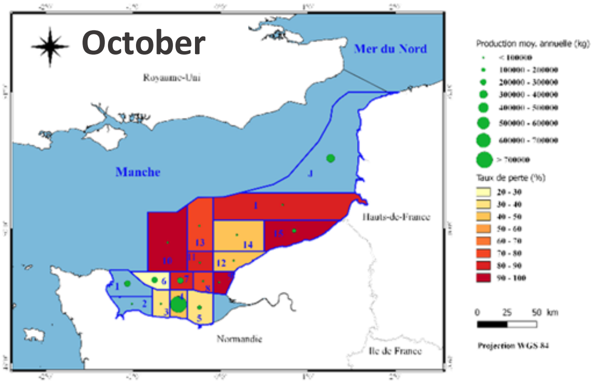

Fig. 4. Exposure map to the HABs risk for the October month.

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 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 to detail the risk according a weekly time scale for instance, allowing fishermen to avoid risky areas. The Web alert system could 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 often expressed in negative impacts as underlined by the introduction to Toxic and Harmful Microalgae of the World Ocean (Lewis et al. 2016): “harmful algal blooms (HABs): micro-organisms that deplete fish stocks, destroy fish farms and bring disease and death both to humans and to marine mammals”, the maps can also underline or questions other impacts that could be positive.
First when a HABs 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 HABs 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 the health of the stock. 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 HABs 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 regulators of the scallop fishery in the eastern Channel.

There's then 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 model to HABs occurrences in order to assess the threshold over 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 alert system can be positive if it contributes to alleviate the HABs constraints and the monitoring and control costs: mitigation of bans and associated costs, optimizing auto controls, storage… But it questions the operational time scale of the tool (adverse effects for management purpose) and alleviating HABs constraints could also contribute to increase the fishing effort over the stocks.

The HABs 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 for revealing 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 others species, activities and areas. This a first use of data from the REPHY/REPHYTOX networks to a management purpose.

Acknowledgements

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