Project	AtlantOS – 633211
Deliverable number	8.6
Deliverable title	**Harmful Algal Bloom Bulletins**
Description	**Use Case Title:** Harmful Algal Blooms **Environmental matrix of interest (Air, Ice, Mar. Water, etc.):** Marine **Study Regions:** Shelf Seas in Norway, Ireland and Spain **Dissemination Method:** Web Providing near real-time and forecast information for the aquaculture industry along Europe's Atlantic coast is of vital importance in mitigating the effects of HABs. In this task, *In-situ* and satellite data will be amalgamated in a decision support system. *In-situ* data include oceanographic data e.g. water column structure, current speeds, biological samples (e.g. algal toxins, phytoplankton cell counts, barcoding) and hydrographic and biogeochemical information where possible. The *In-situ* data will be used to inform and validate biophysical models and to produce circulation forecasts for the coming three to five days. These data will undergo expert interpretation to produce an early warning bulletin to the aquaculture industry in Spain, Norway and Ireland. The bulletin will be distributed over a specified production season to fish farmers and shellfish production facilities so that husbandry and harvesting techniques can reflect the prevailing HAB conditions at any point in time.
Work Package number	8
Work Package title	Societal benefits from observing/information systems
Lead beneficiary	Marine Institute, Rinville, Oranmore, Co. Galway, Ireland. Web: wwww.marine.ie; Email: caroline.cusack@marine.ie Foras na Mara Marine Institute
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Submission date	Bulletins for Ireland and Norway were available online before 30th March. Spanish Bulletin will be available in spring, 2018.
Due date	Month 36 (April 2018)
Comments	n/a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 633211.

Stakeholder engagement <u>relating to this task</u>*

WHO are your most important stakeholders?	Private company (SMEs) National governmental body Others: please see details in the report Please give the name(s) of the stakeholder(s): please see details in the report
WHERE is/are the company(ies) or organization(s) from?	EU and Norway
Is this deliverable a success story? If yes, why? **If not, why?**	Yes we can say that "This deliverable can be considered a success story because we have demonstrated that we can provide a HAB bulletin that has benefits for the aquaculture industry. It can enable them to: • Optimise ongrowing and harvesting techniques to reduce mortality due to anoxia and/or allow farmers time to harvest (particularly shellfish) before a prolonged closure and thus enhancing productivity. • Increase efficiencies, production and sales by optimizing harvesting schedules and reducing mortalities in fish farms. • Save money and maximise their resources by avoiding such losses. • Remove the guesswork involved in when bay closures will occur so that farmers can make informed choices. • Move or harvest stock to avoid the impact of blooms. • Plan husbandry work in relation to future bloom or non-bloom events. • Reduce downtime for processors if product can be stockpiled in advance before the onset of a bloom. • Improve the service to their customers with a more reliable supply of product. In addition for government agencies and scientists the HAB bulletin provide them with information to plan their sampling schedule more efficiently particularly when a severe or unusual bloom is expected. The collaborative nature of this task has also facilitated • Progress on developing a community "best Practice" to share with others interested in developing a HAB bulletin for other regions in the Atlantic and elsewhere.
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	Yes, it is already in use by scientists, regulators and the aquaculture industry.

Table of Contents

Executive summary

The H2020 AtlantOS project strategy is to improve, enhance and integrate the existing ocean observing activities in the Atlantic Ocean following the recommended high level process described in “A Framework for Ocean Observing” (Lindstrom *et al.* 2012).

Work Package 8 “Societal Benefits from observing/information systems” of AtlantOS seeks to provide leadership for Europe in the Atlantic implementation of GEOSS in five areas of societal benefits related to climate, disaster resilience, biodiversity and ecosystems, public health surveillance and water resource management.

As one of the seven AtlantOS WP8 pilot actions seeking to demonstrate the value and societal benefit of the existing observing system, Task 8.1 focuses on Harmful Algal blooms in NW Atlantic European shelf and coastal waters off Norway, Ireland and Spain. In this document, we discuss components of the end-to-end system used in the targeted product (a weekly HAB bulletin) and its subcomponents developed/used in the AtlantOS pilot action for “Harmful Algal Blooms”. Progress related to stakeholder engagement, HAB bulletin production and a “best practice” document developed to share knowledge on “how to create a weekly HAB bulletin” with the wider community are discussed.

A downstream HAB bulletin is produced by integrating information (e.g. data products) from multiple disciplines (physics, biogeochemistry, biology & ecosystems) along the long ocean observing value chain that are interpreted by local experts to determine the HAB outlook in an online published HAB bulletin (Fig. 1). Custom-built reports for the target areas in Norway (proof of concept), Ireland (operational for a number of years) and Spain (weekly delivery scheduled in spring 2018) are linked to the AtlantOS webpage. Background information on the design and content of the bulletins are presented and described in this report.

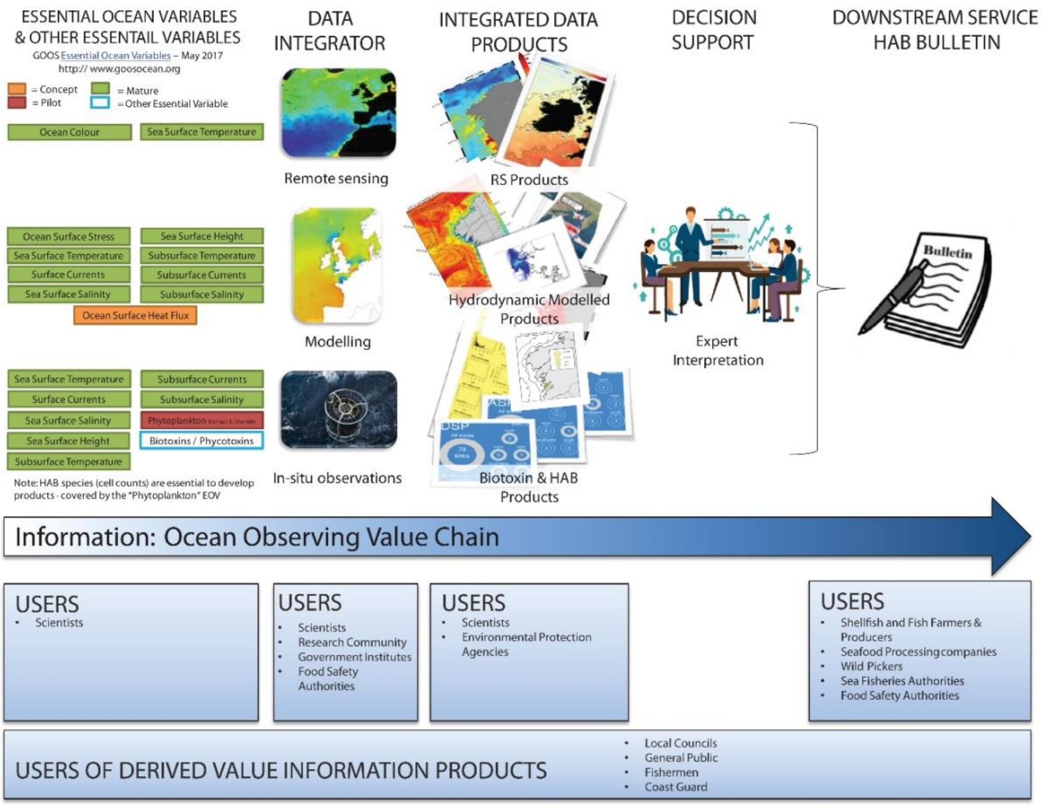


Figure 1. Harmful Algal Bloom Bulletin Production: Application of knowledge along the value chain from *In-situ*, satellite and modelled integrated data through to a knowledge targeted product i.e. HAB bulletin production. The "Users" of data products along the chain are identified.

Glossary: Definitions, Acronyms and Abbreviations

Name/Acronym	Meaning
ASP	Amnesic Shellfish Poisoning
BIM	Board Iascaigh Mhara (Irish Fisheries Board)
CMEMS MCS	Copernicus Marine Environmental Monitoring Service (DG Growth) Marine Core Service
DSP	Diarrheic Shellfish Poisoning
EMODnet	European Marine Observation and Data network (DG Mare) with discipline based themes, an EU programme to support the further development of an Integrated Maritime Policy (Reg. EU 1255/2011)
FEAP	Federation of European Aquaculture Producers (the united voice of the European Aquaculture Industry)
GEOSS	Global Earth Observation System of Systems – Group on Earth Observations "a set of coordinated, independent Earth observation, information and processing systems that interact and provide access to diverse information for a broad range of users in both public and private sectors".
HABs	Harmful Algal Blooms are biological events caused by a small number of phytoplankton species. There are two main types of HABs • High biomass blooms that produce toxins harmful to marine fauna and farmed fish/shellfish and/or cause anoxic conditions to occur resulting in environmental conditions that are unfavourable to marine life and farmed species. Blooms can occur naturally, although in some parts of the world such as Hong Kong and parts of the USA the proliferation of certain HAB species have been attributed to anthropogenic nutrient enrichment. • Low biomass blooms that produce biotoxins can accumulate in shellfish and throughout marine food-webs. If consumed by humans a variety of illnesses can result, the severity of which depends on the causative organisms and the biotoxins they produce.
NOAA	The National Oceanic and Atmospheric Administration is an American scientific agency within the United States Department of Commerce
PSP	Paralytic Shellfish Poisoning
SST	sea surface temperature
ROMS	Regional Ocean Modelling System
Use Case	The AtlantOS Task i.e. pilot action / feasibility study
Use Case Product	Targeted Product e.g. HAB bulletin. A Targeted product build from "input data sets" that are related to "characteristics" and/or Essential Ocean Variables. A Product/Service is a Solution to an end-user requirement

Introduction

The AtlantOS Harmful Algal Bloom (HAB) task is focused on three study areas located in marine waters of Norway, Ireland and Spain where the aquaculture sector face a number of HAB related issues briefly described below.

In 2014, Norway accounted for 58 % of the total European aquaculture production (FEAP, annual report, 2015). The value amounted to 44.3 billion NOK (kr) for 1,332,497 metric tonnes. Salmon accounted for 99.6 % of the total production (www.ssb.no) with fish farming activities located all along the Norwegian west coast. There is a long history of substantial losses to fishfarms related to HAB events in Norway (e.g. Skjoldal & Dundas 1991, Naustvoll *et al.* 2002). In recent years, there was a reduction in the documented accounts of exceptional HABs that threaten fish. However, many ichthyotoxic (toxic to fish) species remain a regular component of the Norwegian marine microflora e.g. *Karenia mikimotoi, Karlodinium veneficum, Prymnesium parvum, Prymnesium polylepis* and *Pseudochattonella farcimen*. In Norway, shellfish production volumes of primarily blue mussels are low and geographically restricted to coastal regions of mid-Norway e.g. Trøndelag and Nordland. It is common for the Norwegian public to harvest wild shellfish. When levels of phytoplankton biotoxins exceed regulatory limits, shellfish farms are closed and the public are advised not to consume wild shellfish (www.matportalen.no/verktoy/blaskjellvarsel).

In Ireland, biotoxins produced by phytoplankton are ranked as a top issue in terms of industry challenges (PricewaterhouseCoopers, 2006). The SW coast of Ireland is an area where intense aquaculture activity takes place; 70 % of the countries longline rope mussel and native oysters are farmed. The estimated mean annual loss to the local economy due to toxin producing HABs is ~ € 530,000 (Cusack *et al.* 2016). Fish farms in the area can also suffer when high biomass blooms that produce ichthyotoxins such as the dinoflagellate, *Karenia mikimotoi* arrive in the bays.

The main dinoflagellates causing toxic outbreaks in Galicia, Spain are *Dinophysis* spp. (*Dinophysis acuminata* and *Dinophysis acuta*) and *Gymnodinium catenatum* associated with Diarrhetic (DSP) and Paralytic Shellfish Poisoning (PSP) events, respectively. Recurrent closures associated with *D. acuminata* occur every year from spring to autumn, although there is strong interannual variability in the duration of the closures (Reguera *et al.* 2012). In the autumn transition, from upwelling to downwelling favourable conditions at the end of summer, blooms of toxic dinoflagellates (*D. acuta, G. catenatum*) can appear in some years (Diaz *et al.* 2016, Ruiz-Villarreal *et al.* 2016). These autumn blooms cause high economic losses to the shellfish industry, especially when closures last for several months and include the winter (Christmas) harvest season (Rodriguez-Rodriguez *et al.* 2011).

Table 1 below lists the main biotoxins of concern and associated HAB phytoplankton responsible for economic losses to the NE Atlantic aquaculture industry. Shellfish farms in Norway, Ireland, and Spain can experience prolonged periods of closures due to HABs (Naustvoll *et al.* 2002, Cusack *et al.* 2016, Reguera *et al.* 2012). Strict EC Regulations are enforced to reduce the risk of contaminated seafood entering the market (e.g. Reg. EC No 853/2004). The shellfish sector is, therefore, heavily monitored to safeguard human health. National programmes, in place in Spain [Galicia; Andalusia], Ireland and Norway, provide vital information to manage aquaculture production areas which are closed when shellfish are contaminated with HAB produced toxins.

Since scientific data is not easy to interpret by non-scientists, HAB information / warning bulletins were developed to disseminate the "big picture" information to a wide audience using easy to interpret plots and explanatory text. The HAB bulletin summaries and forecasts are based on local expert opinion. The summaries provide industry with additional information that can assist with their day to day farm management decisions and help them plan husbandry and harvesting operations in order to minimise risk. Providing near real-time and, when possible, forecast information for the aquaculture industry is of vital importance in mitigating the effects of HABs. In this task, partners amalgamate *In-situ* and satellite data, and available hydrodynamic modelling products in a decision support system to produce a weekly HAB bulletin (PDF format) for the aquaculture industry in Norway, Ireland and Spain (Fig. 1). The HAB bulletin (targeted product) is made up of subcomponents which are output data products from multiple sources (see examples in). Many of the subcomponents of the HAB bulletin are created offline and then compiled by scientists to create a bulletin that is published online. The *In-situ* data streams help to inform decision makers (e.g. biotoxin data determines aquaculture production area closures) and are used to validate numerical models that produce circulation forecasts for the coming three to five days.

A proof of concept of the generation and dissemination of bulletins for HAB forecasts integrating *In-situ*, satellite and modelling results was performed in different Atlantic regions during the EC FP7 ASIMUTH project (Maguire *et al.* 2016). The bulletins were produced on a weekly basis for a demonstration period during the project and some such as the Irish and Scottish HAB warning bulletins continued post project *Scottish HAB warning system*(further developed and funded through EU and national projects such as AtlantOS, the Natural Environment Research Council and Biotechnology and Biological Research Sciences Council). In the USA, several HAB warning systems have been developed through a collaborative effort between researchers and government (NOAA) e.g. Californian and Gulf of Mexico warning systems that target high biomass toxic algae; *Pseudo-nitzschia australis* and *Karenia brevis* through national research and state support. Other examples, mostly at the research stage of development can be found in Anderson *et al.* (2015).

Table 1. Biotoxin chemical groups and associated HAB producers in NW European waters; parameters are reported on in the HAB bulletin.

Type of data	**Parameter**	**Unit**	**Comment**
Hydrophilic toxins	PSP in shellfish	µg STXdiHCl-eq./kg [Irish reports as µg/g]	Saxitoxin (STX)-group toxins [Saxitoxin Grp 30+]; EC Regulatory Limit: 800 µg/Kg (80 µg/g; Produced by the dinoflagellates *Alexandrium* spp. *Gymnodinium catenatum* (recorded in Spain and Portugal, but, not in Ireland or Norway) *and Pyrodinium bahamense* (not a concern in Europe)
Hydrophilic toxins	ASP in shellfish	mg domoic acid and epi-domoic acid/kg [Irish reports as µg/g]	Domoic acid (DA); EC Regulatory Limit: 20 mg/Kg or 20 µg/g; Produced by the diatoms *Pseudo-nitzschia* spp.
Lipophilic toxins	OA group in shellfish	µg OA eq./kg [Irish reports as µg/g]	Okadaic acid (OA) and analogues [Ireland this refers to Okadaic Acid, DTX-1 DTX-2, esters]; PTXs should be expressed in the OA eq. group; EC Regulatory Limit: 16 µg/kg or 0.16 µg/g; Produced by the dinoflagellates *Dinophysis* spp. and *Prorocentrum lima*
Lipophilic toxins	PTXs in shellfish	µg OA eq./kg [Irish reports as µg/g]	Pectenotoxin (PTX)-group toxins; EC Regulatory Limit: 16 µg/kg or 0.16 µg/g; Produced by the dinoflagellates *Dinophysis* spp.
Lipophilic toxins	AZP in shellfish	µg AZA eq./kg [Irish reports as µg/g]	Azaspiracid (AZA)-group toxins; [Azaspiracid. 30+ analogues] Only AZA-1, -2 and -3 regulated for; EC Regulatory Limit: 16 µg/kg or 0.16 µg/g; Produced by the dinoflagellates *Azadinium* spp.
Phytoplankton	*Alexandrium*	Cells/L (cells per litre)	Reported at genus level
Phytoplankton	*Pseudo-nitzschia*	Cells/L (cells per litre)	Reported at genus and sub-group level
Phytoplankton	*Dinophysis*	Cells/L (cells per litre)	Reported at genus and species level
Phytoplankton	*Azadinium*	Cells/L (cells per litre)	Reported at genus [*Azadinium*-like cells] level
Phytoplankton	*Karenia*	Cells/L (cells per litre)	Reported at genus and species level

Note: “in shellfish” in the Irish case, information for the HAB bulletin, only refers to to biotoxin levels in the whole flesh of mussels and oysters.

Table 2. Summary of the optional subcomponents used to create a HAB bulletin.

No.	Product Name	Short Description	Format(s)*
1	HAB Outlook	Predictions for the coming days are provided by local scientists.	Text in the PDF
2	*In-situ* HAB & biotoxin products	HABs and Biotoxins results are presented temporally and spatially in maps, plots and tables. (a) HAB & Biotoxin current conditions (b) Biotoxin prediction (c) Biotoxin historic trends (d) HAB & Biotoxin distributions and abundances in recent weeks (e) HAB & Biotoxin weekly trends for the current year (f) Top five most abundant phytoplankton taxa	Generated R plots and tables form parts of the bulletin (PNG file format) SQL table report of top predominant phytoplankton species.
3	Remote sensing products	The most up-to-date daily Satellite map is presented to provide large spatial scale information on surface phytoplankton blooms (Chl a measurements) and sea surface temperature (SST). (a) Chlorophyll *a* levels and distribution (b) Chlorophyll *a* anomaly levels and distribution (c) Sea Surface Temperature levels and distributions	R derived plots (PNG file format)
4	*In-situ* Chl a, sea surface temperature, sea surface salinity products	The most up-to-date *In-situ* data are presented to provide small to medium spatial scale information on surface phytoplankton blooms (Chl a measurements), sea surface temperature (SST) and sea surface salinity. (a) *In-situ* Chlorophyll a (b) *In-situ* Sea Surface Temperature (c) *In-situ* Sea Surface Salinity	Matlab derived plots (PNG file format)
	Model simulation products	3D hydrodynamic numerical models create predicted water column structure (temperature, salinity and density profiles) at target bay mouths / bay axis / shelf sections, simulated predictions of inflow/outflow (e.g. volumetric fluxes) at the mouths of bays and alongshore transport and lagrangian particle trajectories that represent the possible modes of transport of offshore phytoplankton. (a) Simulated 3D temperature, salinity and density fields (b) Simulated prediction of volumetric fluxes (c) Simulated prediction of Lagrangian particle tracking	MatLab derived plots (PNG file format) Web based products

* pdf, GIS layers, code, excel Tables, etc.

Identification of User Requirements

Use Case activities included an analysis of target users and a review of user needs. Initial shellfish and finfish farmer user requirements as listed in Maguire (2011).

The main target end-user of the HAB bulletin is the aquaculture industry.

Requirement of the service

1. The phytoplankton species / biotoxin present and the severity.
2. The risks associated with the phytoplankton species / toxin.
3. A prediction of the bloom dynamics over time.
4. Hot spot locations of where a bloom is "likely" to occur.
5. Highlight when a bloom has occurred in neighbouring regions.

Notification of a "likely bloom" should be sent by text and a short bulletin should be made available online to download.

Future projects should focus on providing information accessible via a web portal to include:

1. An on-line mapping tool so that farmers can zoom in to their area.
2. Data on phytoplankton levels and toxin concentrations.
3. Analysis of the current state and outlook for the next few days.
4. An ability to query data by parameter and time period as defined by the farmer.
5. Integrated satellite images (if possible but not essential).

Description of the top ten user needs

The initial list below is taken from the ASIMUTH project (Maguire 2011, 2013, Maguire *et al.* 2016).

A HAB warning system should:

1. Help decision-making to minimise mortalities and financial impacts on farms.
2. Provide advance notice to help improve supply logistics (i.e. ability to manage customers' needs), help increase productivity and help reduce mortalities.
3. Give notice of impending HABs to allow exploitation of mitigating strategies and allow "market management" measures. An example of a previous bloom, which resulted in almost 100 % clam mortality at a particular facility, was given to highlight one candidate's experience. In that instance it would have been better to sell the product at a significantly

lower market price, before the HAB had arrived, rather than losing all of the stock to mortalities.

4. Give at least two to three days warning and if possible four days to one week notice. A two-week HAB forecast would be preferable; however, the sector conceded that this may be impossible so they would settle for a 2-3 day forecast.
5. Provide information on the presence and movement of HABs.
6. Help to protect public health and control fish quality.
7. Have an on-line mapping tool so that farmers can zoom in to their area.
8. Provide data on phytoplankton levels and toxin concentrations.
9. Provide analysis of the current state and outlook for the next few days.
10. Be as reliable as possible. A success rate of > 80 % would be considered acceptable.

The forecast system should enable aquaculturists to:

1. Optimise growing and harvesting techniques to reduce mortality due to hypoxia / anoxia and (or) allow farmers time to harvest (particularly shellfish) before a prolonged closure and thus enhancing productivity.
2. Increase efficiencies, production and sales by optimising harvesting schedules and reducing mortalities in fish farms.
3. Save money and maximize their resources by avoiding such losses.
4. Remove the guesswork involved on when bay closures will occur so that farmers can make informed choices.
5. Plan husbandry work in relation to future bloom or non-bloom events.
6. Reduce errors in husbandry practices and harvesting schedule.
7. Reduce downtime for seafood processors if product can be stockpiled in advance before the onset of a bloom.
8. Improve the service to their customers with a more reliable supply of product.

In addition, the forecast system should provide government agencies and scientists with time to plan their sampling schedule more efficiently, particularly when a severe or unusual bloom is expected.

Understanding stakeholder engagement was further advanced through discussions between AtlantOS WP10 and WP8; results from this collaboration are presented below and included an examination of the Stakeholder Engagement step-by step procedure presented in Figure 2 below.

Figure 2. Stakeholder Engagement step-by step procedure; redrawn from the 2013 U.S. IOOS Summit Report (U.S. IOOS Summit Report: A New Decade for the Integrated Ocean Observing System Copyright © 2013 Interagency Ocean Observation Committee).

Stakeholder Engagement Summary Results

Identify Users

We identified users in all three countries (Norway, Ireland and Spain). Using databases of shellfish/finfish/seafood farmers and processors (e.g. from magazines, Google, national databases) and listed potential users.

Prioritise Users and/or Products

As we were focused on a HAB bulletin as a targeted product in T8.1, we narrowed down potential users based on their main activities - particularly shellfish farmers and organisations involved in seafood safety policy-making.

Define User Requirements

Questionnaires were developed to define what the users would like from a forecast bulletin. In some cases, old questionnaires from similar projects such as the FP7 EU ASIMUTH project were included. The questionnaires were analysed and used to develop and optimise the bulletins. We also contacted users after the bulletins were created to ask for feedback.

Develop Products/Solutions

The HAB bulletin is developed based on results from the questionnaires as well as improved modelling data. This is an iterative process as the bulletins continue to develop and new requirements are identified.

Conduct Outreach

This was mainly in the form of advertising where we created outreach material to explain what the bulletins can achieve.

Assess and Maintain Products

In the case of Ireland, the product is maintained by the Marine Institute. In Norway, it is NIVA; and in Galicia (Spain), it is the IEO.

Provide Training

No formal face-to-face training was given. Enquiries from users are dealt with on a case-by-case basis.

Community "Best" Practice

AtlantOS WP6 has a special interest in promoting the development of "Best Practice". Following WP6-WP8 discussions at a workshop in 2017, WP8 agreed to develop a "Best Practice" description document related to the HAB bulletin. Since the Irish Bulletin is at a relatively advanced stage of development, we decided to document the step-by-step process on "Creating a weekly Harmful Algal Bloom bulletin" to share with wider community (Leadbetter *et al.* 2018). The main purpose was to help reduce duplication of effort for those interested in producing their own HAB bulletin in other regions and to encourage the community to advance progress in this field by sharing their "know-how" too. The "Best Practice" document provides details on the software used and links to scripts (e.g. through GitHub) that can be adopted to create plots for a HAB bulletin. An overview of the steps involved in creating a bulletin are presented in Figure 3 below. Details of the "best" practice description "Creating a weekly Harmful Algal Bloom bulletin" (Leadbetter *et al.* 2018).

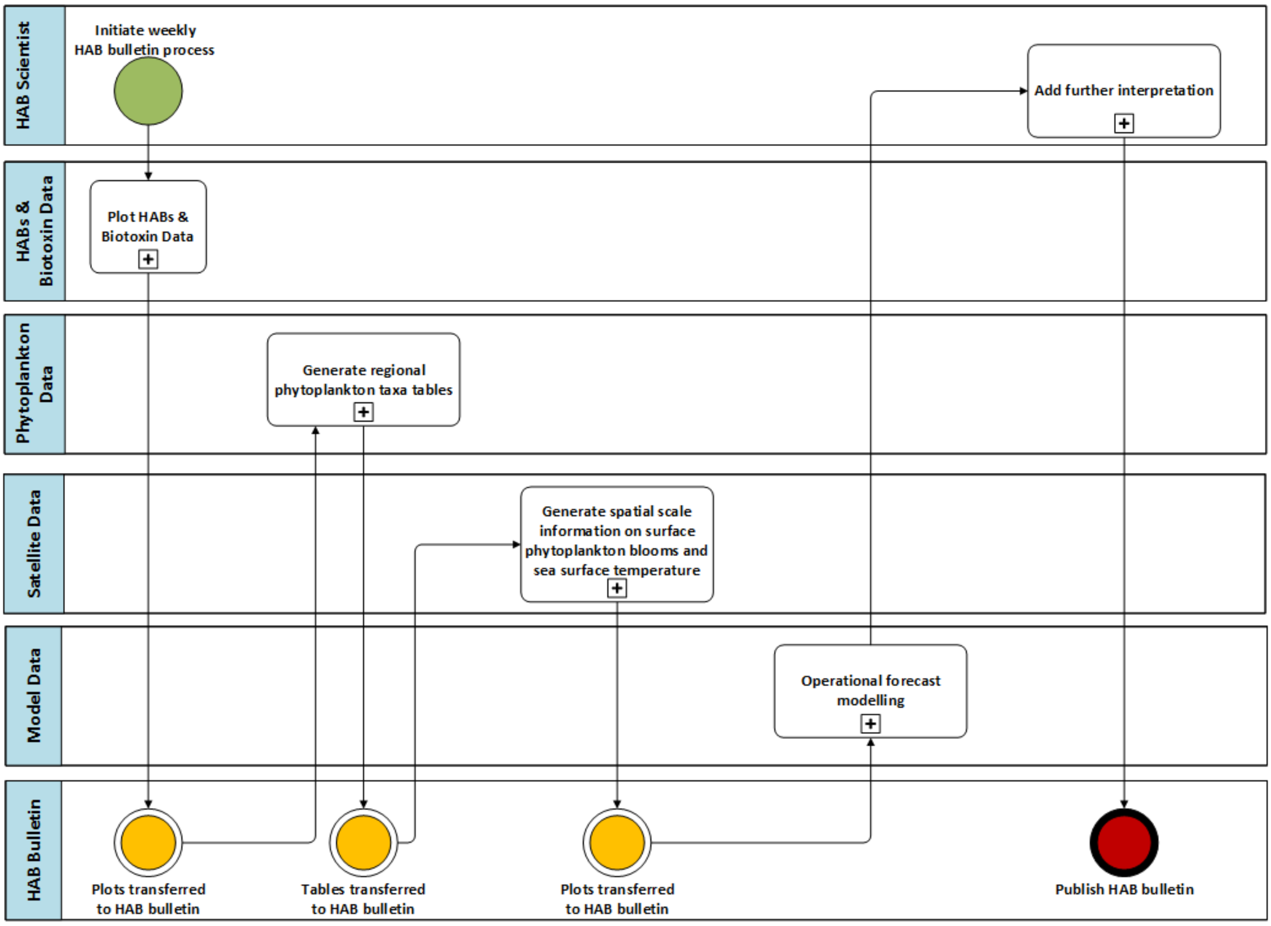


Figure 3. Overview of the complete process to create a weekly HAB bulletin.

Norwegian HAB bulletin

Target Users for the HAB Bulletin Use Case

Table 3. Sector specific target users and needs in Norway.

Target User Name	User needs (previous work or literature)
Primary end-user group:	
(a) Sjømat Norge (Seafood Norway)	➢ Early notification of a harmful/toxic bloom ➢ (2 - 3 day notice at a minimum) ➢ Easy to interpret results
Regulatory authorities:	
(a) Norwegian Food Safety Authority (information site = MatportalenReference, Norway)	➢ Support the scientific advice given to regulatory bodies
Other State Bodies:	
(b) Institute of Marine Research, Norway (c) Fiskeridirektoratet, Norway (d) Miljødirektoratet, Norway (e) Vetrinærinstituttet, Norway	➢ Access to all information in one place to make it easier for local experts to interpret the data and provide early warning notices. ➢ Alert of high biomass blooms in coastal areas used for leisure (e.g. beaches)

Description of methodology to produce the Targeted Products

In-situ ocean observing products

In-situ data (delayed mode) from the national/regional HAB and biotoxins monitoring programmes are extracted from local/national databases.

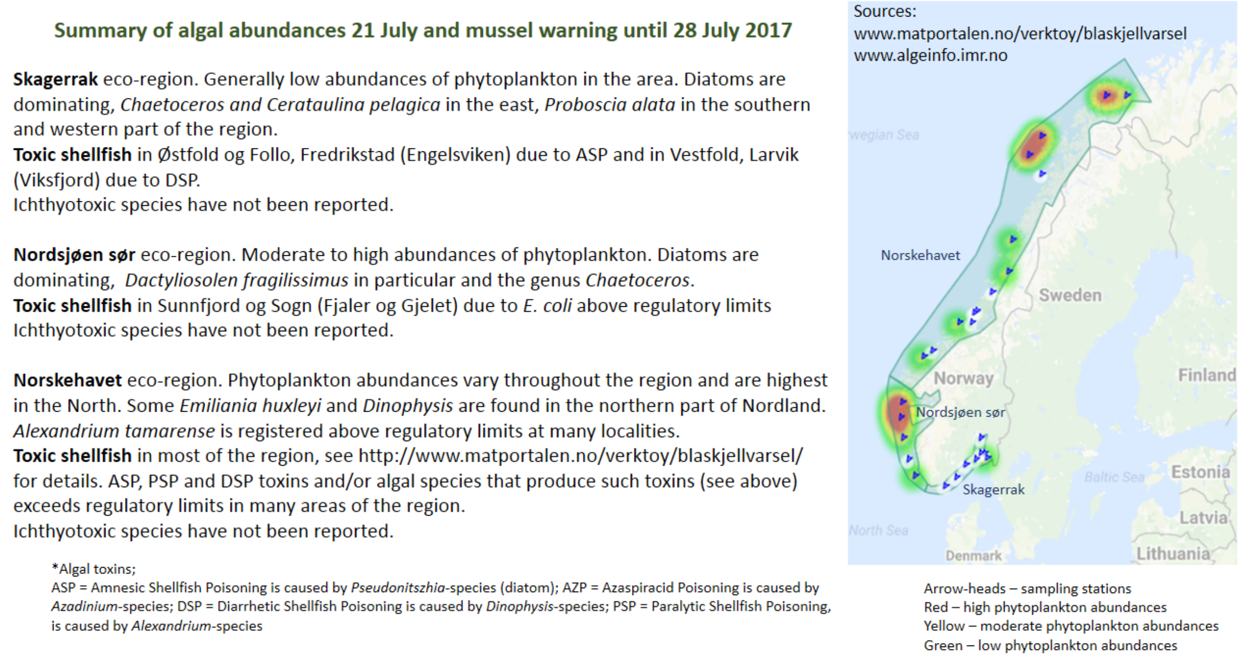
Remote sensing products

Planned: Surface chlorophyll a (µg/L) and SST (°C) satellite data products

Content of the bulletin (Basic elements)

(a) Phytoplankton results are presented on a map.
(b) A Summary is provided on the current conditions related to HABs and Biotoxin results.
(c) A warning for the week ahead based on expert opinion.

Graphical layout


Summary of algal abundances 21 July and mussel warning until 28 July 2017

Skagerrak eco-region. Generally low abundances of phytoplankton in the area. Diatoms are dominating, *Chaetoceros and Cerataulina pelagica* in the east, *Proboscia alata* in the southern and western part of the region.
Toxic shellfish in Østfold og Follo, Fredrikstad (Engelsviken) due to ASP and in Vestfold, Larvik (Viksfjord) due to DSP.
Ichthyotoxic species have not been reported.

Nordsjøen sør eco-region. Moderate to high abundances of phytoplankton. Diatoms are dominating, *Dactyliosolen fragilissimus* in particular and the genus *Chaetoceros*.
Toxic shellfish in Sunnfjord og Sogn (Fjaler og Gjelet) due to *E. coli* above regulatory limits
Ichthyotoxic species have not been reported.

Norskehavet eco-region. Phytoplankton abundances vary throughout the region and are highest in the North. Some *Emiliania huxleyi* and *Dinophysis* are found in the northern part of Nordland. *Alexandrium tamarense* is registered above regulatory limits at many localities.
Toxic shellfish in most of the region, see http://www.matportalen.no/verktoy/blaskjellvarsel/ for details. ASP, PSP and DSP toxins and/or algal species that produce such toxins (see above) exceeds regulatory limits in many areas of the region.
Ichthyotoxic species have not been reported.

*Algal toxins;
ASP = Amnesic Shellfish Poisoning is caused by *Pseudonitszhia*-species (diatom); AZP = Azaspiracid Poisoning is caused by *Azadinium*-species; DSP = Diarrhetic Shellfish Poisoning is caused by *Dinophysis*-species; PSP = Paralytic Shellfish Poisoning, is caused by *Alexandrium*-species

Figure 4. Front page of the Norwegian HAB bulletin (translated into English for this report). This page contains a map of the Norwegian coast showing the current conditions of HABs and biotoxins in the region of interest.

Irish HAB bulletin

Target Users for the HAB Bulletin Use Case

Table 4. Sector specific target users and needs in Ireland.

Target User Name	User needs (previous work or literature)
Primary end-user group:	
(a) Aquaculture industry (Shellfish and Finfish aquaculture industry, Irish Farmers Association - Aquaculture, Irish Shellfish Association, Irish Salmon Growers' Association Ltd.)	➢ Early notification of a harmful/toxic bloom ➢ (2 - 3 day notice at a minimum) ➢ Easy to interpret results
(b) Molluscan Shellfish Safety Committee	
Regulatory authorities:	
(c) Dept. of Agriculture, Food & the Marine	➢ Support the scientific advice given to regulatory bodies
(d) Food Safety Authority Ireland	
(e) other relevant government departments and local authorities	

Description of methodology to produce the Targeted Products

In-situ ocean observing products

In-situ data (delayed mode) from the national/regional HAB and biotoxins monitoring programmes are extracted from local/national databases. Query R scripts extract and display the latest temporal and spatial data as maps and XY scatter plots. Data over the past ten years are retrieved and plotted in tables to show Historic Trends for the week in question. To complement the remote sensing products discussed below, a locally run data query extracts information on the predominant phytoplankton taxa in coastal waters for a set time period (weekly). Taxa are ranked in order of the top five predominant organisms for the week in each target region.

The *In-situ* data from the National Monitoring Programme for HAB and associated biotoxins are held in a SQL HAB database at the Marine Institute Headquarters, Galway. The data is viewed and explored locally; an R script is used to plot temporal and spatial data. Information gathered is used to describe current and past HAB and biotoxins trends in Irish waters. The generated R plots form part of the bulletin. To complement the surface chlorophyll *a* satellite data, a SQL query, run locally, extracts additional information on the predominant phytoplankton taxa in Irish coastal waters. The R scripts used to create the products are presented in Annex 5.

In-situ Data Buoys: *In-situ* results from the Irish weather buoy network. To complement the SST satellite data, *In-situ* results from the Irish weather buoy network are used to create a ten year SST anomaly for the week in question. The anomaly is the weekly difference in SST compared to the long term mean for last 10 years. A Matlab script is run to retrieve the data and create the plots (*.png).

Remote sensing products

Surface chlorophyll a (µg/L) and SST (°C) satellite data products are sourced from those developed by Ifremer/ DYNECO and CERSAT in Brest and NASA [ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/ocean-color/atlantic/EUR-L4-CHL-ATL-v01/] and the CMEMS portal [www.marine.copernicus.eu]. A Matlab script is run to retrieve the data and create grid files (*.grd). An R script (Annex 5) is then used to map the spatial data and visualise daily and weekly images. A weekly chlorophyll *a* anomaly is calculated and plotted; method provided by Michelle Tomlinson and Richard Stumpf, NOAA, USA.

The chlorophyll anomaly is calculated for each day.

- Call today Day 0.
- Download daily chlorophyll data for Day 0.
- Calculate the 60-day median for period ending 14 days ago.
- Subtract 60-day median from daily chlorophyll to give anomaly.

The weekly anomaly is just the mean anomaly for any particular week (i.e. mean of 7 daily anomalies).

Model simulation products

Hydrodynamic models for shelf seas: Time series of water levels, 2D and 3D momentum, temperature and salinity are provided every 10 minutes at the open ocean boundaries. The products developed include the cross-sections through 3-D momentum, temperature, salinity and density along selected transects and operational forecasting of the displacement of lagrangian drifters released at the surface, 20 m depth and bottom along the mouth of important bays where aquaculture takes place. Relevant transect through offshore waters, of importance are also produced. These products aim at quantifying the strength of inflow of shelf waters into bays, upwelling/downwelling events and depicting the strength of Coastal Currents.

Model 1: NEA_ROMS (North East Atlantic Regional Ocean Modelling System) model
The domain covers a significant portion of the North-West European continental shelf, the Porcupine and Rockall Banks, and the Rockall Trough at a variable horizontal resolution, ranging from 1.1-1.6 km in Irish coastal waters to 3.5 km in the south of the domain. There are 40 sigma-coordinate levels in the vertical with a concentration of levels at the surface and the bottom. The model bathymetry utilises data from a several sources including the multibeam dataset produced by the Irish National Seabed Survey and Integrated Mapping for the Sustainable Development of Ireland's Marine Resources (INFOMAR) programmes.

Model 2: BANTRY_ROMS (Bantry Bay model Regional Ocean Modelling System) model
BANTRY_ROMS is a hydrodynamic model of the shelf sea off southwest Ireland. Similar to the NEA_ROMS it is an application of a well-established primitive-equation, free-surface, hydrostatic ROMS model, described in detail in Shchepetkin and McWilliams (2005). The prognostic variables of the hydrodynamic model are surface elevation, potential temperature, salinity and velocity. The model domain aligned with the main bay’s axis consist of 557 x 419 grid cells relating to a horizontal spacing of 200 – 250 metres and 20 vertical levels. The model is nested ‘off-line’ in a regional ROMS_NEA model and run operationally at the Marine Institute and is a refinement of the latter by a factor of five. Time series of water levels, 2D and 3D momentum,

temperature and salinity are provided every 10 minutes at the open ocean boundaries. At the free surface, the model uses the same forcing functions as its parent ROMS_NEA model. Freshwater discharges from five rivers are included in the model. The model bathymetry utilizes data from a number of sources (e.g. Irish National Seabed Survey multibeam dataset) to produce the best possible bathymetry for the area.

Model 3: CONNEMARA_ROMS model
Model is a hydrodynamic model (ROMS 3.6 Hindcast and Forecast Physics) of the shelf sea off west Ireland. The Regional Ocean Modelling System (ROMS) is a free-surface, hydrostatic, primitive equation ocean model described in Shchepetkin and McWilliams, 2005. It is an open-source, community ocean model that uses a horizontal, curvilinear C-grid and a stretched vertical coordinate. The Marine Institute developed a ROMS model for a domain that covers an area on the west of Ireland encompassing Galway Bay and the Connemara coast. This model has a horizontal resolution of 200 metres and there are 20 vertical layers (the ROMS vertical coordinate is terrain-following so the thickness of the layers in the model change with water depth). The model domain is downscaled from the Marine Institute's NE Atlantic operational model (variable resolution from 1.2 to 2.5 km). We use atmospheric forcing from the ECMWF operational system. We also include measured freshwater flux from the river Corrib because it is a very significant driver for the hydrodynamics in Galway Bay. The model has been validated using available temperature and current data. The model is run every day to produce a 3-day forecast for parameters such as temperature, salinity, current and sea surface height. The results are published on our THREDDS server in NetCDF format.

Modelled Products for Task 8.1 "HABs"
Daily automated run Matlab scripts produce hydrodynamic nowcast/forecast model output image files (*.png) for Bantry Bay and Mizen Head situated on southwest Ireland, Killary Harbour and a shelf transect off the west coast; horizontal resolution 200 – 250 m with 20 vertical levels. Files are stored locally. The images used in the bulletin show the latest 3-day volumetric flux forecast for vertical transects at the mouth of Bantry Bay and mid-bay and at the mouth of Killary Harbour. Results are plotted graphically on a map of the bays. Lagrangian model (particle tracking) output files for surface, 20 metres, and bottom waters in the vicinity of Bantry Bay (Mizen Head, southwest Ireland) and at the mouth of Bantry Bay, the transect off the west coast of Ireland and Killary Harbour are also viewed locally. The most informative plots from each transect are included in the bulletin. Predictions (3-day) of temperature, salinity and density are also produced to inform the local experts, but, are currently not part of the bulletin.

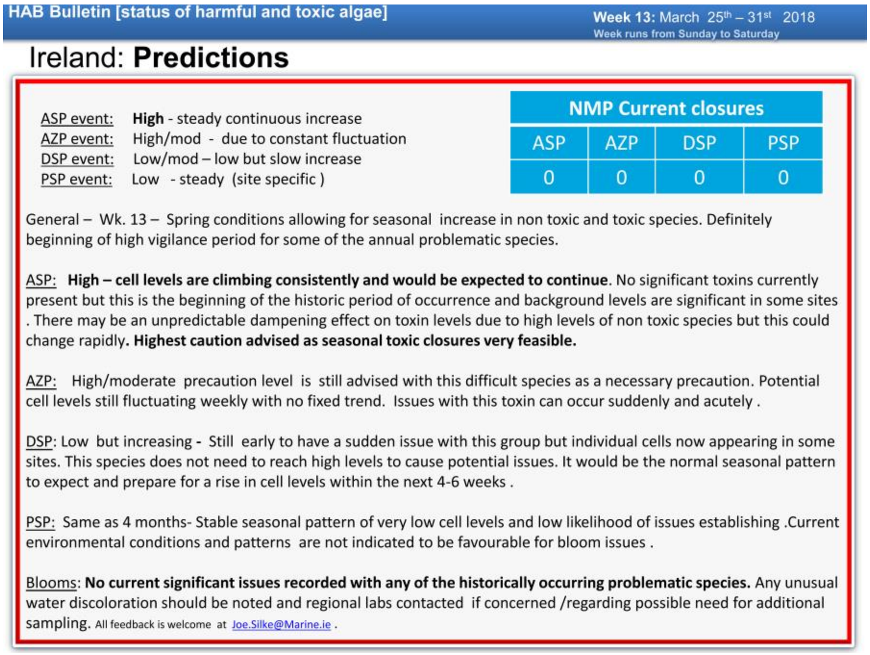
Content of the bulletin (Basic elements)

a) Prediction based on expert interpretation with a rationale based on content of the scientific data products and experience.
b) A historical summary of national biotoxin closures.
c) A national summary of shellfish biotoxin and HAB levels.
d) A national summary of earth observations of chlorophyll *a* and SST, supported by local data.
e) Recent information on potentially harmful high biomass bloom forming phytoplankton.
f) Predicted water movement in the vicinity of Bays off the south and west coasts.
g) Physical water properties at the mouths of Bays where heavy aquaculture activities are carried out.

Graphical layout

Figures 5 - 12 below present the typical content in a weekly bulletin.

The front page of the HAB bulletin gives an overview of the current and past conditions and what is expected to change, if anything, in the next few days (predictive text compiled by the local expert). Page two presents recent temporal and historic patterns of biotoxins and HABs in Irish waters. Pages three to six focus on the national distribution of target toxin producing phytoplankton and their associated biotoxins. Page seven shows satellite imagery with chlorophyll and sea surface temperature levels and a list of the predominant phytoplankton taxa recently blooming in Irish waters. Page eight focuses on bloom formers, historically associated with ecological damage and fish kills. Pages nine to thirteen of the HAB bulletin concentrate on numerical model predictions related to physical dynamics in southwest and western shelf and coastal waters.



HAB Bulletin [status of harmful and toxic algae]

Week 13: March 25th – 31st 2018
Week runs from Sunday to Saturday

Ireland: **Predictions**

ASP event: **High** - steady continuous increase
AZP event: High/mod - due to constant fluctuation
DSP event: Low/mod – low but slow increase
PSP event: Low - steady (site specific)

NMP Current closures			
ASP	AZP	DSP	PSP
0	0	0	0

General – Wk. 13 – Spring conditions allowing for seasonal increase in non toxic and toxic species. Definitely beginning of high vigilance period for some of the annual problematic species.

ASP: **High – cell levels are climbing consistently and would be expected to continue**. No significant toxins currently present but this is the beginning of the historic period of occurrence and background levels are significant in some sites . There may be an unpredictable dampening effect on toxin levels due to high levels of non toxic species but this could change rapidly**. Highest caution advised as seasonal toxic closures very feasible.**

AZP: High/moderate precaution level is still advised with this difficult species as a necessary precaution. Potential cell levels still fluctuating weekly with no fixed trend. Issues with this toxin can occur suddenly and acutely .

DSP: Low but increasing - Still early to have a sudden issue with this group but individual cells now appearing in some sites. This species does not need to reach high levels to cause potential issues. It would be the normal seasonal pattern to expect and prepare for a rise in cell levels within the next 4-6 weeks .

PSP: Same as 4 months- Stable seasonal pattern of very low cell levels and low likelihood of issues establishing .Current environmental conditions and patterns are not indicated to be favourable for bloom issues .

Blooms: **No current significant issues recorded with any of the historically occurring problematic species.** Any unusual water discoloration should be noted and regional labs contacted if concerned /regarding possible need for additional sampling. All feedback is welcome at Joe.Silke@Marine.ie .

Figure 5. Front page of the Irish HAB bulletin presents the HAB and associated biotoxin prediction for the coming days, accompanied with a rationale.

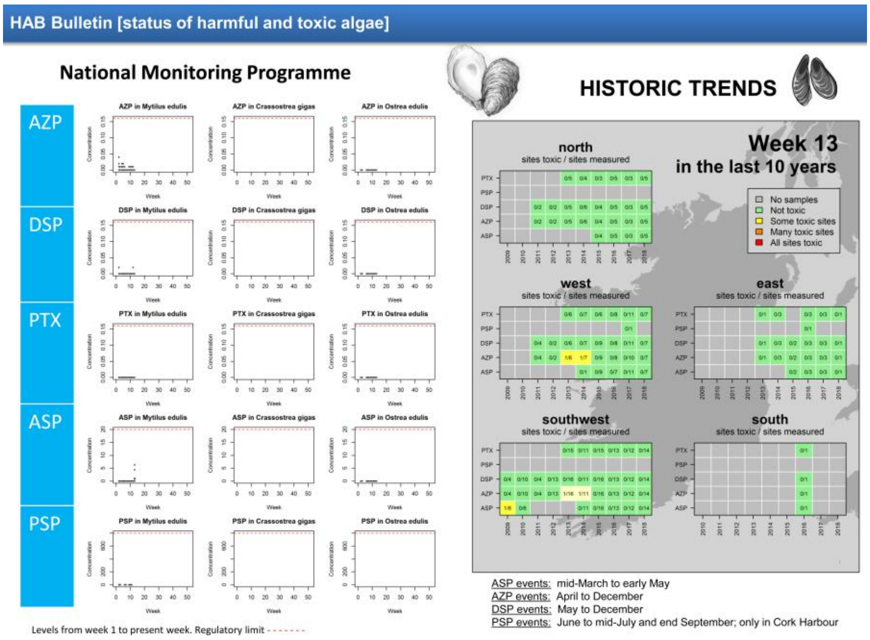


Figure 6. Page two: Historic trends and events where a) temporal plots from week 1 to the current week of HAB and biotoxin levels; this allows the end user to view any upward and/or downward trends in the national dataset and b) a ten-year account of regional aquaculture shellfish harvesting site closures when biotoxins exceeded the EC Regulatory levels in shellfish are presented for a selected week in the year.

The pages that follow in the bulletin show the current status HAB causing organisms and their associated toxin levels in shellfish related to DSP, AZP, ASP and PSP. The national distribution maps show cell densities of a potentially toxic phytoplankton taxon and the biotoxin it produces over a 3 week period. Three maps are produced - one for each week selected by the User. The example below shows the dinoflagellates, *Dinophysis*, a phytoplankton responsible for DSP biotoxin accumulation in shellfish. A Regional overview of toxic and/or nontoxic sites is also presented for the particular biotoxin in question.

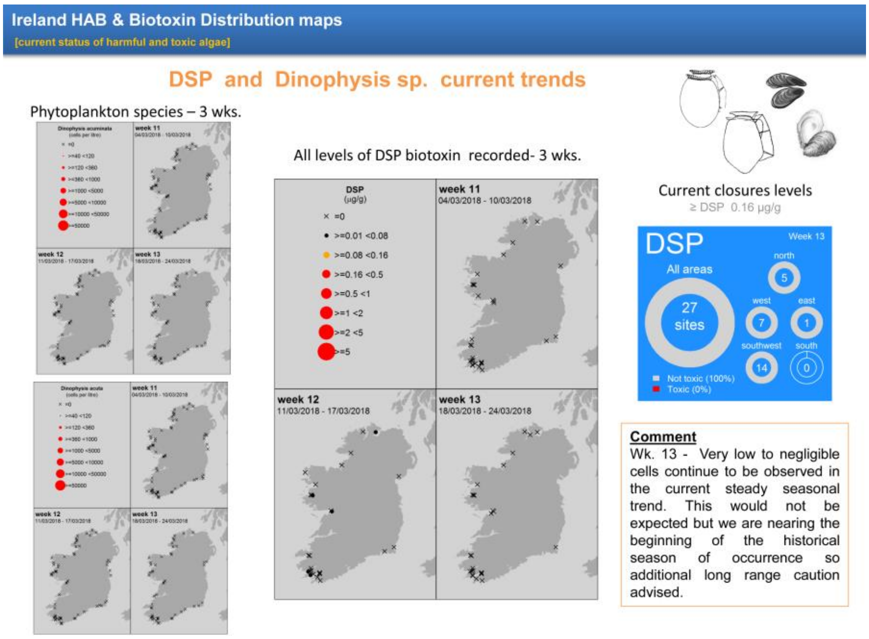
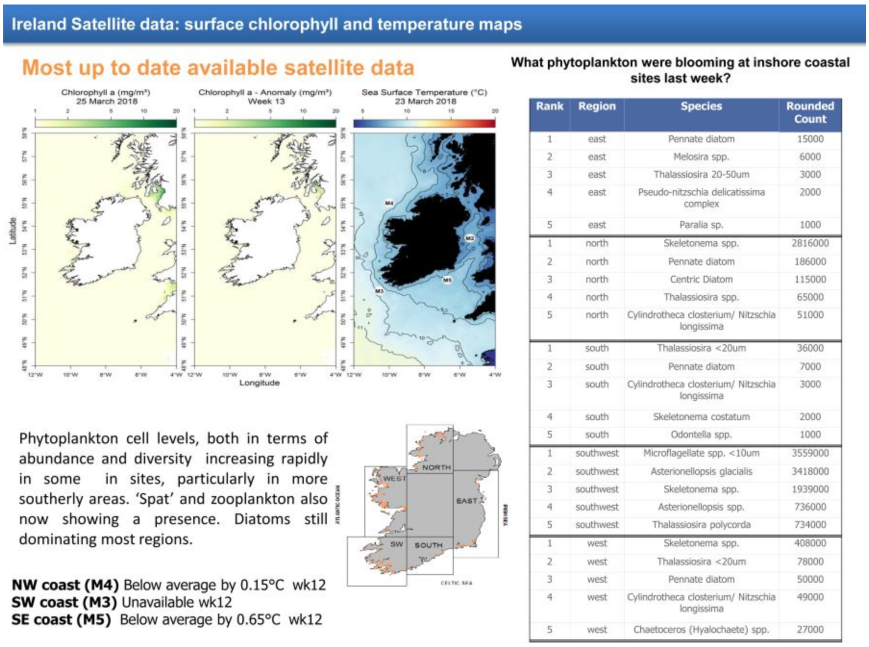


Figure 7. Page three: Bulletin page that displays Biotoxin and HAB geospatial distribution maps of importance for the last 3 weeks, where a) National distribution maps show cell densities of a potentially toxic dinoflagellate from the genus *Dinophysis* over a 3 week period. Three maps are produced - one for each week selected by the User. Some species from the genus *Dinophysis* are known to produce the biotoxins Okadaic acid and its analogues related to DSP events b) National distribution maps show Okadaic acid and analogues levels in shellfish. Three maps are produced - one for each week selected by the User and c) Regional overview of toxic and/or nontoxic sites that have Okadaic acid and analogues (in Ireland, this refers to Okadaic Acid, DTX-1 DTX-2, esters) biotoxins above the EC Regulatory level of 0.16 µg/g in shellfish; displayed as doughnut plots. These biotoxins can cause Diarrheic Shellfish Poisoning in humans if contaminated shellfish are consumed. The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed. Pages four to six, are similar in structure, display information on other potentially toxic phytoplankton and their associated biotoxins.



Rank	Region	Species	Rounded Count
1	east	Pennate diatom	15000
2	east	Melosira spp.	6000
3	east	Thalassiosira 20-50um	3000
4	east	Pseudo-nitzschia delicatissima complex	2000
5	east	Paralia sp.	1000
1	north	Skeletonema spp.	2816000
2	north	Pennate diatom	186000
3	north	Centric Diatom	115000
4	north	Thalassiosira spp.	65000
5	north	Cylindrotheca closterium/ Nitzschia longissima	51000
1	south	Thalassiosira <20um	36000
2	south	Pennate diatom	7000
3	south	Cylindrotheca closterium/ Nitzschia longissima	3000
4	south	Skeletonema costatum	2000
5	south	Odontella spp.	1000
1	southwest	Microflagellate spp. <10um	3559000
2	southwest	Asterionellopsis glacialis	3418000
3	southwest	Skeletonema spp.	1939000
4	southwest	Asterionellopsis spp.	736000
5	southwest	Thalassiosira polycorda	734000
1	west	Skeletonema spp.	408000
2	west	Thalassiosira <20um	78000
3	west	Pennate diatom	50000
4	west	Cylindrotheca closterium/ Nitzschia longissima	49000
5	west	Chaetoceros (Hyalochaete) spp.	27000

Figure 8. Page seven: a) daily satellite maps show spatial information on surface phytoplankton blooms (Chlorophyll *a*) weekly Chlorophyll *a* anomaly map and SST, b) *In-situ* SST data summary from the national weather buoy network, c) comments and d) list of predominant phytoplankton at near shore sites,

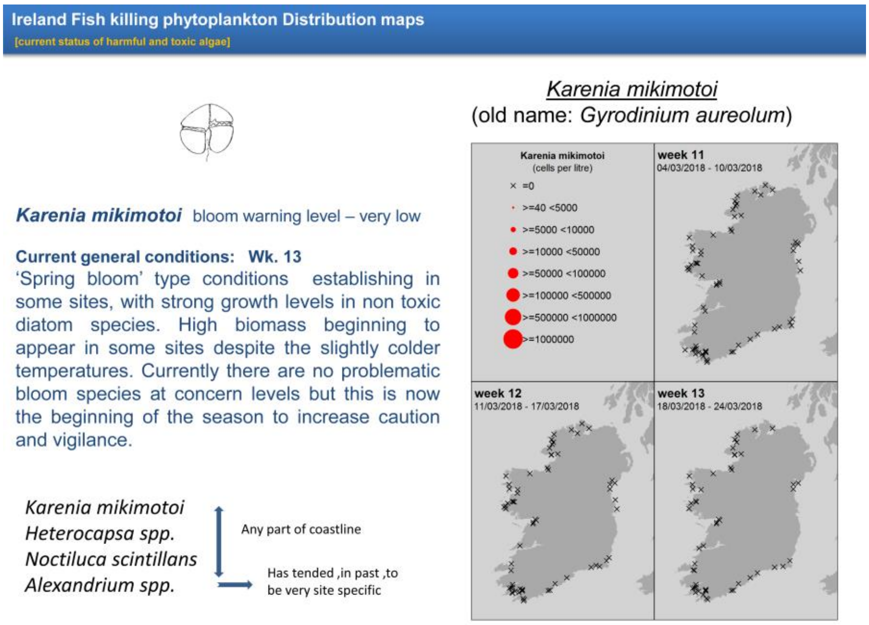


Figure 9. Page eight: Bloom forming phytoplankton genera or species. Example for *Karenia mikimoto*i cell densities from the national dataset are overlaid on the weekly Chlorophyll a anomaly map. *In-situ* SST data summary from the national weather buoy network.

The final pages of the bulletin are dedicated to the modelled data products. This includes summaries of water movements in the vicinity of Bays, prediction of lagrangian water transport, model predictions for the next few days, an image of eulerian water transport in offshore shelf waters and at the mouth of Bays showing predicted volumetric directional flow of water and cross-sections with modelled data of water temperature, salinity and density. Some examples are provided below.

(a) (b) (c)

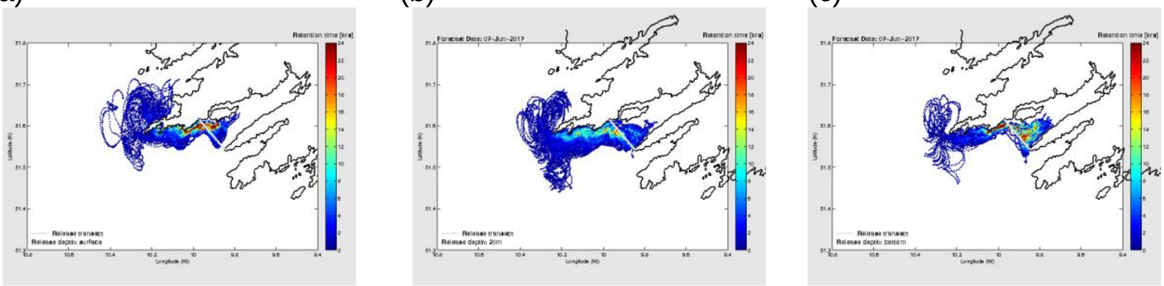


Figure 10. Particle tracking: Aerial view of simulated three day temporal average projected water movements off southwest Ireland. Three water levels (a= surface, b = 20 m and c = bottom waters) from the model are presented. The colour scale relates to the average time, in hours, that particles are retained and the likely distance particles may travel along the projected pathway displayed. In other words, reddish colours represent areas where particles remain longest while cooler colours represent areas where particles remain for shorter periods. Available online @ http://vis.marine.ie/particles/

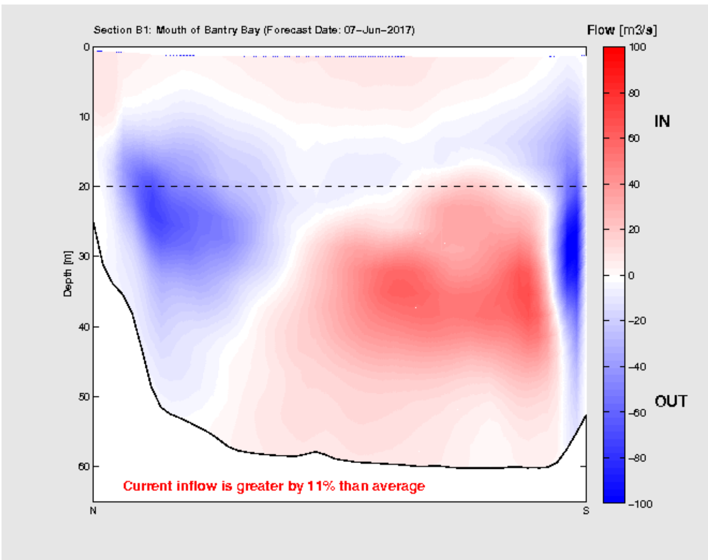
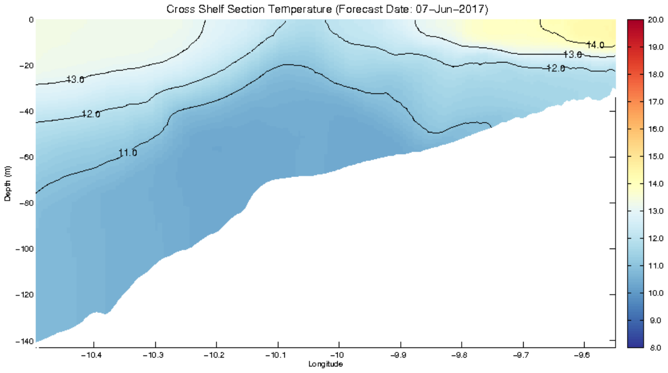
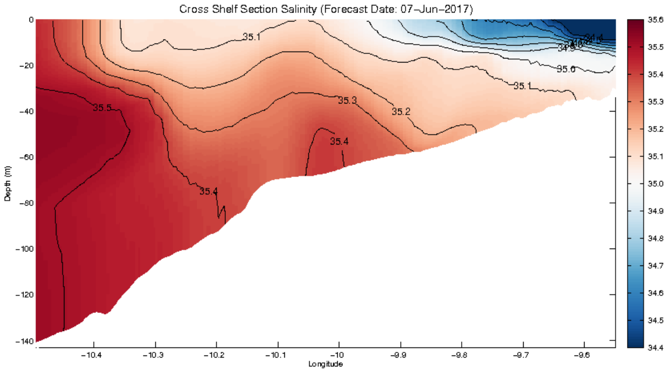


Figure 11. Daily simulated three day temporal average volumetric flux ($m^3.s^{-1}$) forecasts fat the mouth of Bantry Bay. This is one example of a number of transects where physical conditions are simulated, extracted and plotted on a daily operational basis to present local oceanographic phenomenon (e.g. advection of offshore waters into a bay) in the local area of interest.

(a)



(b)



(c)

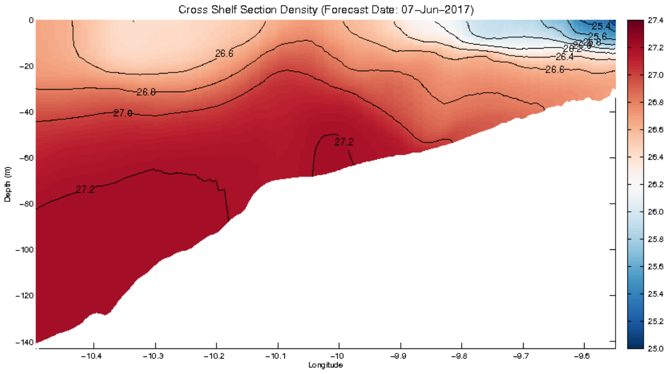


Figure 12. Model simulated (a) temperature (°C), (b) salinity and (c) density σt (kg.m^{-3}) along a southwest – northeast transect from 10° 30’ W (0 km) on the continental shelf to inner Bantry Bay (70+ Km). This is one example of a number of transects where physical conditions are simulated, extracted and plotted on a daily operational basis to present local oceanographic phenomenon e.g. upwelling events in the local area of interest.

Galician (Spanish) HAB bulletin

Target Users for the HAB Bulletin Use Case

Table 5. Sector specific target users and needs in Galicia, Spain

Target User Name	User needs (previous work or literature)
Primary end-user group: (a) Aquaculture mussel farmer associations	➢ Early notification of a harmful/toxic bloom ➢ (2 - 3 day notice at a minimum) ➢ Easy to interpret results
Regulatory authorities: (b) INTECMAR, Xunta de Galicia (c) Consellería do Mar, Xunta de Galicia	➢ Support the scientific advice given to regulatory bodies

The Galician HAB early warning system is aimed at supporting decisions of the monitoring system [INTECMAR, www.intecmar.org] as well as at providing forecasts to the aquaculture industry in Galicia. The bulletins are written in Galician language, the official language of the Galicia autonomous region together with Spanish.

Description of methodology to produce the Targeted Products

In-situ ocean observing products

HAB data in Galicia comprise phytoplankton counts of toxic species and data from toxin analyses from the weekly sampling of shellfish harvesting areas performed by INTECMAR. These data are complemented with monthly phytoplankton counts at stations in the ría de Vigo and the adjacent shelf carried out by IEO as part of the Radiales programme of sustained observations.

There is also information on the status of harvesting areas (open or closed) taken from INTECMAR status reports [www.intecmar.org/informacion/biotoxinas/EstadoZonas].
During ATLANTOS work was performed for submission of weekly HAB data to a SQL database with the objective to automate bulletin production. The availability of a SQL database in standard

format will allow us to make use of some of the tools used to produce the Irish bulletins, therefore easing the incorporation of features such as historical trends.

In-situ Underway systems: Temperature, salinity and fluorescence are measured by the underway system on board research vessels (Navaz and Lura) performing weekly monitoring in Galician Rias Baixas and Rias Altas. Temperature, salinity and fluorescence measured by the underway system provides information about freshwater in the rías and about the penetration of shelf waters.

Other measurements (CTD casts, underway systems) obtained at different routine monitoring cruises performed by IEO in the area can be used to get additional information on oceanographic conditions (stratification, location of fronts etc.).

Upwelling indexes are routinely computed in different locations along the Iberian coast (Gonzalez-Nuevo *et al.* 2014). Forecasts and plots of the evolution in the present month and in previous months and years are distributed through the web page www.indicedeafloramiento.ieo.eswww.indicedeafloramiento.ieo.es22ww. The Upwelling Index (UI) is computed from different data sources (buoys, operational and hindcast atmospheric models) and constitutes a product of interest for the analyses of oceanographic conditions influencing HABs. Upwelling index forecasts obtained from meteorological models off Galician Rías are plotted in the bulletin.

Remote sensing products

MyOcean surface Chlorophyll *a* measurements (Optimal interpolation Near Real Time L4 product at 1 Km resolution for the North Atlantic Atlantic http://cmems-oc.isac.cnr.it/thredds/cmems/V3.3/oc/atl/OCEANCOLOUR_ATL_CHL_L4_NRT_OBSERVATIONS_009_037.html?dataset=dataset-oc-atl-chl-multi-l4-oi_1km_daily-rt-v02) and sea surface temperature (SST, ODYSSEA NWS Sea Surface Temperature analysis) on the closest day to the day of issuing the bulletin are displayed.

Model simulation products

A nested configuration of the ROMS model is run, providing water temperature, salinity, surface elevation, currents and fluxes with a 3 day forecast range. The operational grid domain spans from the Atlantic (from Cape S. Vicente, Portugal) to the Cantabrian shelves (up to Gijón, Spain), with a 4 km resolution, and a higher resolution 1.3 km grid centred in the Galician coast. Another pre-operational configuration runs with a 3.5 km resolution. It extends to the French shelf and provides nutrients, chlorophyll, phytoplankton and zooplankton.

Hydrodynamic models for shelf seas: Time series of water levels, 2D and 3D momentum, temperature and salinity are provided every 10 minutes at the open ocean boundaries. The products developed include the cross-sections through 3-D momentum, temperature, salinity and density along selected transects and operational forecasting of the displacement of lagrangian drifters released at the surface, 20 m depth and bottom along the mouth of important bays where aquaculture takes place. Relevant transect through offshore waters, of importance are also produced. These products aim at quantifying the strength of inflow of shelf waters into bays, upwelling/downwelling events and depicting the strength of Coastal Currents.

A configuration of the Regional Ocean Modeling System (ROMS) (Shchepetkin and McWilliams, 2005) for studying the western and northern Iberian shelf circulation and its effect on the ecosystem has been developed in recent years. This configuration of the ROMS model provides operationally water temperature and salinity, surface elevation, currents and fluxes with a 3-d forecast horizon (see Ruiz-Villarreal *et al.* 2016). We run the Ichtyop (www.ichthyop.org) offline Lagrangian particle-tracking model using the output of our ROMS model configuration. During ATLANTOS we have improved the implementation of the vertical dispersion algorithm in Ichthyop although currently we still neglect vertical dispersion of particles in the Lagrangian simulations for the HAB bulletins. Hourly fields from our hydrodynamical model are used to force the Lagrangian particle tracking model offline. Although the model configuration described above has shown skill in describing oceanographic conditions related to HABs (Ruiz-Villarreal *et al.* 2016), we have been adapting the system for using alternate model output available in the area to fall back on when the IEO ROMS model configuration is not available operationally, For example, we can use the ROMS 2km configuration run by Meteogalicia and available in a THREDDS server (http://mandeo.meteogalicia.es/thredds/catalog/roms/fmrc/files/latest.html?dataset=roms/fmrc/files/20180405/roms_002_20180405_0000.nc4).

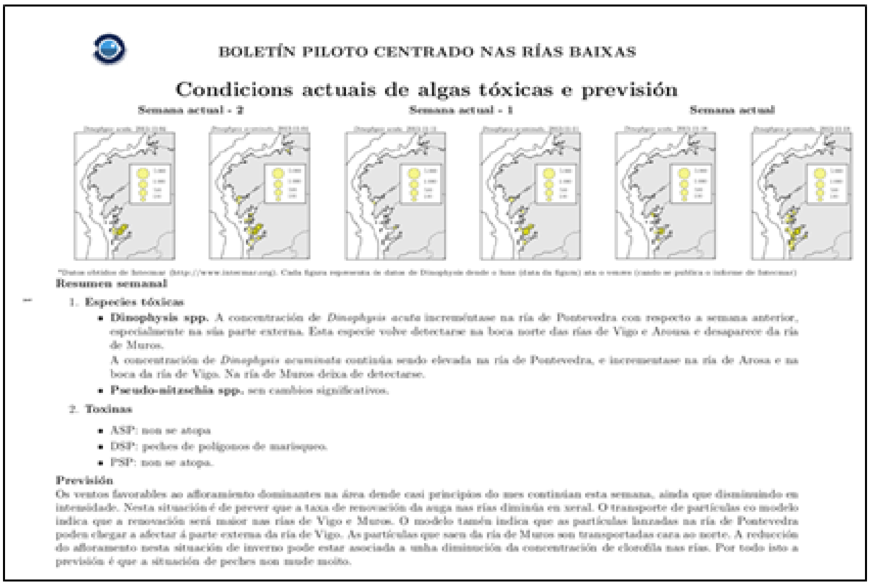
Content of the bulletin (Basic elements)

a) HABs and Biotoxins
b) Temperature, salinity, currents and chlorophyll (in some periods) at different depths are available.
c) Eulerian predictions of inflow-outflow into-out of the Galician rías where most of the aquaculture takes place as well as Eulerian predictions of along-shore transport in several cross-sections on the northern Portuguese shelf.

d) Lagrangian particle-tracking simulations are run to estimate along-shore transport from the northern Portuguese shelf (areas L1 and L2 in the Portuguese bulletin) to Galician shelf and rías and to explore flows between the rías and the shelf. Lagrangian simulations allow us to forecast the eventual transport of HAB species to other rías.

Graphical layout

The Spanish bulletin for ATLANTOS follows a similar format and layout to that used during the ASIMUTH project incorporating improvements recommended after the best practices review process and the feedback loop was performed in ATLANTOS (see next section of this report). It will include the current HAB status of the area and text to describe results of the data products displayed in the bulletin. Figures 13 – 16 below show a mock-up of the planned HAB bulletin. This will be complemented by a web-page where the upwelling index and other relevant model forecasts are updated on a daily basis.



BOLETÍN PILOTO CENTRADO NAS RÍAS BAIXAS

Condicions actuais de algas tóxicas e previsión

Semana actual - 2 | Semana actual - 1 | Semana actual

Resumen semanal

1. **Especies tóxicas**
   - **Dinophysis spp.** A concentración de *Dinophysis acuta* increméntase na ría de Pontevedra con respecto a semana anterior, especialmente na súa parte externa. Esta especie volve detectarse na boca norte das rías de Vigo e Arousa e desaparece da ría de Muros.

     A concentración de *Dinophysis acuminata* continúa sendo elevada na ría de Pontevedra, e incrementase na ría de Arosa e na boca da ría de Vigo. Na ría de Muros deixa de detectarse.
   - **Pseudo-nitzschia spp.** sen cambios significativos.
2. **Toxinas**
   - ASP: non se atopa
   - DSP: peches de polígonos de marisqueo.
   - PSP: non se atopa.

Previsión

Os ventos favorables ao afloramiento dominantes na área dende casi principios do mes continúan esta semana, ainda que diminuindo en intensidade. Nesta situación é de prever que a taxa de renovación da auga nas rías diminúa en xeral. O transporte de partículas co modelo indica que a renovación será maior nas rías de Vigo e Muros. O modelo tamén indica que as partículas lanzadas na ría de Pontevedra poden chegar a afectar á parte externa da ría de Vigo. As partículas que saen da ría de Muros son transportadas cara ao norte. A reducción do afloramento nesta situación de inverno pode estar asociada a unha diminución da concentración de clorofila nas rías. Por todo isto a previsión é que a situación de peches non mude moito.

Figure 13. On the first page plots of the spatial distribution and evolution of cell counts of HAB species for the last 3 weeks (data provided by INTECMAR) are presented. A weekly summary of toxic species and status of harvesting areas closures due to the presence of ASP, DSP and PSP toxins (also from INTECMAR) is included. This page is intended to give a short term forecast on the evolution of oceanographic conditions and how this will likely affect the status of harvesting areas.

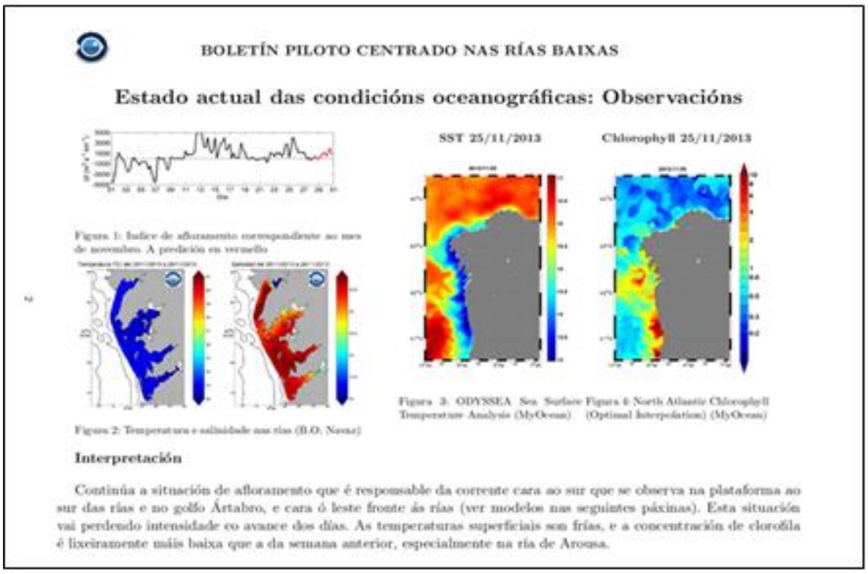


Figure 14. The second page: *In-situ* and remote sensing data of the oceanographic conditions in the area related with HAB evolution (upwelling index, *In-situ* temperature and salinity, ODYSSEA sea surface temperature, and chlorophyll).

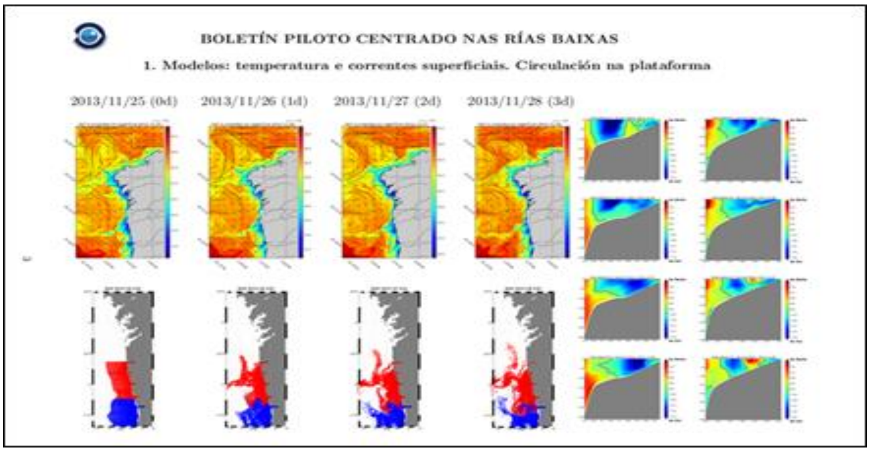


Figure 15. The third page focuses on the Atlantic shelf and shows information of model forecasts for the following 3 days, with detailed forecast information on sea surface temperature and currents. Cross-sections of along-shore currents provide along-shore transport forecasts that could potentially carry HAB populations from Portuguese waters. Plots of Lagrangian particle tracking simulations on the shelf at northern latitudes are displayed.

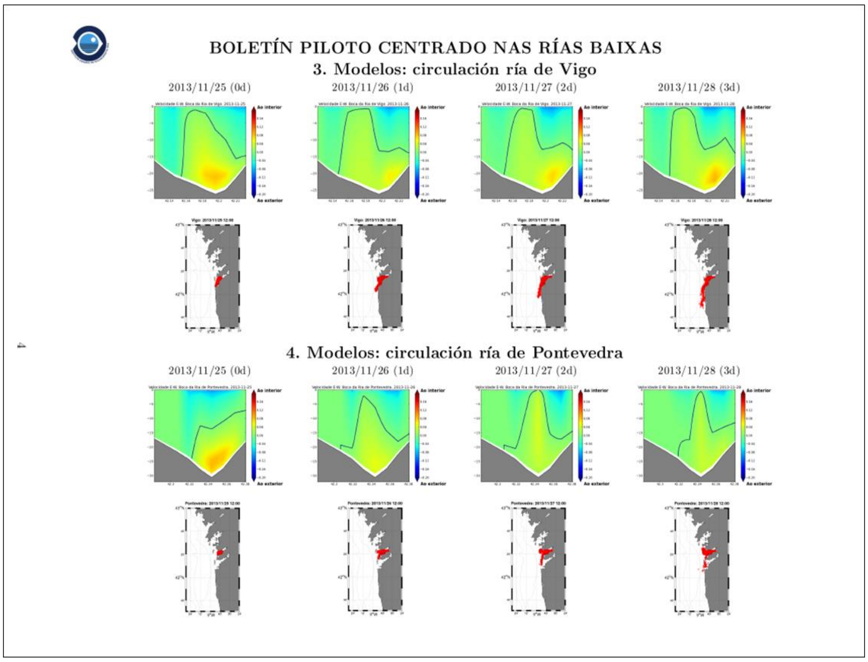


Figure 16. The fourth and fifth pages focus on estimating retention areas in the rías and potential transport between rías. Model forecast of flows into and out of the Galician rías with cross-sections at the mouth of the ría are presented. Additionally, Lagrangian particles shall, as required, be launched from the different rías and tracked for the following 3 days.

Feedback loop

Since the collection of user requirements is an iterative process, in AtlantOS we reviewed user requirements; this should ensure the system continues to mature and evolve.

Recent information gathered on the main customer needs (i.e. aquaculture industry) along with additional information on the wider community (government and public) on HAB forecast needs collected through informal discussions with the Harmful Algal Bloom bulletin end-users are listed below.

Feedback from Irish regulators and the shellfish industry:

Short-term warnings to receive advance notice of a harmful algal bloom are considered sufficient by the end-users. There was a positive response on the content of the current bulletin when compared to not having it at all. Improvement of the current forecast system will be dependent on the arrival of commercial *In-situ* ocean observing technologies, at a reasonable price and of sufficient quality, that allow the current status of the *In-situ* biological and chemical variables to be relayed in near real-time.

Feedback from Spanish HAB experts and monitoring agencies:

All users of the past, proof of concept, bulletin considered the bulletin as a useful tool and they envision they would use it in their monitoring work. The users with more responsibilities in monitoring considered the bulletin as good or acceptable, since their information requirements are higher. One of the remarks was that if bulletins are issued in a period when many polygons are closed, the information that can be obtained from state-of the art models is limited since they do not incorporate toxin dynamics. However, they recognise that in situations when harvesting areas are open, the bulletins could be more useful because they can forecast the risk of a HAB species driven by along-shore and across-shore currents.

All of them suggested that toxin data should be incorporated into the bulletins to provide additional information to status reports on the openings/closures of harvesting areas. All of them considered Lagrangian particle tracking experiments as a very useful tool, and some encouraged us to compute the actual flux between rías. Finally, they gave several suggestions on improvement of the presentation of the results.

Gaps identified in the current HAB Bulletin include:

1. The current bulletin needs to become more automated so maps and graphs are updated as soon as new data is generated.
2. The display / dashboard should be interactive and the user should be able to zoom into a region of interest to find out the latest news on biotoxins and HABs.
3. A dashboard should be made available to allow users to drill down and find easy to interpret visualisations of the supporting datasets e.g. phytoplankton community abundance, separation and abundance of toxic / harmful and beneficial phytoplankton (e.g. diatoms).
4. Since many of the end-users in Ireland and Norway are not familiar with Latin names used in botanical nomenclature, they want to see additional information that clearly shows the abundances of phytoplankton species present that are beneficial [“good”] and harmful [“bad”]. Suggestions included a colour coded table with green for “good” phytoplankton and red for “bad” phytoplankton.
5. The way modelled prediction results (currently available at two pilot sites/bays) on water movement are currently reported can be improved to make it a more useful tool to non-scientists. For example, it should be clear what HABs are associated with water bay exchange events in the “toxic season”. In SW Ireland, UPWELLING events are generally associated with the start of ASP events in mussels and DOWNWELLING events are generally associated with the start of DSP events. The bulletin needs to have a clear message about why this information is important in the “toxic” season. At the moment, end-users find these results difficult to interpret; perhaps they are a more useful tool to the scientists who compose the predictions in the bulletin.
6. The participants would like to see an indication of risk presented in a way similar to a traffic light system.
7. Robust *In-situ* biological and chemical observing technologies that detect phytoplankton and HABs (and biotoxins) in near real-time at selected sites (sentinel sites). These new *In-situ* technologies should operate as a service similar to the Irish weather buoy network with near real-time data presented and updated frequently online.

Summary and Next Steps

In this deliverable we report on HAB bulletins created with available data related to *In-situ*, satellite and model information in a graphical layout, that after expert interpretation are used to produce an early warning bulletin to the aquaculture industry and regulators in Norway, Ireland and Spain. The bulletins are consistently evolving through the interaction and feedback with stakeholders and a "best" practise community description document on "how to create a weekly bulletin" based on the Irish bulletin was prepared in collaboration with AtlantOS WP 6 was generated (Leadbetter *et al.* 2018). Task 8.1 colleagues will review the current draft and we plan for further reviews internationally.

The Irish bulletin has been operational during AtlantOS, the Norwegian bulletin was demonstrated as a proof of concept during spring-summer 2017 and the Spanish bulletin will be operational from spring 2018. AtlantOS has allowed us to demonstrate the use of HAB bulletins based on Atlantic observing systems, and allowed us to improve and develop bulletins in three different Atlantic areas. New projects like PRIMOSE (http://www.atlanticarea.eu/project/12) will continue to develop the HAB bulletins and help fill some of the gaps identified in the current bulletins (automation, traffic light system presentation, web dashboard etc.).

The next step for the AtlantOS HAB task is to follow the EMODnet process to create a Data Adequacy Report for the targeted product (i.e. the HAB bulletin) using the EMODnet Atlantic Checkpoint Sextant GIS database (metadata) with training and support provided Eric Moussat (ProAtlantic - EMODnet Atlantic Check Point project). This assessment activity will investigate if the data existences and availability are appropriate to provide a useful customer targeted HAB bulletin product (output). The methodology helps us to evaluate the quality of the data from current monitoring systems in terms of their accessibility, availability, multiple-use, efficiency, reliability, time consistency, space consistency, as well as the planning of technological advancements, new accessibility, new assembly protocols and observational priorities. The internal AtlantOS Product Specification Document with a description of Targeted products prepared for Task 8.1 is used to prepare the Data Adequacy Report.

In Task 8.1, we have identified a potential for collaboration with AtlantOS T4.1 Gap analysis and critical assessment of coastal observing systems since there is a lack of HAB monitoring on the shelf and transport of some HAB events is related to shelf hydrodynamics (see references in Maguire *et al.* 2016). T8.1 partners will participate in a common workshop with T4.1 scheduled on April 26th in Bordeaux.

Continuing Research activities in this field includes the an INTERREG project called PRIMOSE that plans to automate the production of the bulletin in Atlantic Arc countries including Ireland and Spain and the JPI climate ERA4CS CoCLiME project where the existing HAB bulletin process is used as a basis for developing a climate service offering the aquaculture industry and other stakeholders an insight into potential changes that may affect them on timescales from seasonal to decadal and longer.

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