FORCOAST

Earth Observation Services For Wild Fisheries, Oyster grounds Restoration And Bivalve Mariculture Along European Coasts

PROJECT DELIVERABLE REPORT

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1. Executive Summary

Today, there is a lot of data on oceans and seas available by remote sensing, monitoring programs & local sampling: e.g. Sea Surface Temperature, Salinity, Oxygen concentrations, Wind, Currents, Waves, Upwelling events, Chlorophyll-a concentration, Turbidity, SPM, etc. These data, however, are difficult or not accessible or difficult to interpret by the end user and therefore unused. On the other hand, these data are often used by modellers, to feed hindcast and forecast models. Yet, even these models are developed for other stakeholders and are not fitted or not specific enough for fishermen, shellfish producer or oysterground restorators.

The objective of FORCOAST is to provide Services that disclose this information and can be used as “Fit to use” service according to the specific requirements of fishermen, shellfish farmers and/or oysterground restorators. Therefore, these Service Modules will use next to the data from remote sensing, monitoring programs and local monitoring and models, specific data from the end user and provide as output, depending on the level chosen by the end user: alerts, status reports, maps or standard datasets.

This must enable the end user to make more efficient decisions to plan operations and enable the end user to save money, because of better prediction when to go at sea, where to fish, when to set out oyster spat collectors or to harvest.

Each activity sector, i.e. fisheries, aquaculture and oyster ground restoration, have end users with specific user requirements which are important to setup specific Service Modules. These sectorial user requirements are described in part 3 of the report *D2.1 Stakeholders interests and needs by sector and pilot site* and are translated to deployable sets of post-processing tools and communication strategies that allow to turn marine information/data sets (local and remote sensing) into tailored services to the end users.

According to the end user requirements specific Service Modules were put forward to help the end user and will result in cost-saving solutions.

The initially-identified Service Modules are here given per sector:

Sector Fisheries

1. SM-F1 – Suitable Fishing Areas
2. SM-F2 – Front detection

Sector Aquaculture

3. SM-A1 – Operational scheduler
4. SM-A2 – Land pollution
5. SM-A3 – Prospection for new sites
6. SM-A4 – Assistance for spat captures
7. SM-A5 – Marine conditions at farming site/alarm system

Sector Oyster ground restoration

8. SM-R1 – Retrieve sources of contamination

This document, *D3.9 Sector-specific decision workflow synthesis* describes the setup of an Operational Workflow to describe each of these specific Service Modules.

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2. Table of Contents

List of Figures

List of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870465.

3. Introduction

Each activity sector, namely the fisheries sector, aquaculture sector or oyster reef restoration sector has end users with specific user requirements. The sectorial user requirements are described in part 3 of the report D2.1 Stakeholders interests and needs by sector and pilot site. These requirements are translated to deployable sets of post-processing tools and communication strategies that allow to turn marine information/data sets (local and remote sensing) into tailored services to the end users: the Service Module.

D3.7 provided an inventory on models that were available to set up the Service Modules and what marine state variables are provided by these models (Figure 1).

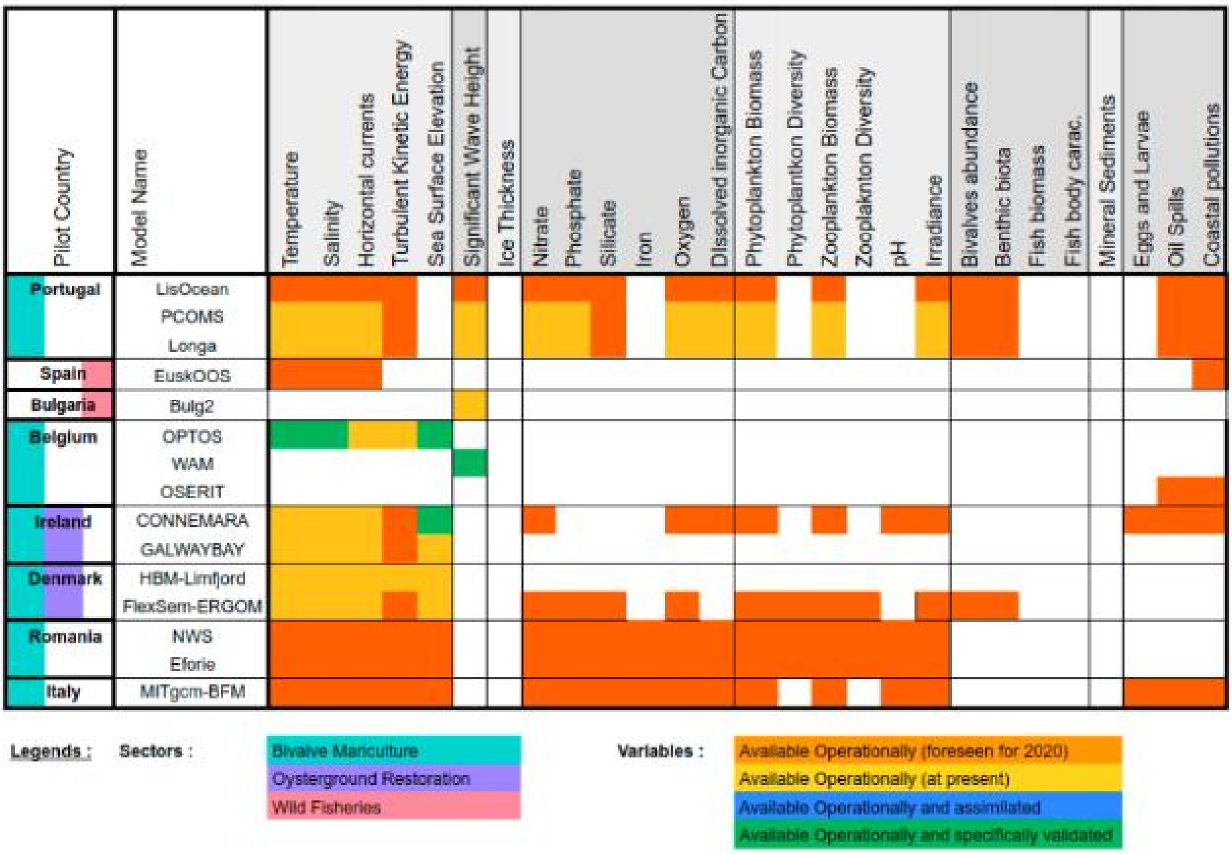

Figure 1. Inventory on available models (Pilots) and the parameters used in these models.

The aim is to develop Service Modules that exploits information from models (Pilots) and make use of CMEMS and local data sets, which are accessible for the end user via a central platform (Figure 2).

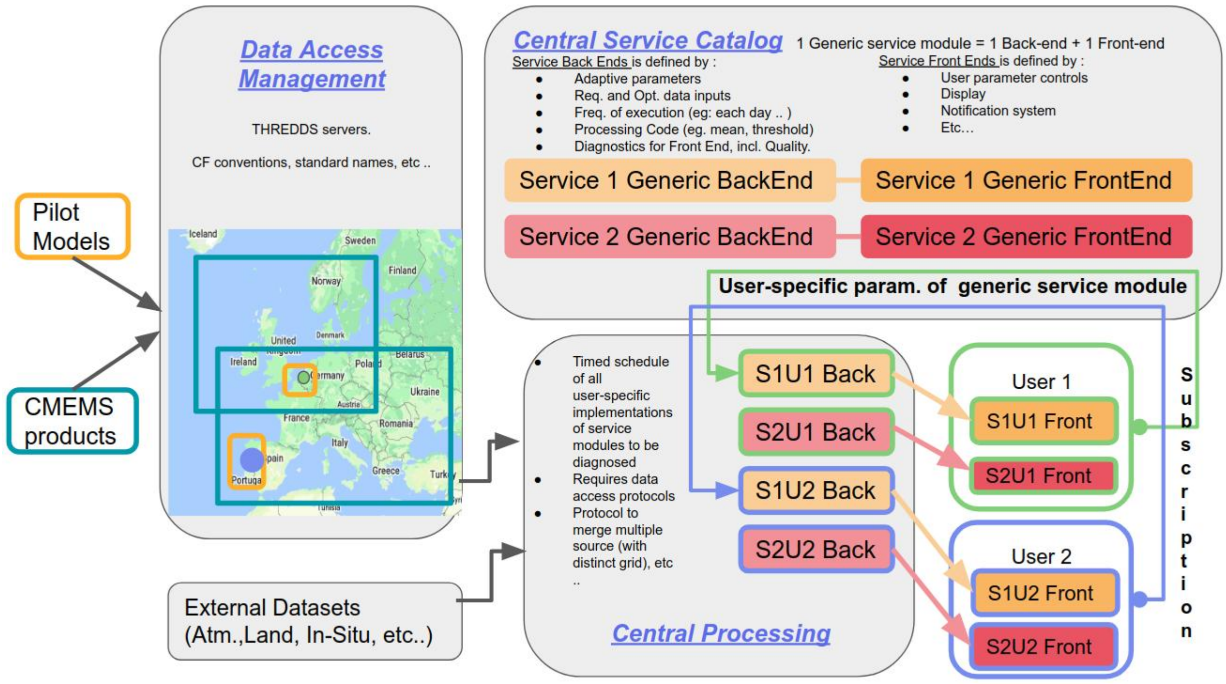

Figure 2. General architecture of the FORCOAST service project.

Based on the end users requirements of the Pilots (D2.1), the following Service Modules were identified (Table 1).

Table 1. List of Service Modules and the leader of this Service Module, with contribution from other Pilots.

Sector	N°	Service module	Leader	With contributions
Fisheries	F1	Suitable fishing area	Pilot 3 (Bulgaria)	
	F2	Front detection	Pilot 2 (Spain)	
Aquaculture	A1	Operation scheduler	Pilot 1 (Portugal)	
	A2	Land pollution (*i.e.* exposure to bacterial outbreaks, harmful substances)	Pilot 7 (Romania)	
	A3	Prospection for new sites	Pilot 6 for Limfjorden, but need to consider wider application of the module (for other sites)	Pilot 8 (Italy) : in particular to pre-process remote sensing data
	A4	Assistance for Spat Captures	Pilot 4 (Belgium)	
	A5	Marine conditions at farming site/alarm system	Pilot 6 (Denmark)	
Oyster ground restoration	R1	Retrieve sources of contamination	Pilot 5 (Ireland)	

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4. Elements of the Service module from different perspectives

Here we aim to set the list of components that should compose a given Service Module definition sheet. To that aim, we describe service modules with different points of view and highlight *elements* that need to be retained in the generic service module definition template. The elements are here defined according to the user needs requirements, the developers technical definition, communication to a wider group, and market uptake enhancement.

4.1 End user requirements

For an end user, a service module is something to which (s)he can subscribe to, in order to enhance the overall production, competitiveness or sustainability of his/her business.

An overview of available services should thus be accessible in a *central catalog,* with *summary* and *illustration* of what this service would provide.

The service should also be adapted to one's specific case (activity), so an input of *personal parameters* to implement a generic service to a personal service should be provided.

It is also important that the end user knows in what way the information needed will be delivered through the Service Module, e.g. in a map, time series or "go or no-go".

4.2 Developers derived Elements in Service module

As a developer, the concern is to ensure that the diagnostics, needed to feed a given service, are computed correctly and in due time.

The developer needs:

- to know which *subset* of marine information should be used for computation;
- a *script or executable* to derive diagnostics from this subset; and
- to know the *schedule of this execution*, in order to manage the central FORCOAST queue.

4.3 Service module from the point of view of Marketing

If a Service Module is to be sold to potential end users, or to explore the business opportunity of selling this service, it is needed to know what *values* it represents to potential customers.

It is also needed to characterize the level of viability of the Service Module, as a kind of guarantee that it would be relevant and is worth subscribing to. This relates to a definition of *service validation protocol*, or ways in which uncertainty is attached to a specific service.

4.4 Service module from the point of view of Communication

At this level, it is important to ensure that subscribing to, setting-up, and using the Service Module is as smooth and intuitive as possible. To do so, it is necessary to define the *service front-end* through which the information of the Service Module is provided to users, and the *interaction mechanism* through which users can provide personal parameters.

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5. Emphasis on the integration of Copernicus data

The emphasis should be on the integration of Copernicus data into the Service Modules, *i.e.* Copernicus Marine Service products, Land Service products and Copernicus Climate Service products, consisting of Earth Observations and model forecasts and/or hindcasts.

Copernicus Marine Service provides numerous products for the Global Oceans and the European Seas. The products include historical data, hindcast (reanalysis), near real-time forecasts, and forecasts. The temporal resolutions vary from hourly and daily to monthly. Furthermore, fine, medium and coarse spatial resolution products are available. Certain CMEMS model products use data assimilation of Sea Surface Temperature, sea level, or Chlorophyll-a into the models. The processing level of CMEMS products ranges from L2 discrete (with quality control flags) through L3 gridded (data with gaps after validation) to L4 grid (gap-free gridded data after validation). Models and observations (in-situ and satellite) are available covering different physical and water quality variables such as:

- Biological (*e.g.* nutrients, plankton, primary production, Chlorophyll-a, oxygen, transparency, turbidity);
- Physical (*e.g.* salinity, temperature, current velocity, sea surface height, bottom stress);
- Wave (*e.g.* wave swell, wave mean direction, wave mean period, and significant height).

Copernicus Land Monitoring Service (CLMS) provides various bio-geophysical variables in near real time that describe the state and evolution of land-related variables globally, in a pan-European scale, and locally. As coastal systems are bounded both by sea and land, good-quality land-based data is required for setting up high-resolution coastal models. The local component, based on very high resolution imagery *and in-situ* measurements, offers the most valuable input to high-resolution coastal models of FORCOAST (*e.g.* measurements of coastal hydrographic data). This dataset includes river flow data for coastal areas including flow volumes, sediment, nutrients, and organisms. Such data will be available from Copernicus in-situ measurements for the Riparian Zone Mapping and the upcoming Coastal Zone product. Furthermore, the global products are available in different spatial resolutions (100m, 300m, >=1 km) as well as non-gridded. These products include vegetation state products (*e.g.* vegetation properties, vegetation indices, leaf area index, fraction of photosynthetic active radiation – PAR absorbed by the vegetation) that can be used for coastal habitat maps. The Pan-European components of the CLMS produce satellite images mosaics, land cover/land use information in the CORINE Land Cover data, and the High Resolution Layers to describe vegetated foreshores and wetlands.

Copernicus Climate Change Service (C3S) provides a climate data store containing seasonal forecast products for air and sea-surface temperature, atmospheric circulation and precipitation. These forecasts are updated every month covering a time range of 6 months and can be very useful tools for aquaculture managers. The data store will contain consistent estimates of Essential Climate Variables and climate indicators. The following products are expected to be available:

- Homogenised time series of in-situ observations and associated metadata;
- Reprocessed climate data records from satellites;
- Output from global and regional reanalysis;

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- Seasonal forecasts;
- Outputs from climate models including projections;
- Searchable metadata relevant to provenance, traceability, use and applicability of all datasets.

At the moment public access to these datasets is only possible externally through the ECMWF WebAPI. FORCOAST has as objective to use the datasets from the Copernicus Climate Change Service Climate Data Store (CDS), together with data products that are complementary to the Copernicus products and are essential for the operation of the Service Modules (*e.g.* regional collected data, sentinel missions or databases, *i.e.* EMODnet).

Those relevant variables are initial potential requirements that can be incorporated into the workflow. Depending on the actual design/workflow of each service, the relevant subset is going to be highlighted below.

6. Why is an operational workflow needed?

The operational workflow explains the different steps in setting up a service module and must result in a gain or profit on the following levels:

6.1 Operational responsiveness

The end users (fishermen, aquaculturist or oyster reef restorator) are in one kind or another managers, which have to respond to certain changes in the current situation. They achieve this through continuous improvement, which requires up-to-date information and the ability to make continuous and *ad hoc* changes in their operations. The development of a specific Service Module must enable the end user to predict certain changes in the environment, to which (s)he can change his/her operations accordingly.

6.2 Operating cost reduction

Service Modules must enable the end users to act on predictions, and result in an operating cost reduction. As business operation performance depends on revenues and costs, these Service Modules must deliver significant value at a reasonable cost, e.g. license fees, fishing trips, harvesting costs, etc. (WP6). It is therefore necessary to inquire the value gain for the introduction of such a Service Module and the cost of the development and operating such a Service Module, *e.g.* by a central platform (WP4) which should allow:

1. To collect (operationally) marine information from specific Thematic Real-time Environmental Distributed Data Services (THREDDS) servers (*i.e.* CMEMS and Pilots) and make them available to centralized post-processing scripts, *i.e.* ensuring common data format and conventions.
2. To derive from specific diagnostics according to end user needs, on the basis of hindcast, observed or forecasted marine information, on a routine basis which is specific to different services (*e.g.* daily update, silent watch and warning system, one-shot assessment).
3. To communicate such diagnostics to the user dashboard (app, personal dashboard on website, etc..).

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6.3 Quality management

As the Service Modules will enable the end users to act at the right time, they can foresee trouble shooting, *e.g.* toxic algal blooms, extreme warm conditions, oxygen depletion, large river plumes with subsequently low water salinity and a higher risk for biological or chemical contamination, the Service Modules will also have a positive effect on the quality of the management. This factor must also be included in the value gain (WP6).

7. Designing an operation workflow

The user requirements for each Service Module implies a number of decisions to be taken that drive the prospection, implementation, operation and interaction with customers. Deliverable 3.9 consists of setting up an operational workflow for each of these Service Modules and listing the involved decisions. These decisions must be oriented on the basis to acquire better knowledge and include specific aspects of the marine environment, which are needed to be described and summarized for the benefit of the sectorial end user. Aspects that concerns specific subsets of activities (*e.g.* tuna fishing, oyster reef restoration, seaweed culture, etc.) will be considered specifically for economically relevant cases, *i.e.* the Pilots. Examples of these activities include: timing for harvesting, respawning, site selection, species selection for farms, etc. These aspects help the evaluation of enhanced CMEMS downstream products and aim for better information of those decisions.

In order to build consistency among the different pilots, where possible, it is very important to have a clear view on the operational workflow for each of the developed modules (Figure 3).

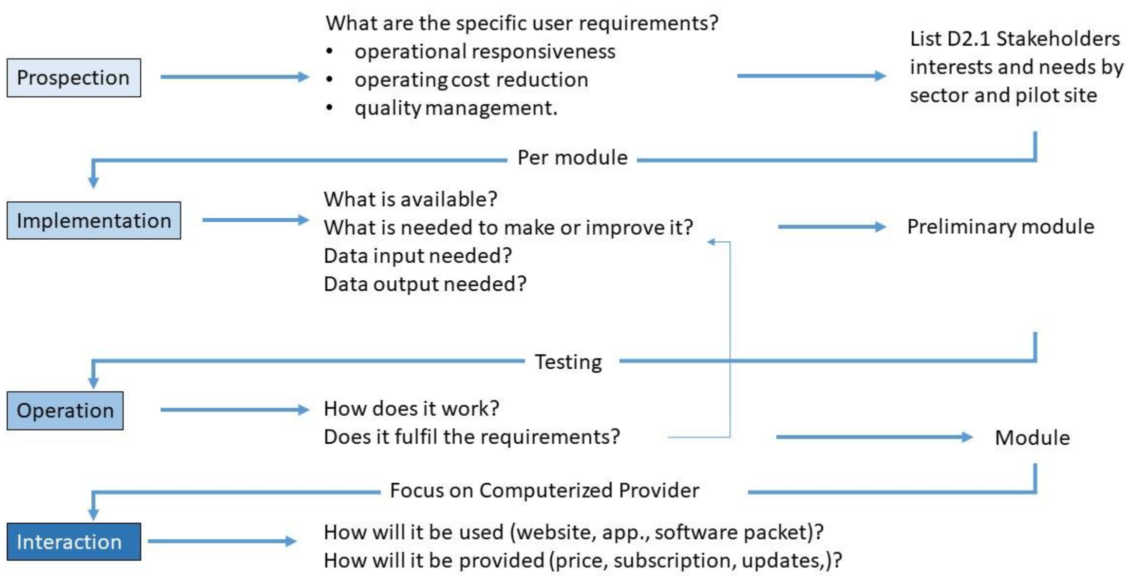

Figure 3. Sector-specific decision workflow.

7.1. Prospection

A first step in this process is the prospection phase. In this phase we learn about the local regularities in the environments and how we can adapt our behaviour accordingly, in order to maximise the outcomes and minimise the risks. In order to do so, it is important to make a list of user requirements per service module, with special attention to operational responsiveness, operating cost reduction and quality management (see above). There is a clear link with Work Package 2: User Engagement and Requirements. The stakeholders interest per sector were identified in D2.1 Stakeholders interests and needs by sector and pilot site. This must be handled per service module as service modules can/must be used across sectors, on a different spatial and temporal resolution. For example the weather forecast module can be used by a manager in nearshore aquaculture to see if it is feasible to go tomorrow at sea 5 km from shore. While a manager for oyster reef restoration would like to know if the oyster grounds offshore are accessible next week, so he can place today an order for juvenile oysters. Or Belgian fishermen would like to know if the next two weeks are good for fishing in the Irish Sea.

In this section a clear description should be made about the necessity of the Service Module:

- Why do the stakeholders need this Service Module?
- Which resolution is needed, for example very local for managers involved in oyster reef restoration, regional for the aquaculture sector (e.g. a bay or estuary) even wider for fishermen (depending on the fishing techniques)?
- What is the operation cost now and what would it be with the Service Module.
- What is the feedback to the end user. For example in SM-A2 three levels of feed-back to the users are considered. SM-A2 operates a routine assessment of potential exposure at each update of the circulation forecast (cf. Sect. operation). If a high risk is identified, Level 1 consists of a notification. Level 2 is a standard display of exposure risk at the farm sites, Level 3 provides a map to appreciate the situation at a larger scale.

These questions can be answered by organising a poll to be sent to the stakeholders of interest (cfr. D2.1). The results of the poll can also be used in WP4 and WP6.

A step in this direction was the feedback collection from potential final users and stakeholders at the General Assembly, where each Service Module had the opportunity to present the services they offer along with the mockups.

7.2. Implementation

The next step is the implementation phase and includes scope analysis, customizations, systems integrations and user policies. In this section it is necessary to point out which data is needed for the Service Module, as well as, which data models are to be used to develop the specific Service Module. So, in order to develop a Service Module, it is necessary to first outline the available remote sensing and local data, as well as existing data models that can be useful for the managers (Figure 4). Special attention should be made to the use of remote sensing data, as this is the main objective of the project: namely to use remote sensing data in the Service Module, extended with local data.

The Sentinel Missions and the Copernicus Services are therefore a valuable starting point as of the continuity of remote observations, including global and regional forecasts providing higher spatial resolution (up to 10 m) and a high temporal repetition of measurements allows for monitoring changes at scales of days or weeks, with the possibility of operating in all weather conditions.

Combining the measured data with localized coastal models permits a better understanding of processes of the coastal during long temporal scales. Therefore, one has to look at the existing model and see what is needed to improve the model. In case no model is available, one has to ask what is needed to make such a service module.

Next to remote sensing data and the local data, the Service Module must be able to be customised. This can be done by integrating the possibility for input of the end user/stakeholder: *e.g.* coordinates of the location, ship length, sector, etc. But also the way how the end user wants to have the data output: what level of output.

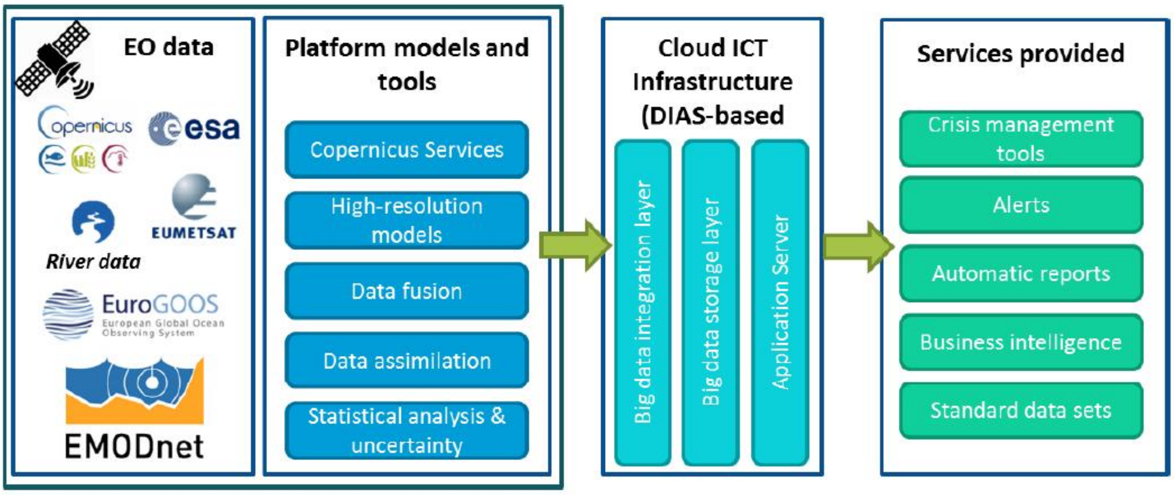

Figure 4. Generic FORCOAST platform architecture.

Developer concerns

Validation of the remote sensing data can be performed with the comparison of data taken *in situ*. For example, data on chlorophyll a from satellite images can be compared with *in situ* measurements of chlorophyll a in the Pilots.

As the Sentinel Missions and the Copernicus data are difficult to access, manipulate or process, they are not readily available to managers and furthermore difficult to interpret. It is therefore necessary to make the data more accessible and easy to read, in order to make it possible for the managers to perform the necessary adjustments to their routine operations. This is done by using the high resolution data that are based on Copernicus Marine Environment Monitoring Service (CMEMS) and Copernicus Land Monitoring Service (CLMS) and the Climate Change Monitoring Service (CMS) as input data for the model.

The model needs to turn the remote sensing data into, for the manager, understandable and usable information. The model can be completed with local environmental data. Designer concerns for the service module are the following: Is there a model readily available for the manager requirements and if so, how can it be used by the manager? What subset of marine information is needed for the necessary output? What script or executable is needed to derive the diagnostics from this subset? Can

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the model be used over a larger spatial and temporal range? If so, what is needed? What is the schedule of execution to manage the central FORCOAST queue? How much data storage space will the module consume? How many lines of program code will it take to perform this function? How can we cut down on CPU time when we run the system? What are the most efficient ways of storing this data? What database management system should we use?

End user concerns

Further data input in the service module is the local data set from the manager, needed to feed the service module and fulfil his essential requirements (e.g. enhance the overall production, competitiveness and/or economical sustainability of the business). The user concerns can be described as: the need to provide personal parameters into the service module to personalise the service module (per sector and per region), which will result in an understanding of the format that is needed for selective applications. Such specific manager input data includes sector, location of activities, type of vessel, etc.. This means that the service module must allow the input of specific manager data. Therefore the service module must allow the personnel input from the manager according to KISS principles ("keep it stupidly simple" or fool proof), as in most cases the managers are not acquainted with ITC techniques and require straight forward input possibilities.

On the other hand, the service module must allow users to choose how the wanted information will be delivered, once the manager has subscribed to the service (e.g. in a map or a time series, forecast or hindcast, etc.). Therefore a questionnaire should be provided at the time of subscription, to establish the requirements of the manager to consult the given information by the service module. This will also shape the design of the service module, as well as on how the output information must look like (e.g. in what form).

The two latter requirements show the important role of the end user in this process, as system implementation benefits from high levels of user involvement. The participation of end users in the design and operation of these modules will shape the module according to their priorities and business requirements, and therefore, they are more likely to react to the change in process.

User concerns are: Will the system deliver the information I need for my work? How quickly can I access the data? How easily can I retrieve the data? How much clerical support will I need to enter data into the system? How will the operation of the system fit into my daily business schedule?

For an end user a service module is something to which he can subscribe to, in order to enhance the overall production, competitiveness or sustainability of his business.

An overview of available services should thus be accessible in a central catalog, with summary and illustration of what this service would provide.

The service should also be adapted to a specific case (activity), so an input of personal parameters to implement a generic service to a personal service should be provided.

It is also important that the end user knows in what way the information needed will be delivered through the Service Module, e.g. in a map, time series or "go or no-go".

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FORCOAST concerns

The main objective of the FORCOAST consortium is to guarantee the continuous service of these service modules, even after the end of the project FORCOAST. It is therefore of the outmost importance that the cost of the service modules includes the continuous service (updates, etc.).

7.3 Operation

In the operation phase, emphasis lays on designing and controlling the process, as well as in the production of services. It explains the functionality and building of the Service Module. In this stage the efficiency in terms of using resources as needed and in terms of meeting the end user requirements. It concerns the transfer of major inputs, such as remote sensing and local data, specific manager data, labour and energy, into outputs (services for the managers). In this phase, the focus is on the production of the Service Modules, quality insurance and the creation of services. During this phase different sectors are covered, such as banking systems, insurance companies, sectorial companies, working with suppliers, technology and customers. The operation phase requires management the production of service modules and accompanying services.

The most important questions to be answered within this phase, are:

- How does the Service Module work and does it fulfil the requirements of the manager/end user? If not, what needs to be done to achieve this.
- What is the operations strategy? This will enable the execution of the direction set by the business and commercial strategy. The manufacturing network and service module will make a structural trade-off between market and product/service coverage, quality, flexibility, innovation and cost, in such a way that efficiency is maximized while delivering high quality products.
- What is the product design? This is the process of deciding on the unique and specific features of the Service Module.
- How must the Service Module be designed?
- How does it control the process? This is the process of identifying the unique features of the production process that will give the product its unique characteristics. Process selection typically goes hand in hand with product design, as it is necessary to create a process that gives rise to the particular product design desired.
- How will it be produced? The Service Module must be conceptualised as a SMART of fully connected and flexible system, in order to fit within the digital supply network.
- Facility planning? The goal of facility planning is to not only recognize opportunities for efficiency, but to anticipate them as well. This will certainly include the setup of the Central Platform within the project FORCOAST (cfr. WP4).

The important decisions made during this phase requires an ability to analyse the current situation and find better solutions to improve the effectiveness and efficiency of manufacturing or service operations. In short, it explains how the Service Module works and if it does fulfil the requirements of the end user. If not, the module needs to go back to the Implementation phase.

It is clear this phase can only be achieved with input from banking systems, consultancy offices (*e.g.* Deloitte, etc.), insurance companies, sectorial companies, suppliers and customers. It has therefore a clear link with WP5, WP6 and WP7 of the project.

To answer these questions one can make a mock-up in order to visualise the Service Module.

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7.4 Interaction

In the Interaction phase the two-way effect of Service Module and end user is investigated. Such an interaction concerns the communication of any sort, in this case, the communication between end user to Service Module and from Service Module to end user.

The end result should be an added value for coastal applications by the end users. It is therefore important to explore in this phase the value of these Service Modules for the end users, in order to sell a service module to potential users or to explore the business opportunity of selling these Service Modules. This can be carried out by the organisation of a poll among stakeholders for a proper evaluation of the willingness to pay for a specific service. This should best be coordinated at a sectorial level, most probably with interviews or polls. For example, a fisherman goes at sea to a certain location where he knows there is a lot of fish with a high commercial value in that season. At arrival, weather conditions are to bad, due to the prevailing strong wind and must choose an alternative location: total cost is the fuel prices to get to the location, fuel cost to go to the other location, less fish, fish with lower commercial value, etc. Or no deliverable goods due to contamination of the water basin after heavy rainfall or toxic algal blooms during high light intensities and temperatures. Make the sum of all these events that turn out negative for the end user and would be avoided if those events could be predicted by a specific Service Module.

It is also important to characterize the level of viability of these Service Modules, as a kind of guarantee that it would be relevant and is worth subscribing to. This relates to a definition of service validation protocol, or ways in which uncertainty is attached to a given Service Module. The communication can be different according to the demands of the end user, such as consultation of the models by computer or phone, or display of forecasts or even function as a “traffic light” (go – no go).

8. Synergies and transferability

Although the Service Modules are constructed per sector in this project, harmonisation between the sectors is important, so that Service Modules can be interchangeable between sectors. During the setup of the D3.9, this transferability of Service Modules over a wider range than the Pilots under which these Service Modules were developed, was not considered, but will be explored further during the course of the project (Figure 5). This transferability has as advantages that a larger number of end users can be covered, it also expands the user community feedbacks essential for the fine tuning of the service design, and it expands the functionality/generality of services.

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	Service name		2 Spain	3 Bulgaria	1 Portugal	4 Belgium	7 Romania	8 Italy	6 Denmark	5 Ireland
	Model data use	*EO data use*	THREDDS	?	THREDDS	ERRDAP	THREDDS	THREDDS	FTP	THREDDS
F1	**Fish suitability index** Upwelling index	Calibrated use	X				X			
F2	**Front detection** SST, (Chl)	SST, (Chl)		X	X		X			
A1/5	**Marine conditions** Any (hindcast + forcast)	blend for hindcast?			X		X X		X	XX
A2	**Harmful Land Discharges** Currents, Turbulence, (Waves)	/			X	X				XX
A3	**Prospection for new sites** Phys, BGC, Food Sources	/							X	X
A4	**Assistance for Spat Captures** Specific	/				X				X
R1	**Retrieve source of contaminants** Currents, Turbulence, (Waves)	/		X						X

Legend	
Implementing this Service in This Pilot should be a priority	X
Leading Service Module	
Service Module tested	
Feasible	
Require specific calibration	
Require additional data input	
Irrelevant	

Figure 5. Synergies and transferability between the Pilots.

9. Operational workflow for the Service Modules

In order to set up an operational workflow and listing the decisions, it is necessary to illustrate the different service modules that have been suggested for the relevant sectors, which can be used on an international level, instead of providing solutions to local or national actor (Prospection). Next is how could these models be implemented for the specific activity (Implementation), which also relates in how these models would work (Operation). The last phase is the way how these models would be used by the different sectorial users (Interaction). This involves iterations and exchanges among the different work packages.

9.1 Wild fisheries

Service Module F1 – Suitable Fishing areas

Prospection

Ocean information is useful in fisheries to search for suitable habitats of small pelagic fish and avoid other species. This information must enable the fishermen to increase catches and reduce unwanted bycatch (especially with the European landing obligation), but also save fuel (direct transits to good fishing grounds). In that way, this information would reduce the costs associated with days at sea (person-work, fuel, fungible...) and thus optimizing the total operational costs. For this purpose, it is needed that the end users receive at least daily updated ocean data (hourly information and 3 days forecasts would be welcome also). These requirements are needed in the short-term time scale (within the next hours or next weeks). Regarding the spatial scale, surface maps of at least 1 to 4 km spatial resolution would be desirable (more details in section 3.1 of deliverable D2.1).

Implementation

To develop this Service Module the following EO and model data from CMEMS are available: sea surface temperature and salinity, currents, mixed layer depth, sea surface height, chlorophyll a concentration, primary production, euphotic zone depth (more details in section 3.2 of deliverable D3.2). In addition to this regional information, outputs from a local model data (based on ROMS numerical model) is also available, *e.g.* temperature, salinity, and currents.

Nevertheless, these data should be customized, to facilitate the interpretation. For example, the development of a tool to compute fronts and estimate Lagrangian coherent structures. In addition, the model will be more realistic if river discharge data is incorporated. People involved in the implantation of this Service Module are Modellers & Service Module designers. The former for advancing the outputs from models based on the existing configuration and the latter for designing and development of an easy-to-use application.

Operation

The Service Module should be based on a web-based online single-application, easily to use. The major inputs, remote sensing and model data will be mapped in the application. Local information could be added by the end users by means of specific tools. For a better understanding of the information, the data should be plotted in colour coded icons on the maps and coded maps. It would be also helpful to include an overview of threshold exceedances using green, amber, red colour coding. Furthermore, it should provide the possibility to key their own (custom) thresholds if required. A further requirement for the Service Module is that it must include a way to verify that the provided data is being correctly processed and updated.

Interaction

Communication between the end users and the Service Module should be required, for improving the application (tools, information...). The Service Module must result in an added value to the current coastal applications (e.g. EuskOOS service). The value of the Service Module will be calculated by comparing it with similar free and paid services, in order to assess if this service is worth subscribing to.

Figure 6. Mock-up screen for SM-F1 – Suitable fishing areas.

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Service Module F2 – Front detection

Prospection

Ocean fronts are areas where a sharp gradient between the characteristics of two water masses occur. Across frontal areas there is a strong gradient in the physical and biochemical properties of the sea water over a short horizontal distance. Therefore, different types of fronts depending on their location, persistence, and size can be identified. As such frontal areas play an important role in the ecosystems, they can influence human activities, such as fisheries since there is usually a higher concentration of commercial fisheries along fronts. In our study area (Bay of Biscay, eastern boundary current, temperate area) we will focus on the following fronts: shelf, shelf-break, coastal-upwelling and estuarine fronts; as well as, on frontal areas in the deep ocean. Ocean fronts information together with other ocean information is useful in fisheries to search for suitable habitat for small pelagic and avoid other species. This information would reduce the costs associated with days at sea (person-work, fuel, fungible…); thus, optimizing the operations in the sea cost. For this purpose, these end users require at least daily updated ocean data (hourly information and 3 days forecast would be welcome also). These requirements are needed in the short-term time scale (within the next hours or next weeks). Regarding the spatial scale, surface maps of at least 1 to 4 km spatial resolution would be desirable (more details in section 3.1 of deliverable D2.1). The feedback to the end users will be a daily map based on the satellite data and model outputs, showing the location and the shape of the fronts.

Implementation

To develop this Service Module the following EO and IBI model data from CMEMS are needed: sea surface temperature and chlorophyll a concentration. In addition to this regional information sea surface temperature maps from a local model data (based on ROMS numerical model) are also needed. Outputs from this local model will be more realistic since river discharge data is incorporated. Fronts will be calculated from these maps and it will be possible to observe if there is coherence between satellite and model outputs derived sea surface temperature and chlorophyll concentration fronts. A possible customization that could be applied by the end users is to fix a threshold for the sea surface temperature or chlorophyll concentration gradient, in order to consider or not a frontal area.

Operation

The Service Module will work inside an easy to use web-based online single-application inside the “Fishery” application. The option to visualize the fronts may be activated/deactivated directly from the website.

It must be designed to be easy to handle. The following figure (Figure 7) shows an example of the mock-ups:

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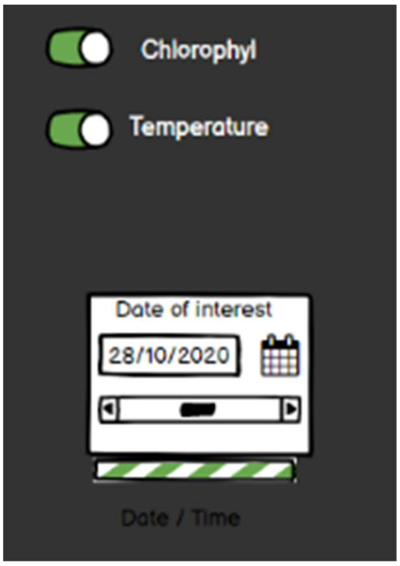

Figure 7. Mock-up of the selection screen for the different fronts: Chlorophyll a and/or Sea Surface Temperature.

The end-user controls the process by activating or deactivating the option to visualize the fronts. Moving sideways the scroll, only one type of front, both, and none of them can be visualized.

Since satellite sea surface temperature and chlorophyll maps are usually provided on a daily basis, the fronts will also be provided with this resolution. The end user will have the opportunity to select a date from a calendar by the sideways scroll or directly from the calendar.

The major inputs for this Service Module, are sea surface temperature and chlorophyll a from remote sensing and model data. Local information could be added by the end users by means of specific tools. The sea surface temperature and chlorophyll a maps will be processed by a python code.

Regarding the production of this Service Module, first, satellite maps and model outputs will be updated with a daily frequency. Once locating these data in a specific folder, a python code will be applied to the maps and the fronts will be identified. This binary data will be afterwards uploaded and codified on the website.

The design of the product could be similar to the following mock-up (Figure 8):

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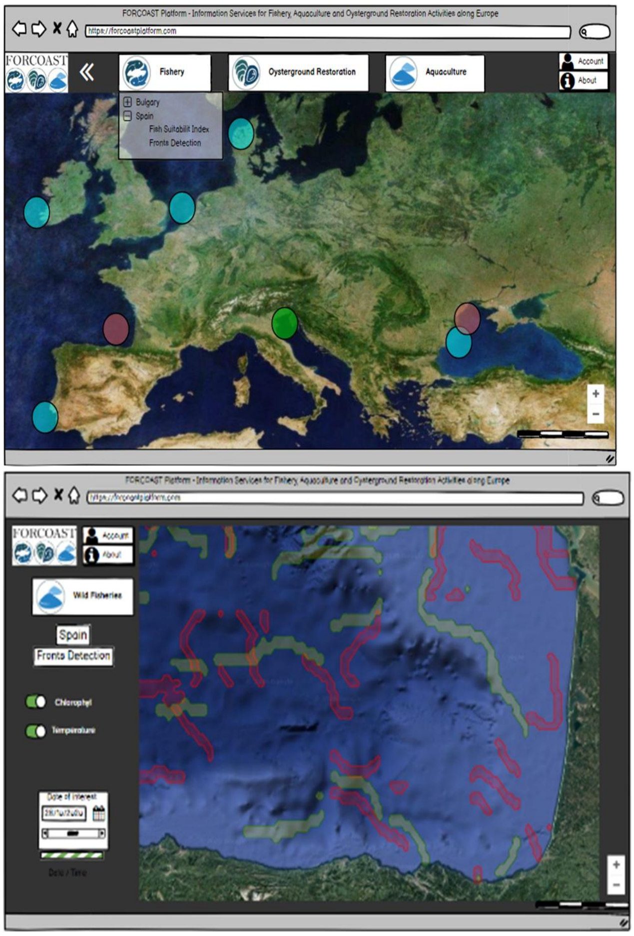

Figure 8. Mock-ups for the F2 – Front detection Service Module. Left: shows the map on which the end user needs to select the area of interest; Right: shows the map with different fronts in the selected area of interest.

Interaction

Communication between the end users and the Service Module should be required, for improving the application (tools, information…). The end result would be an added value to the current coastal applications (e.g. EuskOOS service). The value of the Service Module will be calculated by comparing it with similar free and with paying services. And when this value is calculated it would be assessed if this service is worth subscribing too. The principal benefit of this Service Module is to reduce the time at sea and the distance travelled. This will contribute to lower costs (fuel, person/month, fungibles…), lower emissions of GHGs and to a more comfortable work at sea.

9.2 Aquaculture

A1 – Operation scheduler

Prospection

End users will need to provide the environmental variables that affect or limit their operations at the sea (maybe with a scale, soft or hard difficulties to work). For that, well defined threshold values are needed. These can be modified or adapted in a later stage, *i.e.* interaction phase.

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According to the site of interest, the variables could be more or less important and they could also be ordered or rated according to their importance. For instance in Pilot 1, several variables were initially identified:

- Water level: this is the most relevant for the Pilot 1 end-user since the production area is reached by boat and arriving earlier means having to wait to start work and arriving late means losing effective working time;
- Sunlight: The activities are done in open environments and with natural light so they need to know when the sun rises and sets;
- Wind conditions: they can influence the feasibility to operate and even to cancel operations. This variable can be important for planning activities or taking actions to reduce damages under severe conditions;
- Waves: this parameter is not significant for Pilot 1, but can be for other end users;
- Currents: this parameter is not significant for Pilot 1, but can be for others. It may have an impact in navigation time.

Implementation

The implementation can be carried out in two phases according to the cyclic conditions of the variables:

- Cyclic variables: tides (water level and currents) and sunlight have their own cycles and can be produced, with some margin of error, with plenty of antecedences. The first phase will provide a year ahead sunlight and tidal water levels. These values will be improved in a second phase with operational models, with water levels and sunlight periods that are corrected with meteorological conditions;
- Non cyclic variables: waves and wind conditions can only be provided daily with 14-days forecasts using operational models.

Operation

Numerical models will be implemented in one or two phases according to the end users requirements. Two options for service operation are possible:

- Defined locations: the end users know exactly where they want the forecast to be obtained (*i.e.* aquaculture production areas, port, etc.);
- On demand locations: The user may want to know the conditions in different areas (*i.e*. fishing or wild collection)

This service will focus on aquaculture defined locations. In this case, the operator will define time series outputs on specific locations. The time series will be stored in daily files that will be replaced with more recent forecasts. Another software will analyse the values in those time series and will extract information and analyse thresholds. The extracted values will be sunrise and sunset (according to sun radiation levels) and high-low tides times at the location and converted to local time. According to the thresholds the software will indicate optimal working times. The rated conditions will serve to generate green, orange and red conditions.

A system evaluating that the operational system is working is needed to ensure that the service is 95% of the time active.

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Interaction

Based on his/her experience, the end user will be able to change the rates for each variable (personal parameters) and to adapt the thresholds and alerts. He/she will receive the alerts by e-mail, sms, app or other methods (WP6).

A2 – Land pollution (*i.e.* exposure to bacterial outbreaks, harmful substances)

Prospection

The prospective stage which has led to the present definition of Service Module A2 was achieved mostly on the basis of pilot meetings (*i.e.* with Romanian stakeholders) and on the basis of the D2.1 "User requirements", section specific to Aquaculture.

The first circle of stakeholders included all members of FORCOAST involved in the Aquaculture sector, *i.e.* from research institutes, SMEs or in the Scientific Advisory Board. The second circle included external stakeholders such as the EATIP (European Aquaculture Technology and Innovation Platform) and the FAO-GFCM (Food and Agriculture - General Fisheries Commission for the Mediterranean).

During the first rounds of interactions, the problem of bacterial outbreak of terrestrial origins that may lead to contamination of shellfish production in nearshore/offshore aquaculture farms came out as one of the priorities for the sector. Typical stories include operators having to close their entire business due to unspotted contamination which was discovered too late, when the product was already on the market. With SM-A2, we aim to give the producers the opportunity to predict a potential harmful outbreak and decide to harvest sooner and/or keep the bivalves in a depuration tank. The developed Service Module will enable the mussel farm managers to evaluate the risk of any harmful discharge potentially reaching the farm site, according to which they can change their operations and save money in this way, thus resulting in an operational cost reduction. We consider that this service should not supersede current quality management operations, but instead should be used as a support to plan such operations, eventually providing the means for optimization of associated costs.

SM-A2 is primarily proposed as a support for Product Quality Management, since its main objective is to predict the risk of contamination. Providing the risk of farm exposure to harmful substances at the typical forecast capacity of met-ocean products (~5 days) allows for fast reaction responses from the farm managers (end user), including for instance :

- To accelerate harvest before potential contamination;
- To delay scheduled harvest to let production cure from infection;
- To intensify *in situ* sampling program for pollution;
- To initiate mitigation measures against pollution at the farm site.

If the service can be validated to a satisfying degree, SM-A2 could be used to save costs by reducing the frequency of systematic water quality sampling, and focussing the efforts when the risk of exposure is high.

The spatial resolution of input data (*i.e.* currents waves and wind components affecting the transport of harmful substances) should be available at a spatial resolution that allows to resolve the flows potentially linking harmful substance release points to farming area. Any obstacle (*e.g.* dike, sand banks, tidal flats) affecting the connectivity between these two locations should be resolved in a model providing input data, preferable on a sub-kilometer spatial resolution.

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Implementation

Data input

For the implementation, different kinds of data input is needed:

- Input required from FORCOAST data providers:
  - *Models*: the SM-A2 uses a lagrangian particle tracker to assess the potential influence of user-defined hazardous release points, on user-defined farming sites.
    The module's minimal requirement in terms of marine information consists of 2D model current forecasts. The highest possible temporal resolution will be used, but it is considered that a resolution coarser than 3h is limiting in terms of service quality (at first guess). The module may be executed on the basis of bi-dimensional surface currents, but has the capacity to exploit 3D circulation data, which is preferred. When available, surface waves data are used to include a Stokes' drift component to the particle trajectory. Similarly, vertical and horizontal diffusion coefficients (or turbulent kinetic energy) may also be considered to include a Brownian diffusion component. Note that, at the current stage, the module does not consider any along-track evolution for the particles, such as bacterial growth or pollutant decay. It is in this sense that the model only characterizes "potential influence" for resource points. The main reason is that resolving any evolution of the substance would require much more user-specific developments, which cannot be envisaged within FORCOAST's framework, aiming at first for generic services modules. A consequence is that scalar fields (e.g. temperature, chlorophyll, ..) are not considered for this module at this stage. Note that the use of scalar fields, to infer marine conditions along particle tracks and indicate potential evolution of harmful substances along their drift, is a development that remains possible at a longer time scale if deemed essential within interaction steps.
  - *Satellite data*: since SM-A2 is a forecast service it mainly exploits model data input. At this stage, satellite information will thus only be involved in the case of data assimilation within circulation models.
- Inputs from users upon subscription to SM-A2:
  To initiate the service, end users will be asked to define one or several farming areas, in the form of polygons. Point-and-click facilities will be deployed to support this step. In addition, users needs to define pre-identified release points of potential harmful substances (*e.g.* water treatment effluents of overflows, pollution sites, weapon/ammunition dumping sites, ...), which are defined as points.

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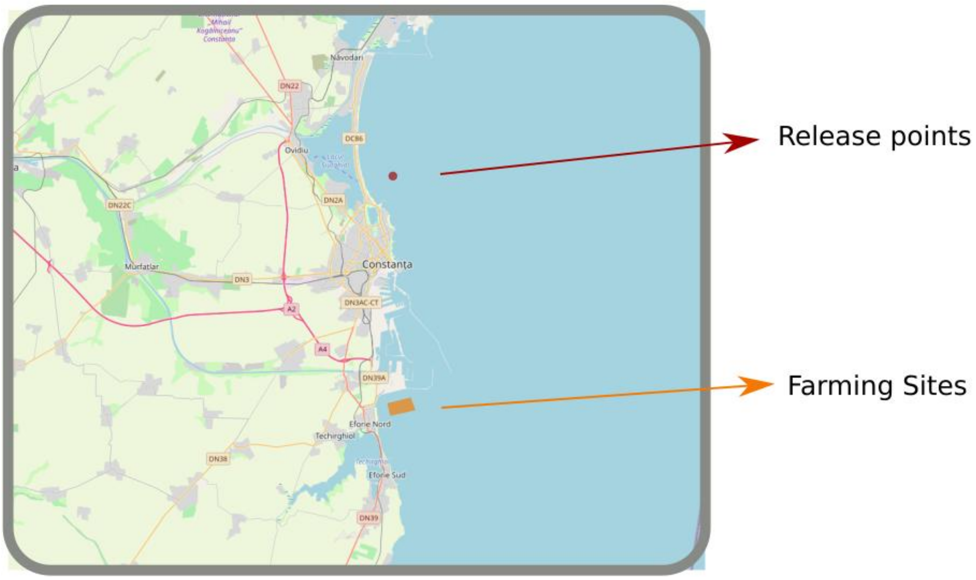

Figure 9. Example for user input interface. Hazardous release sources are defined as point sources. Farming sites are defined as polygons.

At a first stage, release points are only defined by their positions. Regular substance release is stimulated to identify potential influence at the farming sites. In later development stages, the release could be quantitatively constrained with temporal variability. However this would require much more demanding user inputs, more user-specific development, whereas we first aim for generic service modules.

Data output

For the output to the end users, three levels of feed-back are considered. SM-A2 operates a routine assessment of potential exposure at each update of the circulation forecast (cf. Operation):

Level 1 : Notification

The risk of hazardous influence from surrounding release points depends on the intensity of this influence (how much of the material released is susceptible to reach the farming sites) and on the timescale of this influence (the travel time from the release points to the farming site). If both criteria reach a critical level (user-defined with default value), a notification (phone message, mail, app notification, ..) is sent to the user in order to allow:

1) a refined appreciation of the risk (based on outputs level 2 & 3

2) taking action (*e.g.* secure production, fast harvest, initiate extra quality assessment, etc ...).

The first level ensures that the service is profitable to end users without requiring a regular watch on the FORCOAST front end (App).

Level 2 : Probability against time

The second level display will be the basic information available on SM-A2 welcome screen, *i.e.* when users actively access the website/app.

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It represents the forecasted probability of having a farming site affected by contaminants released at given source points. Different curves correspond to certain classes of age. The spread of the curves (*i.e.* area) results from uncertainty in the currents and advection (Figure 10). The currently considered approaches so as how to reach those values are described in section *Operation*.

Typically, there would be as many panels as user-defined farming sites. One could consider to superimpose different source points by using different colors, while age-classes are considered with transparency levels.

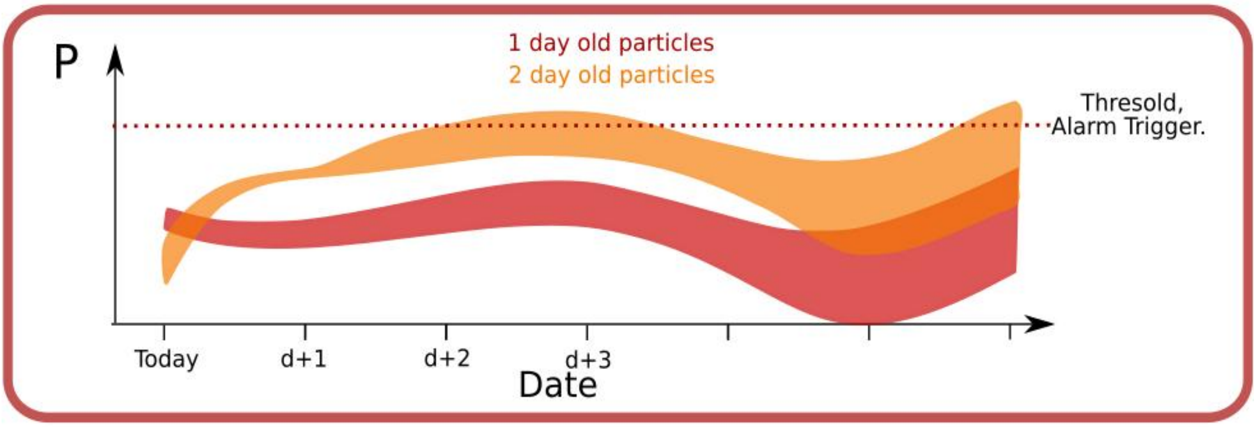

Figure 10. Shows a possible display at Level 2, in which curves with different colors are shown as different age classes of particles/contaminants, and the spread of the curves relating to the uncertainty in currents and advection.

Level 3 : Density maps

The third level of display is to be provided when end users ask for more information, *i.e.* upon specific requests. In the same sense that one would want to look at atmospheric pressure maps when a meteorological warning is issued, these displays should provide the end user with a larger overview of the situation. Level 3 consists of animated maps displaying the forecasted spread of release points' influence. Superimposed with circulation features, it is intended to give a better appreciation of the general conditions, *i.e.* allowing the user to consider it with his own appreciation, rather than depending solely on probability charts (*i.e.* level 2 display).

Customization

Customization options available to the user includes :

- Definition of potentially harmful release point(s);
- Definition of farming site(s);
- Age classes of interest, for each release points (*e.g.* classes of two hours, one day, …), this is important as relevance may differ for the type of substance under consideration;
- (Optional) Refinement of releases, in the form of specific temporal variability;
- (Optional) Definition of alarm trigger levels (ie. in the sense of time during release and reaching the farming site, and relative concentration).

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Operation

Within the operation stage of the workflow, special attention is given to:

- *Background operation*: Technically, the Service Module operates as a post-processing independent module (*i.e.* it is independent from circulation models). Passive particles are numerically released at regular intervals (at first level, see customization options above), from all end user-defined release points and are nominally referenced to this release point. Typically one can consider the release of hundreds of particles every 10 min.

  The lagrangian OceanParcels module, written in python, is used to compute the dispersion of those particles under the action of currents and, optionally, waves, and turbulences. Importantly, particles are tagged with their age, i.e. time since release. Particles older than a certain age threshold (*e.g* 10 days) are removed. The computation of particle tracks is initiated 3 days before present time and extends over the entire forecast time (*i.e.* present plus five days). Typically, the above set of computation is re-initiated upon each update of current forecasts, typically every day.

  For a set of predefined outputs dates (e.g. each 3 hours from present to furthest forecast time), the module computes: 1) the density of particles within the farming sites, and 2) the age distribution of these particles. The idea is that the potential harmful influence is important if a high number of released particles reach the farming sites and if they reach it relatively fast. So these two diagnostics are essential to build the feedback to the end user.

- *Diagnostics*: The risk of potential influence will be assessed based on the proportion of released particles that actually reach the farm. By comparing flow of particles to the farm, to flow of particles released at the source, we can obtain a probability indicator that does not depend too strongly on the actual release rate. Note that, as it will be difficult to have a proper estimation of such release rate, the service is foreseen to provide a conservative (*i.e.* upper bound) estimate of risk of exposure. This may be refined in the cases where users provide the necessary to detail the temporal variability of release.
- *Uncertainty estimate*: As forecast time elongates, the spread of released particles increases, as do the uncertainty of forecast circulation. The brownian dispersion component could be used to represent uncertainty on advection currents. Based on this consideration, the above protocol may repeat a certain number of times, in order to provide a relative uncertainty assessment on the probability estimate.
- *Created Service*: By providing an assessment of the potential influence of harmful sources, SM-A2 aims to provide users with the possibility to optimize any system currently used to assess the risk of contamination. For instance, high-risk alarm could be an incentive to operate in-situ risk assessment measures, or an indication to delay/advance harvest and/or embed a step involving depuration tank between production and market. The gain includes optimization of quality control protocols, and most importantly avoided important losses in the case where contamination goes unnoticed before the harvest reaches the markets.
- *From EO data to SM-A2*: In order to fulfil its purposes, SM-A2 requires the availability of a dedicated circulation model, at a spatial resolution allowing to resolve circulation features at the scale of the exploitation farms. For instance the presence of dikes, harbours, refined bathymetry should be included in the domain, and their effect on circulation correctly reproduced. This means, that opening the service to new users, *i.e.* users outside of the

current FORCOAST pilot cases, demand to implement a dedicated model, downstream of CMEMS forecasts, which requires expertise, computation and storage resources. The cost of such implementation lies mainly in the implementation of the local circulation model, which goes along with specific validation procedures exploiting local datasets or very-high resolution remote sensing data. Considering along-track specific models to represent bacterial growth of pollutant decay increase the resources needed for setting up the local implementation (*i.e.* more state variables need to be resolved). It is thus of the first priority to gather from potential users how much they would valuate such level of details, and if this value is sufficient to cover the additional implementation costs. After setup, a continuous maintenance effort is required, plus research and development, if it can be demonstrated that further development would be relevant in terms of return on investment, *i.e.* the price of development is matched by a substantial increase of the service's value.

Interaction

Within the Interaction stage following items are considered:

- *Feed-back loop on prospection*: It was considered that the prospection step, *i.e.* to define the internal and external circles of relevant stakeholders has been achieved in the first stages of the FORCOAST project (*i.e.* WP2 & WP7). At a later stage, or eventually beyond FORCOAST lifetime, external stakeholders could be contacted to enrich the list of potential end users. In the same order of idea, the BlueCloud aquaculture Atlas could be consulted to identify end users, or areas (countries) with a specific interest in shellfish aquaculture. However, it is considered that SM-A2 will be already an operational workflow involving actual stakeholders, and that further enlargement should only be considered after operationalization of the service, in order to benefit from end user-story and actual usage feedback from the current circles. Given the limited number of end users specific to Pilot 7, it is of utmost importance that SM-A2 can be deployed in other Pilots, in order to optimize the end user-feedback mechanisms. At this stage, it is not obvious, however, whether the collection of end user feedbacks should be implemented at the service level (*i.e.* the team of SM-A2 sets out its own feedback protocol, such as interactive polls, and proceed to end user-survey), or if feedback to services should be organized at a project level (*e.g.* multi-service surveys, general assembly, etc.). The latter would probably help in saving project-resources, homogenize and optimize end user feed-backs in general, and minimize the harassment of collaborators from the private sectors. Call for interests to other pilots have been launched at the sectoral meetings (November 2020), and a number of interested pilots have been short-listed. SM-A2 is currently being tested for the interested sites (Pilot 5 Ireland). Additional end user feedback was gathered during the General Assembly meeting with stakeholders in February 2021.
- *Feed-back loop on implementation*: The end user protocols and interfaces proposed within SM-A2 are obviously subjected to evolution along interactions within and beyond the FORCOAST consortium. First, mock-ups will be built to provide a feeling of what the service would look-like, from a user point of view. The first round of interaction took place at the sectoral FORCOAST meeting in November 2020. From thereon, feedback was collected on the proposed interface, and considered the synergy between SM-A2 and other aquaculture oriented service modules. A point of interest would be the adequacy of our "potential influence" approach, which greatly simplifies the input requested from users and end user-specific development efforts, yet does not render consider dynamic terms in the evolution of harmful substances. Instead the age-since-release is exploited in this regard. In a second stage,

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the revised SM-A2 will be exposed to external stakeholders such as the EATIP (European Aquaculture Technology and Innovation Platform) and the FAO-GFCM, for further refinement.

- *Feed-back loop on operation*: As concerns evolution of the technical, operational implementation of SM-A2 (*i.e.* numerical issues, definition of statistical metrics, etc ..). The objective is to aim to submit a scientific manuscript describing the objectives, methodology and validation results. This would expose FORCOAST to scientific peer-reviewing, which is in our opinion the best way to achieve scientific adequation for the risk assessment. As concern deployment of the service on a central FORCOAST platform, the module will first be developed on the basis of readily accessible Pilot 7 model outputs. From there, interaction with WP4 is needed to devise the best strategy in embedding SM-A2 within an online container, exploiting data from other pilots through THREDDs servers.
- *SM-A2 validation protocol*: Within Pilot 7, currently the opportunity to deploy *in-situ* drifters is considered to validate the lagrangian tool. From the sectoral meeting, it was not clear that such deployment would be feasible in other Pilots. In particular, COVID conditions strongly limits the possibility of research cruises in several FORCOAST consortium countries. Targeted service quality assessment (for instance regarding bacterial outbreaks) has never been considered in the drafting stages of FORCOAST. Therefore, no resources have been allocated for *in-situ* sampling, labwork, etc. This will largely limit the possibility of a service validation targeting explicitly bacterial contamination. However, by multiplying the number of Pilots where SM-A2 will be deployed, the aim is to gather specific validation cases where *in situ* data would allow targeted validation.
- *SM-A2 valuation and business opportunity assessment*: it is considered that the service module should be made available to end users (managers) via mobile or desktop apps free of charge, given the struggle of investors to develop mussel aquaculture. In some areas, such as the Romanian coast, the context of so many constraints (environmental, financial and legislative), the availability of a free service would definitely foster the development of mariculture in the area and would be a beneficial incentive for other potential investors, which on the long term may be interesting for FORCOAST business plan as a demonstration of the service relevance, and as an incentive for further subscriptions. A poll will be organized among stakeholders for a proper evaluation of the willingness to pay for a service such as SM-A2. In our opinion, such efforts should be coordinated at a project of sectoral level, in order to minimize the harassment on FORCOAST stakeholders.
- *SM-A2 description sheet* (preliminary): “SM-A2 : Exposure to harmful substances” provides the user with an assessment of the probability that farming sites are affected by harmful substances released in neighbouring potential sources identified by the end users.

  By providing a forecast of the risk of influence , SM-A2 provides to the user means to anticipate potential contaminations, to plan in-situ risk assessment protocols, and acts as a decision support tool for protective measure, or rescheduling of the harvesting operation.

  → User-specific parameters:
    - Essential : Farming sites, Potential harmful substances release points
    - Optional : Temporal variability for release sources
    - Interface : Relevant age classes for the released substances, Trigger warning thresholds

  → Required marine information variables:
    - Essential : Surface horizontal currents
    - Optional : 3D currents, Diffusion coefficients, Stokes drift component, related uncertainties.

- A computing protocol, script or executable: Relies on offline usage of the OceanParcels python package.
- Scheduling guidelines: Involves routine reassessment upon update of the above products. Additional post-processing of the results of the tracking module can be considered only "on-demand".
- Guidelines for qualification of the service quality:
  - Uncertainty assessment can be done on bootstrap basis, *i.e.* repetition of the experiments, considering a random component scaled to the uncertainty attached to input data.
  - Specific validation protocol based on in-situ drifter campaigns, but this requires specific deployment.
- Service Delivery protocol:
  - Level 1: warning notification, sent by the app when user-defined thresholds for exposure are attained.
  - Level 2: probability charts displayed graphically on the relevant app page.
  - Level 3: consists of animated maps showing area of releases' influence.
- Price, or financial options for subscription:
  - Level 2 can be considered as a free-ware demonstration facility.
  - Level 1 and warning can be an optional subscription.
  - Level 3 may be considered as an additional subscription level.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870465.

A3 – Prospection for new sites

Prospection

By using hydrodynamic-biogeochemical hindcasts in Limfjorden generated in a pre-operational model in FORCOAST by AU, a tailored made product of marine conditions at potential new farming sites can be provided to the customers. This service can support oyster farmers in the planning of new sites and evaluation of existing sites for aquaculture.

The Limfjorden contains a large shellfish fishery based primarily on wild populations with annual landings of 20.000–25.000 tons of blue mussels and 150 tons of flat oysters mainly for human consumption. In recent years, oyster cultivation practices designed for human consumption have also been tested in the Limfjorden, although with mixed results. The SME OysterBoat is the primary producer of flat European oysters in Denmark and developed a prototype for oyster culturing. The aim is to increase production to be economically sustainable. However, they experience high mortality among the juvenile oysters and they need information of the best locations for potential culture sites. The focus of the project is to provide modelling products and services that can help to identify suitable sites and increase oyster production. The planned activities are:

- Provide multi-year hind-cast products of T, S, currents, mixing from HBM
- Provide multi-year run for ecological variables from FlexSem-ERGOM
- Make pre-operational forecasting for physical parameters using HBM
- Design model products and indicators for site selection to oyster farmer
- Indicators could be temperature, salinity, turbidity, food flux, Chl a, oxygen, …
- Identify and map optimal locations for restoration and culturing
- The models cover the Limfjorden, but focus will be on the western site Nissum Bredning with the main oyster population
- Model resolutions are down to 150-200 m
- Potential losses are related to field safety, low growth rate or unhealthy food conditions for flat oysters, bad aquafarming site for oysters and abnormal temperatures

Implementation

The implementation of the Service Module includes following stages:

- Designing service product (AU)
- Develop a hydrodynamic Limfjord hindcast model to generate long-term forcing for BGC model Flexsem (DMI)
- Generate multi-year hydrodynamic hindcast in Limfjord (DMI)
- Develop a biogeochemical model for Limfjord (AU)
- Generate the tailored products based on AU FlexSem model system and physical boundary conditions provided from DMI (AU)
- Develop software for generating the tailored products from Flexsem hindcast
- Make the tailored products available online (AU)
- Display the tailored product in the FORCOAST portal and information system – this can be done either through an interactive way or pre-defined way (Deltares)
- Service online for testing period
- Service online for pre-operational mode

Timeline of the implementation will be coordinated with the Service coordinator of Deltares.

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Operation

The Operation stage involves the following actions:

- The biogeochemical model is developed by AU
- Physical hind-cast products are developed by DMI
- hind-casts are conducted
- the service is developed

The service will be based on hind-casts of relevant ecological variables for aquaculture and it will not need to run operationally. The work is going from TRL 3 to TRL4/5 during the project.

SM-A3 will answer following 3 user scenarios:

- Aqua-farming related information (statistics) for a given potential site: the service scenario is that a user has a potential site already, but the user would like to know relevant physical-biogeochemical conditions at that position.
- An end user has two potential sites, he wants to compare the environmental conditions in the two sites to decide which one is better.
- Within a user-defined area, user would like to choose one or more sites suitable for aqua-farming.

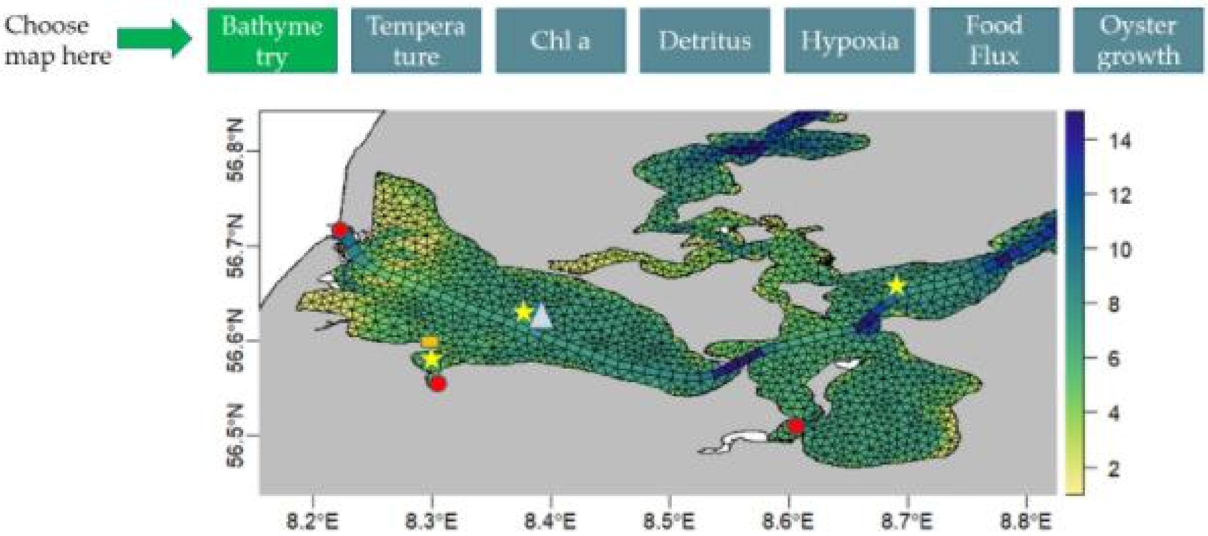

Figure 11. Muck-up screen for SM-A3 - Prospection for new sites.

A protocol should be developed, including producing a set of indicators (both time series and statistics.

Interaction

During the tailored product development and Service Module testing period, close interaction with the OysterBoat is needed. Inputs and feedbacks from the OysterBoat are essential during this stage.

The end user should provide inputs for different service scenarios:

- One location (lat, lon)

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- Two locations
- An area

The service platform should then operate the protocol to generate results, which will be presented in the user interface. The FORCOAST input data does not need to be updated (long viability). In this sense it's static. However, a dynamic user interface can be enabled to have interactions with end users.

Potential losses are related to field safety, low growth rate or unhealthy food conditions for oysters, bad aquafarming site for oysters and abnormal temperatures, but has not been quantified.

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A4 – Assistance for Spat Captures

Prospection

The prospective stage has led to the present definition of SM-A4 and was achieved mostly based on Pilot meetings and on the basis of the D2.1 "User requirements", section specific to Aquaculture.

The capture of spat requires the installation of spat collectors, which have to be installed before the arrival of the target organisms, but not too long before the time of arrival, as spat collectors can be colonized with other organisms (biofouling), which go into competition with the target shellfish spat for space and feed. It is therefore of the outmost importance to have a reliable prediction of the arrival date of shellfish spat.

Especially for the flat oyster spat, it is known that spat capture is the most efficient when biofouling is not extensive. Because blue mussel seed and *Jassa* sp. shrimps are the major biofouling organisms in the Belgian part of the North Sea, new substrates are colonized by these organisms, shortly after their submerging in sea. As the settlement of flat oysters takes place after the first settlement peak and before the second peak of settlement for mussels, this provides only a small window. If the spat collectors for flat oysters are introduced during the settlement of the blue mussel seed, low settlement of oyster spat will be the result.

It is also possible that the mariculture site is situated in an area with low bivalve recruitment. It is therefore necessary to pinpoint the ideal settlement locations of spat of the target species next to the culture sites, in order to collect enough spat and subsequently transfer the juveniles to the mariculture sites for further grow out.

For many organisms, spawning events are related to environmental conditions (such as temperature, chlorophyll concentration, moon cycle, tidal currents, waves....). Therefore, an efficient tool should be developed to predict spawning events of the target species and to estimate the most likely arrival date and location. Developing an online Lagrangian (larval transport) model will not be possible in the timeframe of the FORCOAST project and thus an easier model, based on an alarm system for spawning combined with information on pelagic larval duration will be initiated at first.

Implementation

For the implementation, different kinds of data input are needed:

Data input from end user

- *Input required from FORCOAST data providers*: The aim of the SM-A4 module is to determine the period where spat of specific species is likely to arrive in the collecting location(s). That implies to have information on potential areas where spat could arrive, on cue(s) conditioning the release of larvae as well as an estimation of the time lag between the larvae release and the arrival of spat in the farm. These information are given by local expertise.
- *Input from end user*:
    - → *Cue conditioning release events*: Each species has a specific reproduction period, which can depend on the location. In the case of Pilot 4, one of the candidate species is the flat oyster. For this species, spawning occurs 10 days after the first time where the water temperature reaches 15°C in Spring. For other species, in addition to

temperature, spawning events could be related to other environmental conditions such as day duration, chlorophyll concentration, waves height or moon phase.

- *Duration of release events*: Knowledge about the spawning event duration is needed to determine the potential date of arrival. Usually this period is species specific and fixed. In the case of the Pilot 4 for example, the period is 10 days for flat oyster and 90 days for mussels.
- *Dispersal duration*: The drift duration is also specific of a considered species. In addition, this value can also be dependent of environmental conditions and must be locally assessed. An interval of drift duration (Pelagic Larval Duration minimum - PLDmin and Pelagic Larval Duration maximum - PLDmax corresponding to the shorter and longer pelagic duration estimate respectively), could be provided by experts taking into account uncertainties, this interval could be reduced by local expertise and data obtained in the farm. This interval would represent uncertainties in the estimation of PLD coming from 3 main sources: uncertainties of the growth rate, uncertainties due to different environmental conditions met by larvae of the same cohort (as for example temperature or food availability which could affect the growth rate) and interannual variability.
- *Source location(s)*: SM-A4 needs to consider potential source location(s) where the population of the considered species is present (either natural or farmed population) and can provide larvae to the collecting location(s). This information could come from different sources as for example, local expertise and/or from a drift model. In the case of Pilot 4, this information will be provided by a larval transport model.

Data output to end user

- The aim of SM-A4 is to indicate likely period of spat arrival at the location of interest. The output will provide the potential starting and ending of the spat arrival from each of the source locations. In addition of arrival period from each source location, the whole period of potential arrival is also estimated by combining all source locations. The output is a table (Table 1) summarizes the likely arrival period for the target species selected and the source location(s) associated to this arrival.

Table 2. Prediction of settlement period for shellfish larvae at a given location of interest, according to their source of origin.

Source location	Arrival expected from	Arrival expected until
Source area 1	19 June 2020	30 June 2020
Source area 2	Not known yet	Not known yet
Source area …		
Source area n	25 June 2020	11 July 2020
Total	19 June 2020	11 July 2020

This table summarizes the information (potential first/last arrival from a given source) for the different source locations as well as the total period of potential arrival. The mention "Not known yet" means that the conditions for a spawning event have not been met yet in the considered area. The missing information will be provided as soon as the information on spawning event will be available, and the table will be weekly updated.

- An alarm system in the source location(s) is needed to determine likely spawning event: In the aim to determine by advance this event, this alarm is preferentially based on forecast if the information is available. This forecast can be provided by hydrodynamic model (temperature, wave) and/or biogeochemical model (chlorophyll). Satellite information can also be used for chlorophyll data.

Customization

- Direct information could be provided from online Lagrangian model, providing that long-term meteorological forecast is available. This customization would help to reduce the uncertainties. In some cases (years), source location(s) will not necessarily provide spat to collecting location(s) due to specific hydrodynamic conditions.
- If enough data are available, a spawning distribution could be considered to improve the estimation instead of considering a constant larvae release during the spawning period. For some species, the spawning distribution exhibits a non-constant distribution with a maximum (ex. gaussian distribution) and spat collection could be more efficient during the peak of arrival rather than early or later within the arrival season.
- If information on the relative contribution of different (sub)populations source (expressed as a percentage of arrivals in the collecting location) is known, this information could be included in the table as an additional column. The different contributions of the different sources come from the fact that all the sources do not have the same population density and that hydrodynamics could prevent spat from different sources to drift in the same proportion. Such additional information could only be indicative, the validation of this type of estimation is extremely complex and cannot be done in the frame of the project.

Operation

Background operations

The module is organized in three steps:

1. Once a day, a verification procedure is performed to check if the required spawning conditions for a spawning event are met in the source location(s);
2. If the test is negative (ex. water temperature is below the threshold): do nothing, if the test is positive (ex. water temperature is upper the threshold) an estimation of the spawning period is calculated. Next the PLDmin and PLDmax (and the swarming period if needed as in the case of flat oyster) will be added to the date of the spawning event in the source location(s) to determine a possible date of spat arrival in the collecting location(s). Then, the procedure will either stop if there is a unique spawning event or go back to step 1 in case there are multiple spawning events (depending on the considered species).
3. Return the likely date of arrival in the farm by combining the information from the different source locations.

Diagnostics

The potential spat arrival at the collecting location(s) will be assessed based on the potential arrival time from the different (spawning/swarming) areas. Note that, as it will be difficult to have a proper

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estimation of such release rates, the service is foreseen to provide an indicative estimation of arrival timing.

Uncertainty estimate

Uncertainty estimate is complex in the case of spat capture and is strongly dependent on the available data. An estimation of uncertainties will be provided by experts and will be included in the estimation of pelagic duration for a specific species and site.

Uncertainty on the source location(s) which could provide spat will increase uncertainties on the arrival period.

Created Services

By providing an assessment of the potential arrival period of spat, SM-A4 aims to provide users with the possibility to install collectors at the optimal period/place in order to maximize the capture of spat. The table summarizing the prediction (see Implementation - Data output to end user) and allowing to know the potential arrival period in advance (around a month in the case of oyster spat in the Belgian part of North Sea), will be updated once a week and put at disposal of the end users, according to a format defined by the end users in advance (ex. Personal access to a Web page, email)

Service functioning and long term availability

The setup of the service is estimated around 10-15 working days , providing that the required input defined in *Implementation - Data input from end user* is available. Otherwise, an additional time will be needed to gather all requested input (species/site dependent). The maintenance of this operational service, provided by RBINS, is estimated at 5 working days per year[1]. This will guarantee that the service will continuously be provided on time and, in case of issue (ex. No meteorological forecast delivered, HPC failure), that the users will be notified. Regarding the Belgian part of North Sea, this services will be maintained on the long-term beyond the FORCOAST project as other products provided by the Belgian Marine Forecasting center (https://odnature.naturalsciences.be/marine-forecasting-centre/).

Interaction

Within the Interaction stage following items are considered:

- *Feedback loop on prospection*: Prospection step to define the internal and external circles of stakeholders has been achieved in the first stage of FORCOAST project (WP2 and WP7). After operationalization and feedback from the current circles, additional external stakeholders will be contacted to enrich the list of potential users at a later stage. In the same order of idea, the BlueCloud aquaculture Atlas could be consulted to identify users, or areas (countries) with a specific interest in shellfish aquaculture.
- Feedback loop on implementation: The user protocols and interfaces proposed within SM-A4 are subjected to evolution along interactions within and beyond the FORCOAST project. A first round of interaction was organize at the sectoral FORCOAST meeting in November 2020. From thereon, feedback was collected on the proposed interface and the synergy between SM-A4 and other aquaculture-oriented Service Modules was taken into consideration. In a second stage, the revised SM-A4 was presented to end users of the Pilot (such as Brevisco, Colruyt group or UNITED) for further refinement. A last feedback round was organized during the General Assembly meeting with stakeholders.

[1] At the cost of 627€/day according to the RBINS tariff applicable for services provided to for-profit organizations in Belgium and abroad in 2020.

- *Feed-back loop on operation:* Concerning the evolution of the technical, operational implementation of SM-A4 (i.e. numerical issues, definition of statistical metrics, etc ..), the aim is to compare the model prediction with the *in-situ* data on spat arrival at the Pilot site and to prepare a scientific manuscript describing the objectives, methodology and validation results. This would expose us to scientific peer-reviewing, which is in our opinion the best way to achieve scientific adequation for the risk assessment. Concerning the deployment of the service on a central FORCOAST platform, the Service Module will first be developed based on accessible Pilot 4 model outputs.
- *Interaction with end-users*: The end-users must provide the location and the species of interest in addition to other information which are site/species specific and can help to implement the Service Module. Feedback from the end users to the service developer on spat collection during the service utilization will help to calibrate/validate (see *Interaction - SM-A4 validation protocol*) locally the services. The end users will receive weekly a table summarizing the likely period to collect the selected species at a specific location (see *Implementation - Output to end users*) according to a format defined with the users in advance (ex. Personal access to a Web page, email). The table will be accompanied by a color code system allowing to quickly know if the potential period of spat capture already started (green), is imminent (orange) and spat collectors need to be prepared, or not (red) (Figure X).

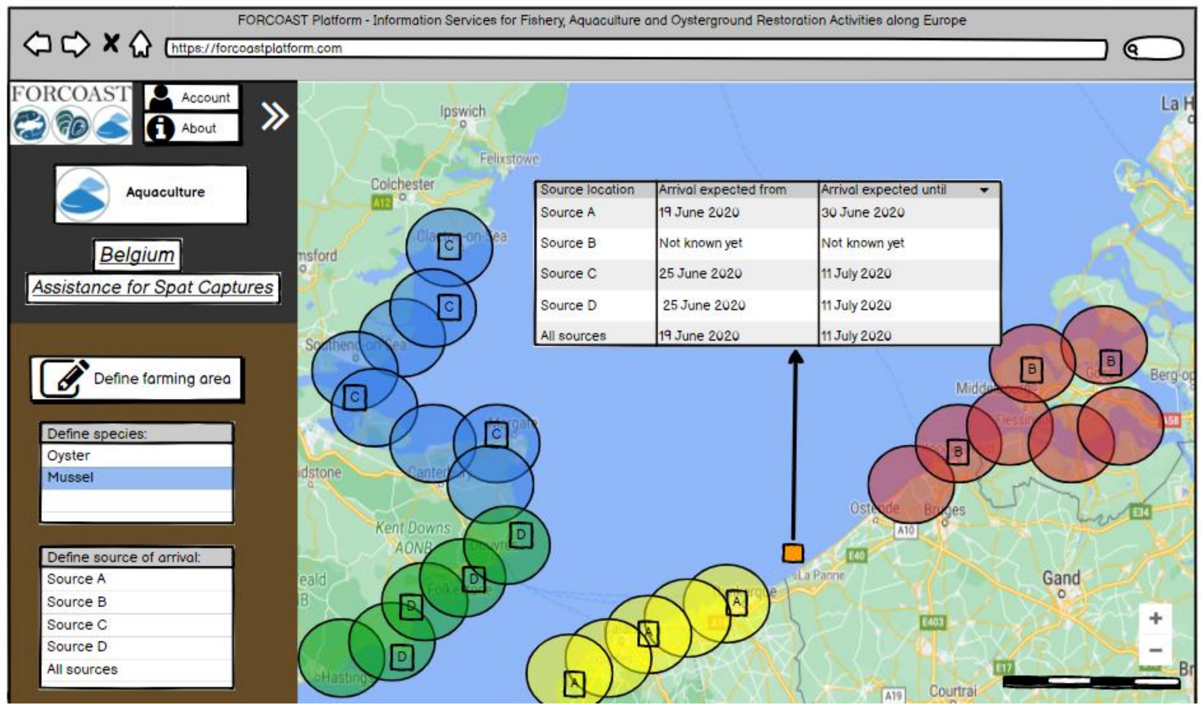

Figure 12. Mock-up of the SM-A4 for Assistance for Spat Captures. The end user can choose from different shellfish species, as well as source location of spat and collector locations.

- *SM-A4 validation protocol:* In the first year of the project different kinds of spat collectors for flat oysters were deployed within Pilot 4, in order to see if oyster spat, and more specific from flat oysters, is available at Westdiep. Next to that one type was installed at different times, in order to assess the arrival period of the oyster spat. In 2021 the same practical test will take place for blue mussels in Spring 2021 for a number of consecutive weeks (March 2021 – May 2021). During this period small (appr. 100 cm2) rigid substrates will be placed in the water column at a depth of appr. 3 m, at preferably (depending on the weather conditions) weekly intervals. After a week, the substrates will be studied in the laboratory for the number of settled mussel spat on the collector plate. Similar experiments will be conducted for flat oysters. In this way we hope to quantify the intensity of the spat in the water column as a function of time.

- *Roadmap towards SM-A4 valuation and business opportunity assessment*: Today there is already quite some data/info available from several sources. To evaluate the price of the service, added value of the Service Module should be demonstrated. That could be investigated by assessing the efficiency of the service to increase spat capture, by taking into account price of spat on the market, and by estimating the different costs linked with maintenance and installation of collectors. Added value should be demonstrated as the profitability of offshore mariculture.

  SM-A4 is based on the COHERENS modelling system, which is a RBINS Research Infrastructure which is maintained on the long-term, which will ensure that a basic service will be maintained for the long-term by the permanent staff involved in the modelling maintenance and development. For additional fit for purpose services, a price estimation will have to be discussed case by case especially in function of site and species and local expertise.

  The Service Module will help end users to maximize spat collection. The estimated gain concerns the reduction of effort to collect spats (by installing collectors at the most likely timeframe), increase the capture, decreasing then the need for buying spat on market.

  It is suggested that the Service Module will be made available to end users (managers) via mobile or desktop apps or website free of charge in a first time to demonstrate its utility. The availability of a free service would definitely foster the development of offshore mariculture in the area and would be a beneficial incentive for other potential investors, which on the long term might be interesting for FORCOAST business plan as a demonstration of the service relevance, and as an incentive for further subscriptions.

  The service should be considered in interaction with other aquaculture-oriented Service Modules, and a business plan is coordinated at the project sector level (see WP6).

  The long term maintenance of the service can be insured for end-users by the Belgian Marine Forecast center (see *Operation - Service functioning and long term availability*), which will ensure the viability of the service.

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A5 – Marine conditions at farming site/alarm system

Prospection

By using hydrodynamic forecasts in Limfjorden generated in a pre-operational model in FORCOAST by DMI, a tailored product of marine conditions at given farming sites can be provided to the customers in near real time mode. This service can support oyster farming daily operations and planning.

Implementation

The implementation of the service includes following stages:

- Designing service product (DMI) which is intended to help end users with operational planning in a time range of 5 days and long-term.
- Certain environmental conditions may cause problems on growth of aqua-species. With an accurate forecast, end users may be able to take some protection and/or mitigation measures.
- Extreme weather, sea level, waves, currents and marine heat waves can cause dameges and risks for planned operations.
- Develop software to generate the tailored products based on DMI forecast for the service (DMI)
- Set up a ftp site to upload DMI forecast and tailored product (DMI)
- Display the tailored product in the FORCOAST portal and information system – this can be done either through an interactive way or pre-defined way (Deltares)
- Service online for testing period
- Service online for pre-operational mode

Timeline of the implementation will be coordinated with Service coordinator Deltares.

Operation

Planned operation will be a pre-operational run, which is an automatic run. If something wrong happens, they will be fixed during the work hours from Monday till Friday.

- The DMI Limfjord hydrodynamic model will be run twice a day (DMI)
- Tailored made products will be developed for given locations (currently provided by Oyster Boat) twice per day (if Deltares implemented an online version to interactively generate the tailored products, the offline tailored products may not needed) (DMI)
- DMI Limfjord forecasts and tailored products will be uploaded to a DMI ftp site (DMI)

Interaction

During the tailored product development and service testing period, close interaction with the OysterBoat is needed, as inputs and feedbacks from Oyster Boat are essential.

The service design will provide three sub-Service Modules:

- Forecast service in 5 days;
- Historical information service for long term planning (both model and observations data;
- Product quality documents.

The service will be located at the central FORCOAST platform.

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By entering the central portal, an end user will first select a production area of interest and a service option (either from a 2D map or dropdown list): forecast service or long term information service (Figure 13).

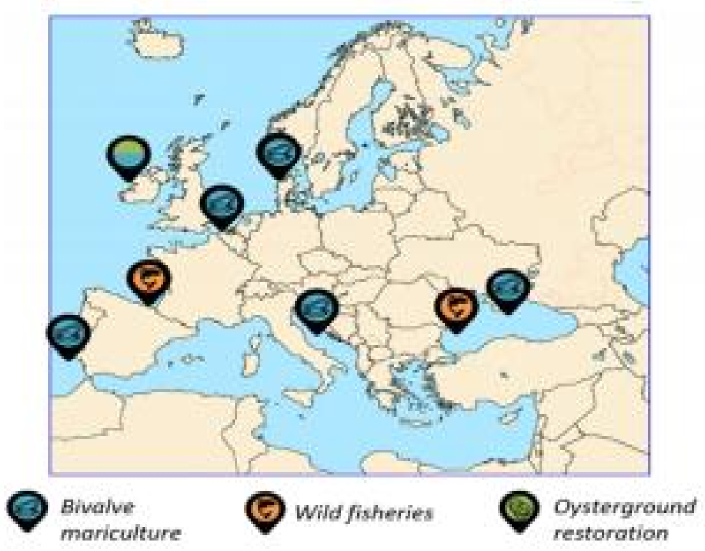

Figure 13. First screen with selection options for production area and kind of service.

By entering the forecast service, the end user will be provided with the following major functions:

- The end users sees a 2D snapshot and animation of a forecast (waves, winds, SST, currents, sea level, etc.);
- By clicking on a location in the 2D map, the end user can get a plot of forecast time series (together with the past few days historical information if resource is allowed), with a threshold of official warning level presented (Figure X);
-
- Duration and frequency of current conditions;
- End users can set up their own threshold in the forecast time series map;
- End users can brows existing observations and upload new observations;
- A quality information link is provided.

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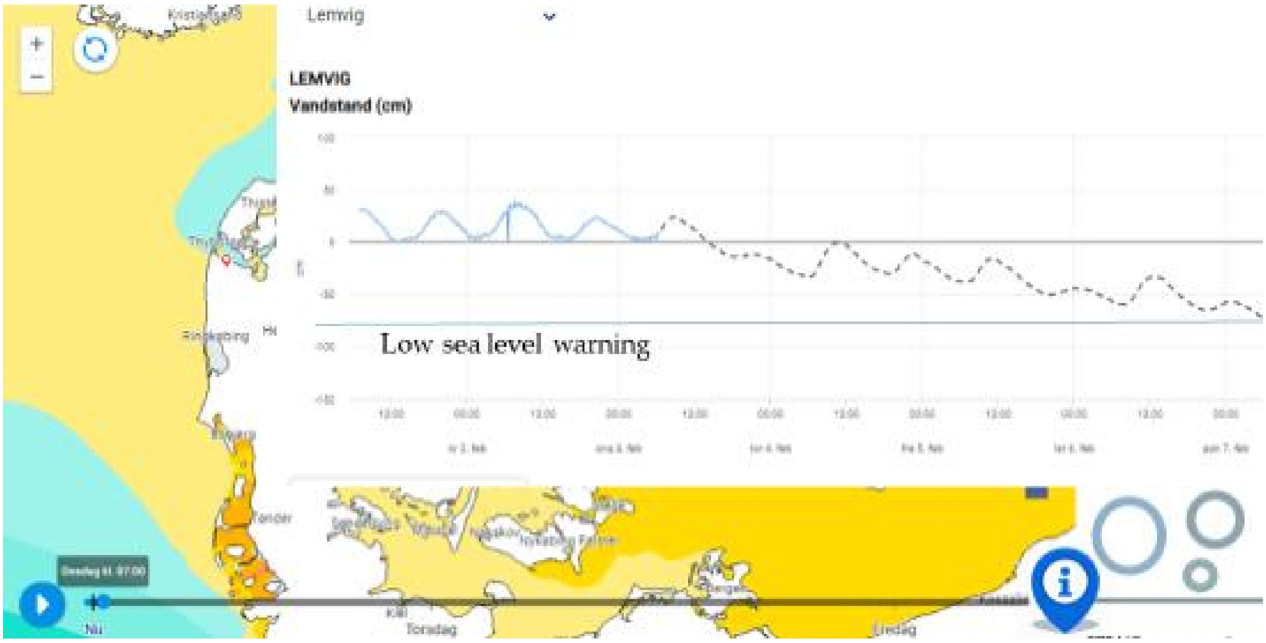

Figure 14. Mock-up screen when the end user had chosen for a plot of forecast time series (together with the past few days historical information. In this case sea level.

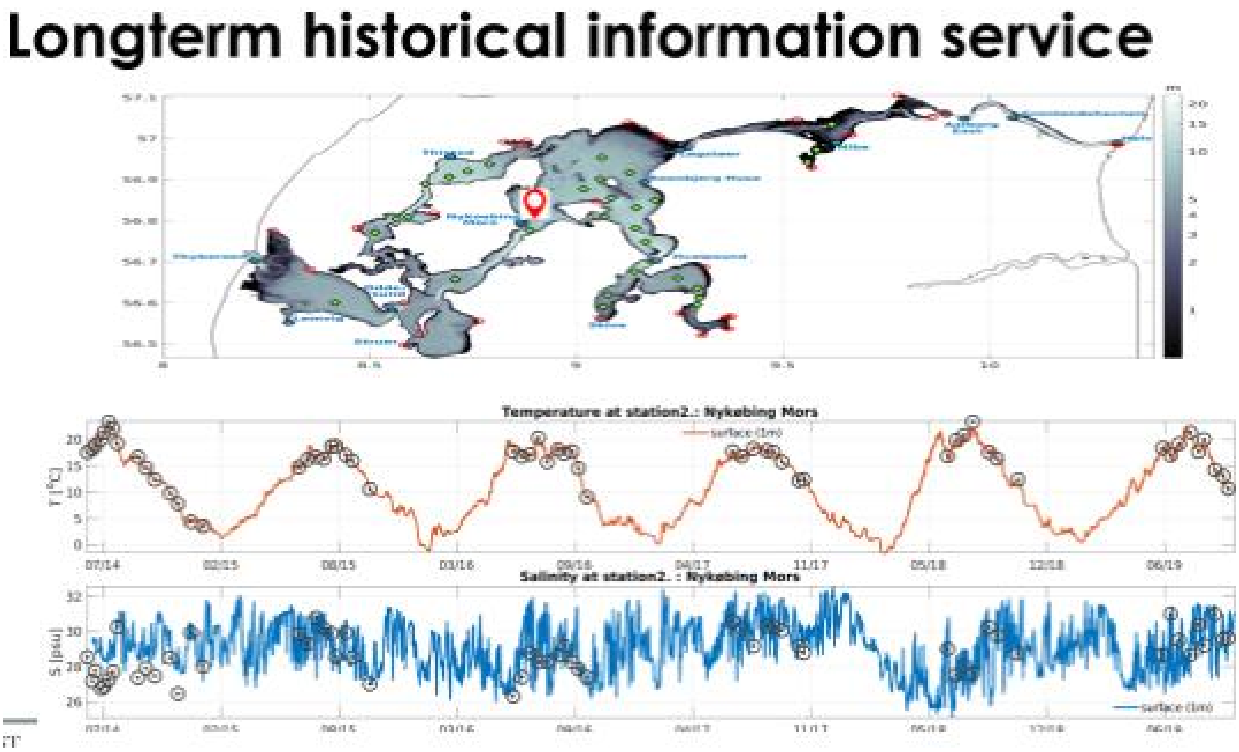

Figure 15. Long term historical data for a specific production area of interest.

One uncertain part is the question of including near real time delivery of observations, mainly CMEMS SST and Chl-a data in Limfjord. This is an extra workload as for Pilot 6 our main budget is for developing a Limfjord forecast model.

9.3 Oyster reef restoration

R1 – Retrieve sources of contamination

Prospection

In order to determine the main user requirements for service module R1, the first stage involved meetings with critical stakeholders, which in Pilot 5 - Ireland are represented by Cuan Beo. According to earlier discussions, the main requirements for oyster farmers regarding crop health is to retrieve source of contamination. Sewage pollution occurs often in Kinvara Bay due to the presence of a sewage discharge point. For example, a sewage discharge event was reported to take place last 16th of June 2020 at the Kinvara Castle Pumping Station and stakeholders are interested in the impact that this episode would have in the St. Georges Bed farming area located nearby. Given that oysters are filter feeders, it is of high importance to predict the concentration of faecal coliform bacteria such as *E. coli* in the waters. In this sense, it would be highly practical to dispose of an operational system capable of:

- predicting the path followed by a sewage discharge from typical source locations and ;
- retrieving the most likely sources of pollution for a given farming area.

In order to satisfy stakeholders' needs, this information will have to be covered in an operational platform. A meeting with stakeholders took place at the 5th of October 2020 to further discuss user's requirements.

Implementation

The Marine Institute has developed two ROMS-based applications to predict the ocean state in the Galway Bay: The Connemara Operational model and the Galway Bay model. The latter is nested in the former. The Galway Bay model is still undergoing development regarding the assimilation of realistic freshwater flow at the Submarine Groundwater Discharge at Kinvara Bay, which is the result of the interaction of rainfall water with a large karst system located in the southern part of Galway Bay.

The next step is to validate the hydrodynamic model based both on remote sensing data and *in situ* data:

- Most remote sensing data sets available are too coarse for the small-scale domain covered by the service model, which is just the inner sector of the Galway Bay. A possible approach consists of getting the spatial average of the remote sensing dataset over the whole model domain and compare with that from the model. Remote sensing validation will mostly focus on sea surface temperature.
- There are a number of *in situ* time series which will contribute to model validation. These include: (a) sea level from the Galway Port tide gauge and Kinvara tide gauge, (b) ADCP data from three sensors deployed during 2018, (c) the Kinvara and Killeenaran CPT loggers, providing temperature and salinity records.

The third step will include the implementation of an online tool providing access to the functionality described in the Prospection section:

- Forward Lagrangian tracking can be applied to predict the path of a sewage discharge from typical sources, like the Kinvara Castle Pumping Station. The particle-tracking model would

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read the 3-day current forecast from the operational models and get an estimation of the path followed by the sewage flow. In order to retrieve the source of contamination, backward Lagrangian tracking should be applied, using the farm locations as starting location. For both, several particle-tracking models have been developed, but OpenDrift has observed to get reliable results when operating with ROMS outputs.

Operation

Access to Service Module products would be through an online-based interface. The end user should be able to select a location on a map or type in the coordinates and either run a forward simulation or a backward simulation. The end user will also select the date, time and duration of such simulation. Forecasts would be visualized by means of graphical animations which should be easily comprehensible by the end users.

Interaction

After the Service Module is available, communication between end users and service manager will be of paramount importance to determine whether the service fulfils stakeholders' requirements or rather further improvements are needed to get a high-quality product which is indeed helpful for oyster farmers in Galway Bay.

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10. Services provided by the Service Modules

An overview of available services will be accessible in a central catalogue, with summary and illustration of what this service would provide to me.

Sector Fisheries

1. SM-F1 – Suitable Fishing Areas
   Gives the fishermen maps of suitable habitats of small pelagic fish and avoid other species (bycatch), based on sea surface temperature, salinity, currents, mixed layer depth, sea surface height, chlorophyll a concentration, primary production and euphotic zone depth.

2. SM-F2 – Front detection
   Gives the fishermen locations where fronts (shelf, shelf-break, coastal-upwelling and estuarine fronts, and frontal areas in the deep ocean) are located, based on sea surface temperature and chlorophyll a concentrations, as these are areas with high fish concentrations.

Sector Aquaculture

3. SM-A1 – Operational scheduler
   Gives the shellfish farmer the opportunity to plan their activities in advance based on predictions of water level, sunlight period, wind conditions, waves and currents.

4. SM-A2 – Land pollution
   Gives the shellfish farmer the opportunity to foresee troubleshooting due to contamination of harmful discharges and adapt his plan of actions. The Service Modules makes use of data on currents and the specific behaviour of pollutants in the water column.

5. SM-A3 – Prospection for new sites
   This Service Module can support the shellfish farmer in the planning of new sites and evaluation of existing sites for aquaculture, based on hind-cast products of surface sea temperature, salinity, currents, turbidity, food flux, chlorophyll a, oxygen concentration, growth and condition indices from shellfish species.

6. SM-A4 – Assistance for spat captures
   Give the shellfish farmer the opportunity to predict the spat arrival and therefore increase the efficiency of the spat collectors. The Service Module is based on surface sea temperature, currents and source areas of shellfish larvae.

7. SM-A5 – Marine conditions at farming site/alarm system
   This Service Module will give the shellfish farmer the marine conditions at given farming sites in near real time mode and can support in daily operations and planning, based on weather, sea level, waves, currents and sea surface temperature.

Sector Oyster ground restoration

8. SM-R1 – Retrieve sources of contamination

Provides the oyster ground restorator with the prediction of the path followed by a sewage discharge from typical source locations and retrieving the most likely sources of pollution for a given farming area.

11. Conclusions

Based on the work of D2.1 and D3.1 , the user requiremnets have been identified. In this document, those needs have been translated into specifications that would fit each target sector, extended with the concept of services. The work have been divided into several Service Modules that provide information that cover the user needs in each given sector.In total 8 Service Modules, spread over three different sectors, i.e. Fisheries, Aquaculture and Oyster Ground Restoration, were identified as essential for the specific end user. Those has been presented to the user community as a first confirmation with their embded needs in a workshop. The analysis of the workshop is part of D2.2, which provides the first iterative improvement on the services concept. This iterative process is continuous, thus Service Module redefinitions, merging of synergistic ones, harmonizations and some variations are expected due to future stakeholder interactions in order to best adjust to user needs.

It is worth mentioning that due to COVID19 regulations the work on D3.9 has encountered a delay. However, several non-physical meetings per Pilot would gather enough information to start the Operational Workflow on specific Service Modules. In a later stage, broader stakeholder meetings will be organized to confirm the complying of the services to the end user requirements. At this stage and in this deliverable, not all Service Modules are on the same Technical readiness level (TRL). it is the objective of FORCOAST to further develop these Service Modules to their target TRL (Task 5.5) and also to unroll a roadmap (D5.7) to provide these Service Modules to the end user and to a wider market uptake working beyond the end of the project FORCOAST.

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