FORCOAST

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

Project Deliverable Report

Deliverable Number: D6.2

Deliverable: Final Market Analysis

Author(s): Marcel Bruggers, Alec Reid

Work Package Number: WP6

Work Package Title: Innovation Management, Exploitation & Business Planning

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

FORCOAST Project Information	
Project full title	Earth Observation Services For Wild Fisheries, Oystergrounds Restoration And Bivalve Mariculture Along European Coasts
Project acronym	FORCOAST
Grant agreement number	870465
Project coordinator	Ghada El Serafy, Deltares
Project start date and duration	1st November 2019, 36 months
Project website	https://forcoast.eu/

Deliverable Information	
Work package number	WP6
Work package title	Innovation Management, Exploitation & Business Planning
Deliverable number	D6.2
Deliverable title	Final market analysis
Description	This final deliverable addresses an analysis of barriers to the market for the three target sectors (i.e. bivalve mariculture, oysterground restoration, and wild fisheries), the sustainability of the service and the impact of no longer having access to free data provided by the EU. The final market analysis includes lessons learnt from the exploitation activities during the project (task 6.1). In D6.2 the market barrier will be addressed, such as the scale of the market, the positioning in the market, the product differentiation and the strength of potential competitors, the capital requirement for keeping in the market after EU funding, the government policy (for example, licensing requirements, competition agreements).
Lead beneficiary	Cuan Beo
Lead Author(s)	Alec Reid, Marcel Bruggers
Contributor(s)	Deltares, Pilot and Service Module teams
Revision number	7
Revision Date	15/10/2022

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

Status (Final (F), Draft (D), Revised Draft (RV))	F
Dissemination level (Public (PU), Restricted to other program participants (PP), Restricted to a group specified by the consortium (RE), Confidential for consortium members only (CO))	PU

Document History			
Revision	**Date**	**Modification**	**Author**
1	20/07/2022	Structure of the document	Marcel Bruggers
2	(Until) 10/10/2022	Addition of contributions in working sessions	Alec Reid, Pilot and Service Module teams
3	14/10/2022	Review and formatting	Luis Rodriguez
4	15/10/2022	Review	Ghada El Serafy
5	24/10/2022	Drafting and review	Ghada El Serafy, Marcel Bruggers
6	26/10/2022	Review	Sonja Wanke
7	31/10/2022	Check	Ghada El Serafy

Approvals				
	Name	**Organisation**	**Date**	**Signature (initials)**
Coordinator	Ghada El Serafy	Deltares	31/10/2022	GES
WP Leaders	Daan Delbare	EV ILVO	26/10/2022	DD

Table of Contents

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

Table of Figures

Table of Tables

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

1 Introduction

This deliverable is confidential and intended only for members of the FORCOAST consortium, the European Commission Services and other relevant parties as deemed appropriate by the project co-ordinators.

The purpose of this deliverable is to provide the FORCOAST consortium with an in-depth knowledge of the Fisheries, Aquaculture and Oyster Reef Restoration (ORR) industries' user requirement for an Earth Observations based solution for marine water quality parameter analysis and environmental condition monitoring. Achieving this will allow the FORCOAST Platform to identify the most feasible product-market combination to develop marine environmental monitoring solutions to service these industries.

To this effect, the initial market analysis will outline the following;

- An overview of the market size for each of these industries within the EU,
- An overview of the market size of these industries globally,
- The market needs these industries have for an earth observations based marine environment condition monitoring solution,
- The current situation of these markets, the future situation and what opportunities we see,
- The user segmentation that exists within these industries,
- The competing Integrated Marine Environment Condition Monitor Solutions that can provide similar solutions to satisfy the identified user's market needs,
- The barriers to entry that would affect the ability of the FORCOAST platform to deliver the envisaged services to the final users identified.
- How to position the FORCOAST Platform in this market and identify the propositions the FORCOAST Platform should offer.
- Identify the dependencies required to deliverer identified propositions.

To determine the above this deliverable contains an analysis of the results of a number of research activities undertaken by the FORCOAST Consortium including engagement with potential users from the three target industries, engagement with competing service providers and engagement with service developers, regulators and potential additional marine users to ascertain the barriers to entry the FORCOAST platform may encounter in delivering the envisaged services to the final users identified.

Overview of Groups Contributing to D6.1 Initial Market Analysis

A better understanding of the coastal environment and integrated monitoring and forecasting of the coastal environment by the use of data from different sources (including earth observations from satellites) is key to minimising the potential impacts of human activities on the coastal area. This activity can be crucial in the development of added-value operational products that will clearly represent a new market uptake and facilitate the deployment of those sectors in Europe.

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

To guarantee the uptake of the products and services FORCOAST must ensure they are co-designed, from the beginning of the project, by the collaboration between academic and research organisations working together with SMEs which are partners in the consortium and also with a wide range of stakeholders (i.e. parties with a stake or interest on the project results, including users, scientists, decision makers, investors, etc.) and also with shareholders (parties investing money in the development of products).

For this reason, FORCOAST is organised in eight pilot service uptake sites, which cover the three FORCOAST target sectors and five different regional waters (i.e. North Sea, Baltic Sea, Mediterranean Sea, Black Sea and the coastal Atlantic Ocean, see Figure 1). Through these pilots, FORCOAST will ensure an effective co-design of tailored products to meet user needs, which must be developed and demonstrated in hand with partners' clients and identified stakeholders in these areas.

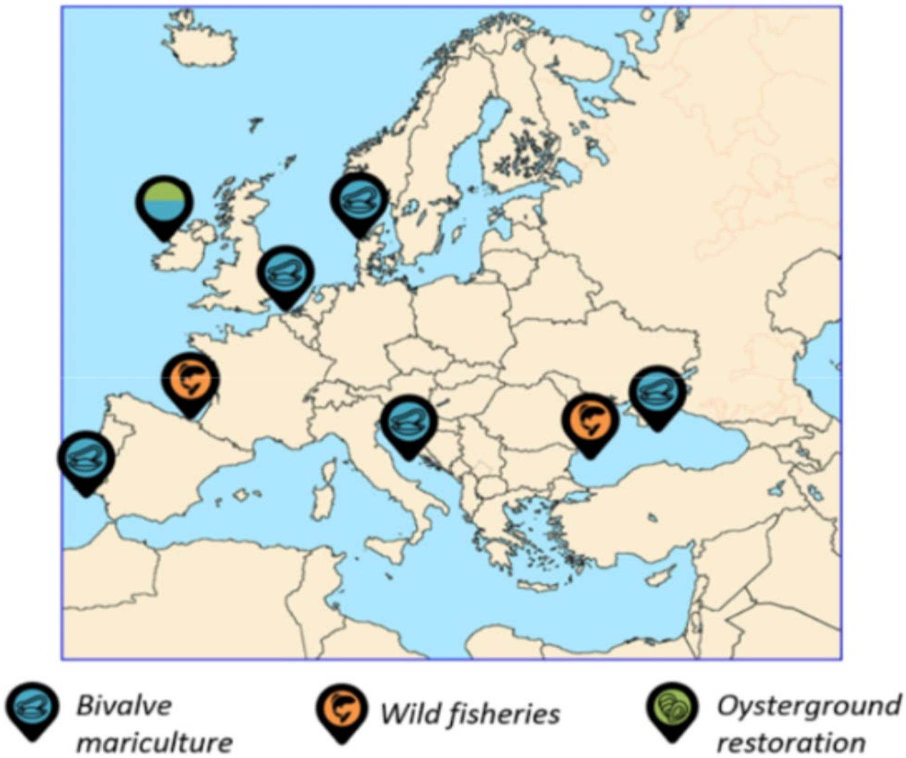


Figure 1. Map of FORCOAST Pilot Areas and Their Respective Activity Sectors

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

2 Target Industries

2.1 Oyster Reef Restoration Market Overview

2.1.1 Current Situation

2.1.1.1 The Ecological Restoration Market Place

Oyster Reef Restoration (ORR) falls under the category of 'Ecological Restoration' which is a rapidly growing industry that has seen significant investment in recent years as a result of its potential to mitigate against environmental challenges including climate change, increased carbon emissions, wildlife habitat loss, ecosystem services loss and the overconsumption of natural capital resources.

In 2021, the United Nations launched 'The UN Decade on Ecological Restoration' and forecasted that "*between now and 2030, the restoration of 350 million hectares of degraded terrestrial and aquatic ecosystems could generate US$9 trillion in ecosystem services*"[1], thus highlighting the market expansion potential of the ecological restoration industry. In relation to the specific context of ORR the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) utilised its nature valuation tool to estimate that the *"Great Barrier Reef makes a contribution of US $5.7 billion a year to the Australian Economy and supports 69,000 jobs"*[2].

These valuations of natural capital gains and habitat loss mitigation have attracted significant attention and investment in the ecological restoration industry. The Ecosystem Marketplace Publication in 2015 cited that '*Ecological restoration is a $25 billion industry that generates 220,000 jobs*' [3]and the World Economic Forum outlined in 2021 that investing in ecological restoration is beneficial for companies to achieve '*business resilience, business profitability and growth, and value-based leadership*'.[4] Accordingly, there has been significant uptake in community groups, governments, private companies, universities and environmental groups investing in ecological restoration projects. See below figure 2 showcasing 'large scale' corporate investment in global forest ecological restoration.

[1] https://www.decadeonrestoration.org/what-ecosystem-restoration

[2] https://www.weforum.org/agenda/2018/10/this-is-why-putting-a-price-on-the-value-of-nature-could-help-the-environment/

[3] https://www.ecosystemmarketplace.com/articles/ecological-restoration-25-billion-industry-generates-220000-jobs/

[4] https://www.weforum.org/agenda/2021/06/3-reasons-companies-are-investing-in-forest-conservation-and-restoration-and-how-they-do-it

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

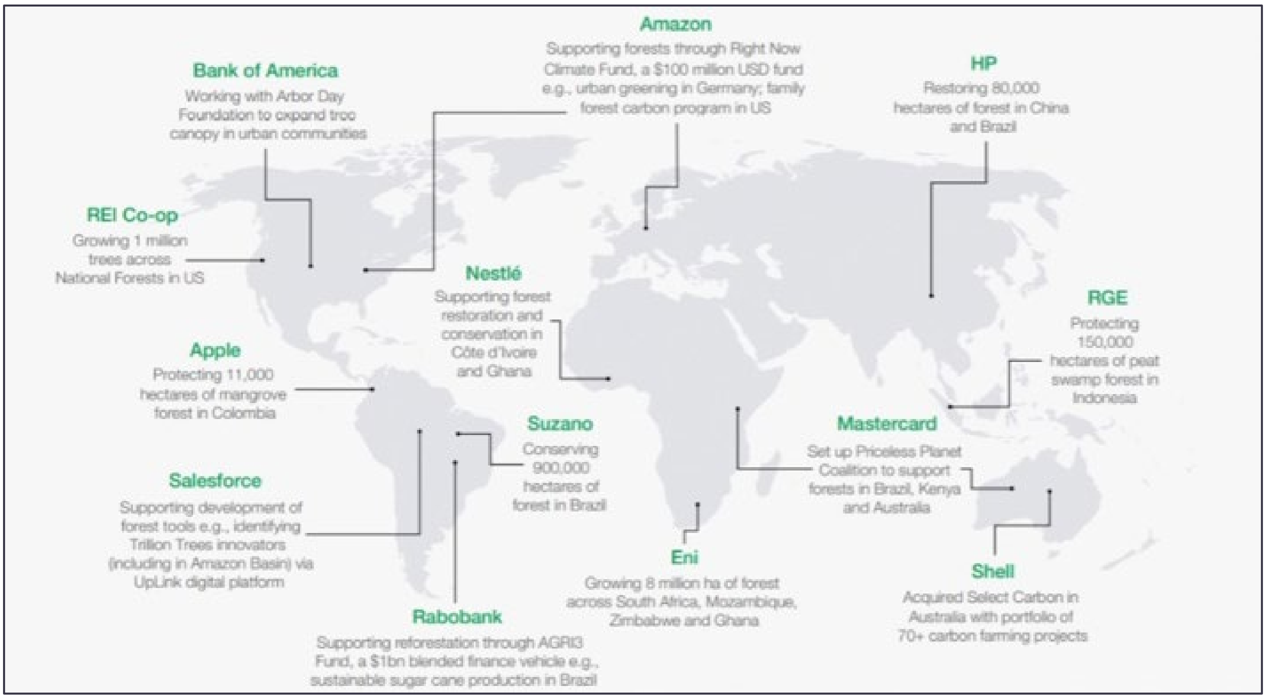


Figure 2. Worldwide Corporate Pledges on Forest Conservation and Ecology Restoration - Source World Economic Forum[5]

This increased investment and uptake in terrestrial ecological restoration projects such as forest conservation has also been experienced in the marine environment through initiatives like Oyster Reef Restoration, Kelp Forest Restoration and Sea Grass Restoration.

Native Oyster (*Ostrea Edulis*) reefs are among the most threatened marine habitats in Europe, with populations in the UK and Ireland alone suffering a decline of approximately 95%[6]. This substantial population decline has heightened the requirement for '*active intervention*' to reduce the further decline of native oyster populations and prevent the species from going extinct. In response to this significant population loss, ORR has become a growing marine industry in Europe with the number of ORR collaborative projects ongoing in Europe expanding from 5 in 2015 to 33 in 2022.[i]

Oyster Reef Restoration (ORR) involves the restoration of historical oyster reefs that have suffered extinction or the rejuvenation of active oyster reefs that have suffered a decline in population. ORR generally involves establishing an area for restoration, deploying suitable substrate to promote larval settlement, identifying the distribution of critical habitat for native oysters including modelling of temperature and salinity, developing spatial management of oyster fisheries that will include closed areas for oyster reef development and improving coastal water quality. Additional works including ocean modelling, artificial substrate construction and marine environment monitoring are also undertaken depending on the individual project.

[5] https://www.weforum.org/agenda/2021/06/3-reasons-companies-are-investing-in-forest-conservation-and-restoration-and-how-they-do-it

[6] https://noraeurope.eu/wp-content/uploads/other-publications/European-Native-Oyster-Habitat-Restoration-Handbook.pdf

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

The Oyster Reef Restoration (ORR) sector is the smallest of the three industries currently being serviced by the FORCOAST system with only 19 ORR groups identified in Europe. ORR groups have also been identified in America, Canada, Australia and Asia and three of the largest of these have been included in this Initial Market Analysis. Commercial Oyster Fishery groups have also been included in this Initial Market Analysis as their market need is similar to that of ORR groups given that they work with the same species (*Ostrea edulis*), work on the seabed and suffer oyster moralities owing to the same environmental challenges facing ORR. In the ORR Pilot country Ireland, eight commercial oyster fisheries are identified. ORR projects also often take place within a larger programme of marine habitat conservation and accordingly a number of third-party users including state institutions, scientific institutions, community groups and educational institutions are often involved. This adds a wide range of additional potential Users who have a similar market need for marine environmental condition monitoring.

2.1.1.3 Cycles of ORR-projects

ORR projects generally involve the following three cycles:

Cycle 1: Project Planning - This cycle involves the planning stage of an ORR project which can include the following;

- Securing Licensing
- Securing Permission to Conduct ORR Activity
- Securing Project Funding
- Recruiting Participants
- Establishing a Management Structure for Project Facilitation
- Designing Work Packages for Restoration Activity

Cycle 2: Project Facilitation - This cycle involves facilitating the environmental restoration activities required to achieve the rejuvenation of the oyster reef which often include the following;

- Marine Condition Monitoring
- Marine Seabed Mapping
- Cultch Deployment (Substrate Deployment for Oyster Recruitment)
- Native Oyster Spat Production
- Oyster Gonad Development Monitoring
- Oyster Larval Settlement Monitoring
- Oyster Survival Against Marine Condition Monitoring

Cycle 3: Project Promotion and Communication - This cycle involves the communication and outreach activities of an ORR project which can require projects to produce the following research additional to the activities of ORR;

- Producing Research for Marine Biodiversity Enhancement
- Producing Research to Advance Conservation Policy Decision Making
- Producing Research to Advance Community Environmental Education
- Producing Research to Evaluate the Impact of Climate Change and Human Activity on Marine Habitats

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

- Producing Research to Inform Marine Technology Development/ Fishery Management Policies

2.1.1.3 EU-market

ORR is an established and growing industry in the UK and Ireland with a number of groups engaged in restoration activity at sites in Ireland, Northern Ireland, Scotland, Wales and England. These countries also contain active *Ostrea Edulis (*native oyster*)* fisheries and *Ostrea Edulis* aquaculture farms which means that there exists a commercial interest to restore oyster reefs in these regions additional to the motivation of biodiversity enhancement. The *Native Oyster Network UK & Ireland* currently lists 14 active ORR projects ongoing in the UK and Ireland, with additional native oyster fisheries and native oyster aquaculture production also ongoing in these regions.[7]

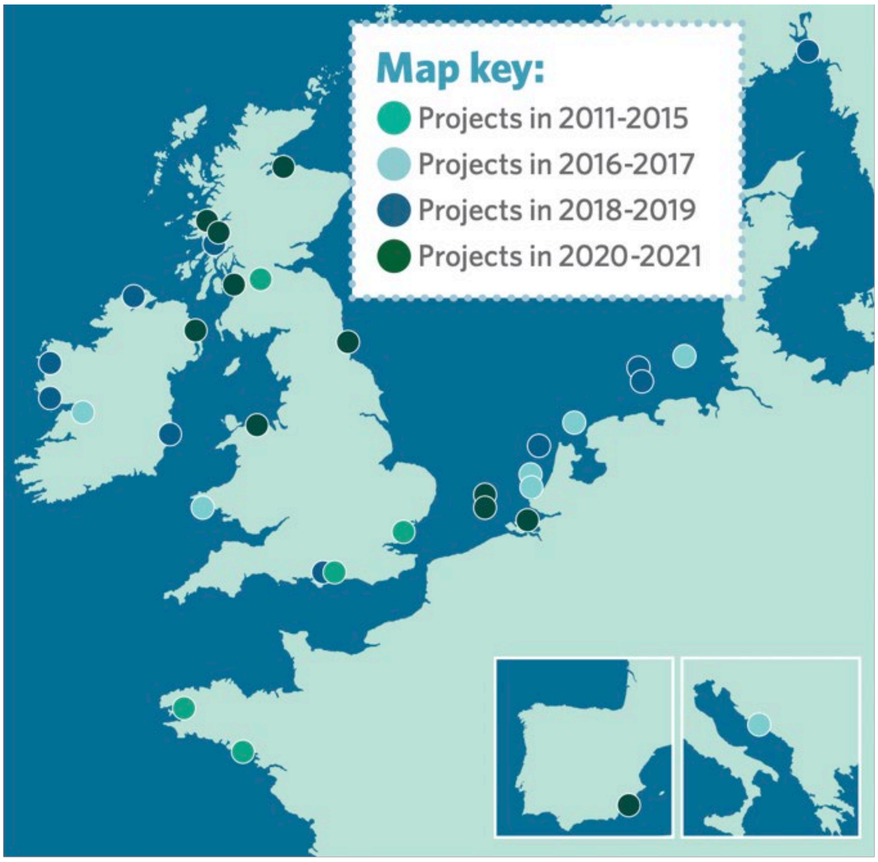


Figure 3. Ostrea Edulis Restoration projects active in 2015, 2017 and 2028[8]

Although ORR is still at a pilot or experimental phase for a number of projects within Europe, the establishment of ORR networking groups including the Native Oyster Network UK and Ireland and the Native Oyster Restoration Alliance has allowed projects to develop rapidly in scale, innovation and knowledge transfer. Accordingly, the industry is growing in Europe with

[7] Info sourced from https://nativeoysternetwork.org/restoration-projects-partnerships/

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

large funding being The Native Oyster Restoration Alliance currently lists 33 ORR projects ongoing in Europe.[8]

These projects also engage in a wide range of activities additionally to ORR with six working group categories established under the Native Oyster Restoration Alliance. These working groups include; (a) Biosecurity, (b) Historical Ecology, (c) Monitoring, (d) Outreach, (e) Oyster Production and (f) Site Selection. Involvement in these work programmes provides additional activity for ORR projects to engage in and allows them to offer services in markets additional to ecological restoration including;

- Marine Education
- Fishery and Coastal Management Consultation
- Marine Environmental Monitoring
- Research and Project Reporting

European ORR Project Sample - ENNOI Project

The Essex Native Oyster Restoration Initiative was established in 2011 with multiple stakeholders involved in the project including the University of Essex, The Nature Conservancy, Zoological Society of London, Essex Wildlife Trust, Natural England, Cefas, Rich Roach Oyster Company, Kent and Essex Inshore Fisheries and Conservation Authority. The project goals are to restore oyster populations in the Blackwater, Crouch, Roach and Colne Estuaries where native oyster populations have decreased by over 95%. [9]

Figure 4. Essex Native Oyster Restoration Initiative

Work packages under the project that would benefit from an earth observations marine monitoring solution include:

- **Substrate Deployment** - 'In 2021, over 7000m^2 of the seabed was actively improved by cultch deployment. Since this deployment, monitoring results have shown

[8] https://noraeurope.eu/wp-content/uploads/other-publications/European-Native-Oyster-Habitat-Restoration-Monitoring-Handbook-updated-03-2022.pdf

[9] https://nativeoysternetwork.org/portfolio/enori/

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

increased biodiversity on the deployed cultch compared to control areas, as well as good settlement of native oysters. This large-scale restoration work has continued in 2022 with a further 900m3 of cultch deployed to double the size of restored habitat.'[10]

European ORR Project Sample - Galway Bay Oyster Reef Restoration Project

Figure 5. Galway Bay Oyster Reef Restoration Project

The Galway Bay Oyster Reef Restoration Project is a community, state and scientific institution-led initiative that aims to restore the native oyster (*Ostrea edulis*) populations in Galway Bay. The project goals are to restore native oyster habitats, identify the distribution of critical habitat for native oysters, develop spatial management of fisheries that will include closed areas for oyster reef development and sustainable fishing, gain an in-depth knowledge of native oyster habitat restoration through practical research and to improve water quality in Galway Bay by fostering a community understanding that land-based activities have an impact on coastal water quality. The project contains multiple stakeholders including Cuan Beo Environmental CLG, the Marine Institute and Bord Iascaigh na Mhara. The project is funded under the EMFF Biodiversity Scheme.

The native oyster population in Galway Bay has suffered a substantial decline owing to a number of factors including fishery management, disease introduction and significant environmental pressures owing to increased land use and land drainage management. The increased land use and land drainage have placed substantial pollution pressures on freshwater inputs into Galway Bay which has resulted in significant environmental challenges for native oyster populations. These environmental challenges include;

[10] https://noraeurope.eu/enori-update-on-cultch-deployment/#more-6139

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

- Substantial drops in salinity and temperature owing to large freshwater discharges.
- Marine water pollution originating from land-based pollutants.
- Increased eutrophication to feed Harmful Algae Blooms.
- Increased sedimentation of suitable habitat.
- Increased Turbidity inhibiting algae growth.

The accumulation of these environmental challenges has resulted in large areas of inner Galway Bay becoming unfavourable for oyster survival. Accordingly, an ocean model capable of displaying how freshwater inputs discharge into the marine environment is incredibly valuable for site selection in ORR and can assist the user in identifying the areas of the bay that will result in the highest yield of (a) oyster settlement, (b) oyster larvae survival and (c) mature oyster survival.

Tasks and objectives within the project that would benefit from an earth observations marine monitoring solution include:

- **Salinity and Temperature Oyster Stress Testing –** The Galway Bay ORR project measures oyster survival against different thresholds of salinity and temperature to determine their survival against different ranges of these environmental conditions.
- **Oyster Larval Settlement –** The Galway Bay ORR project identifies when oyster larvae are present in the water and monitors salinity and temperature to assess environmental conditions suitability for oyster settlement.
- **Oyster Gonad Monitoring -** The Galway Bay ORR project assesses the different stages of oyster gonad development and monitors salinity and temperature at the time of sampling to determine at what intervals oyster gonads begin to develop.
- **Native Oyster Spat Production –** The Galway Bay ORR project produces oyster spat in spatting ponds and monitors marine environmental conditions to determine the best time to deploy the spat produced in the marine environment.
- **Water Quality Policy Engagement -** The Galway Bay ORR project engages in water policy consultation and provides feedback to policy makers on how particular environmental conditions affect oyster survival and settlement in Galway Bay.
- **Substrate Deployment** – The Galway Bay ORR project has deployed 500t of cultch (settlement substrate) for native oysters to settle on since the beginning of the project and assess oyster settlement on this cultch against environmental conditions.

2.1.1.4 US-market

North America has a long-established and large-scale ORR industry with some of the largest and longest-running ORR projects in operation globally. For example, the South Carolina Oyster Restoration and Enhancement project (SCORE) has been ongoing since 2001 with ORR activity spanning approximately 200 miles off coastline with 188 reefs constructed at 35 sites since the project's inception.[11] The longevity of the ORR industry in America has allowed significant federal, state and private investment funds for ORR projects to develop.

[11] https://apnews.com/article/7e1ac7344ceb4498875f22b80f64cbb7

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

The Supporting Oyster Aquaculture and Restoration (SOAR) initiative provides finance for American ORR groups to purchase oysters from aquaculture oyster producers.[12] The PEW Research Centre outlines that; "*SOAR was developed by Pew and The Nature Conservancy, with guidance and support from state and federal agencies… It is the largest partnership between growers and restoration experts to date, with $2 million in funding, and expects to buy at least 5 million oysters to populate 27 acres of reefs across 20 restoration sites…more than 100 shellfish companies will sell to the program, and that revenue from those sales will help support 200 jobs in New England, the Mid-Atlantic, and Washington state.*" [13]

Additional to multi-agency funds such as SOAR, individual States invest significant funds in regional ORR projects. In 2020, Governor of Virginia Ralph Northam announced a fund of $10 million investment to support the future of Oyster Restoration in the Chesapeake Bay. In 2018, the North Carolina Oyster Blueprint Action Plan for Restoration and Protection received $850,000 from the state to construct an oyster sanctuary in the Pamlico Sound. As a result of the $204.7 million settlement Deepwater Horizon Oil Spill in 2010, the Louisiana Department of Wildlife and Fisheries (LDWF) was allocated £25.6 million for oyster reef restoration-related projects.

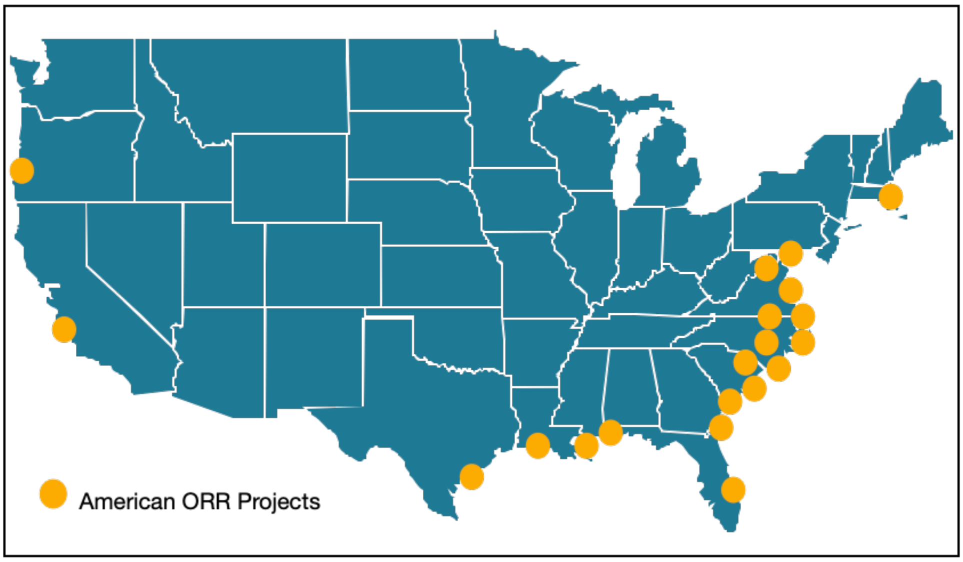


Figure 6. American Oyster Reef Restoration Projects

2.1.2 Future Developments

Oyster Reef Restoration is a new sector as natural oyster reefs are nearly extinct. Therefore, oyster reef restoration is needed, not only for the oysters themselves but also due to the fact that oystergrounds support a large number of natural services including sediment stabilization, water filtration, and provisioning of food for animals and society, among many others. Therefore, restoration activities not only benefit the landings of oysters, but also the associated species utilizing the habitats and therefore contributes to national economic growth. A 2019 review of oyster restoration case studies show a growing global application of the process as construction and restoration of oyster

[12] https://www.nature.org/en-us/what-we-do/our-priorities/provide-food-and-water-sustainably/food-and-water-stories/oyster-covid-relief-restoration/?vu=soar

[13] https://www.pewtrusts.org/en/research-and-analysis/articles/2020/10/21/oyster-restoration-offers-new-market-for-shellfish-farmers

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

grounds results in massive economic results: 100 miles of oyster restoration can create 380 jobs per year for 10 years or 3800 jobs during one decade of construction, boost regional household income by $9.7 million a year during a 10-year construction period, increase direct harvesting revenues by $7.87 million annually, noting investment and the number of oyster restoration activities globally is has been increasing since the turn of the century (Wight and Nichols, 2019). FORCOAST presents two services that can help the oyster reef restorators in their activities and make them more cost-effective.

2.1.3 Customer Identification

2.1.3.1 Characteristics

The sector of oystergrounds restoration is represented in Pilot 5, where one intermediate and one final user are working closely with other external organizations for the restoration of Galway Bay natural habitats and oyster fisheries (Table 1).

P	Location	INTERNAL USERS		EXTERNAL USERS
		Intermediate	Final	
5	Galway Bay	Marine Institute (Research)	Cuan Beo – SME (Restoration)	Irish native Oyster Fisheries Forum (INOFF) Native Oyster network https://nativeoysternetwork.org/ Native Oyster Restoration Alliance (NORA) https://noraeurope.eu/

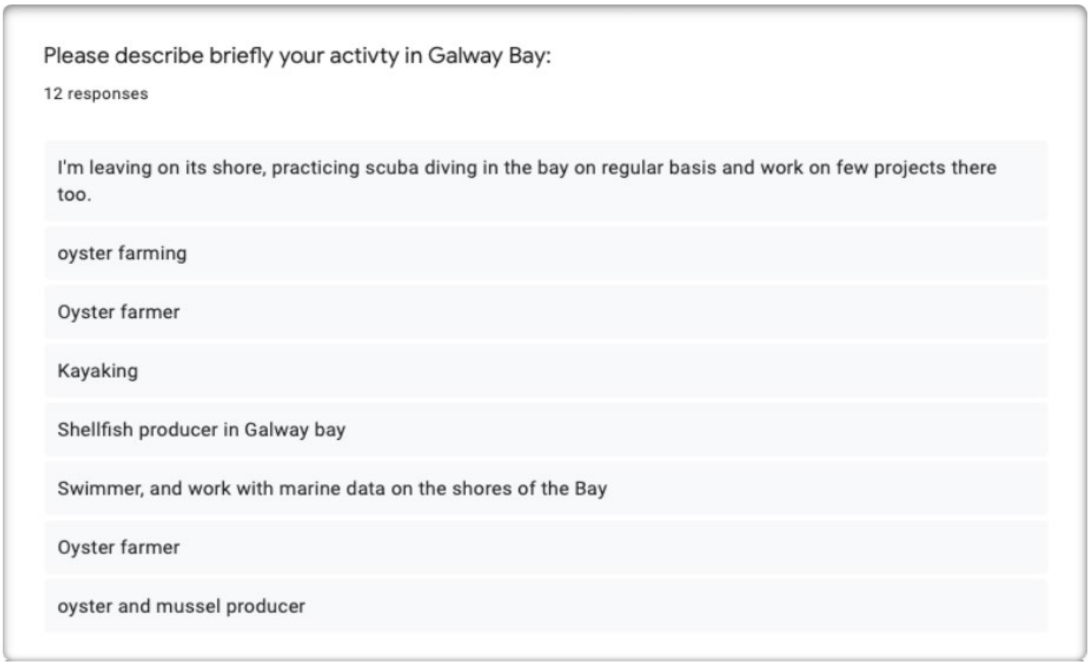
Table 1. Detail on users inside the consortium (intermediate or final) and sectorial final users for the Oysterground restoration sector

The ORR target market user is unique depending on the oyster restoration project. Users vary from scientific institutions, state institutions, community groups and aquaculture producer groups. Some oyster restoration groups are actively involved in reef restoration, others are involved in reef restoration as part of a larger marine habitat conservation project, and others are only involved in raising awareness and creating educational materials. All these groups have a need for good water quality and a need to understand potential contamination pressures on coastal waters. The ORR users can be segmented into 3 categories (a) Active Restoration, (b) Passive Restoration and (c) Partial Restoration.

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

Figure 7. Case sample for pilot 5 Ireland "Galway bay oyster restoration project".

ORR projects generally take place in a large area in which other groups including state institutions, scientific institutions, educational institutions, recreational groups and water safety groups also operate. These additional groups may also be interested in marine environmental condition monitoring and data.


Please describe briefly your activty in Galway Bay:

12 responses

I'm leaving on its shore, practicing scuba diving in the bay on regular basis and work on few projects there too.

oyster farming

Oyster farmer

Kayaking

Shellfish producer in Galway bay

Swimmer, and work with marine data on the shores of the Bay

Oyster farmer

oyster and mussel producer

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

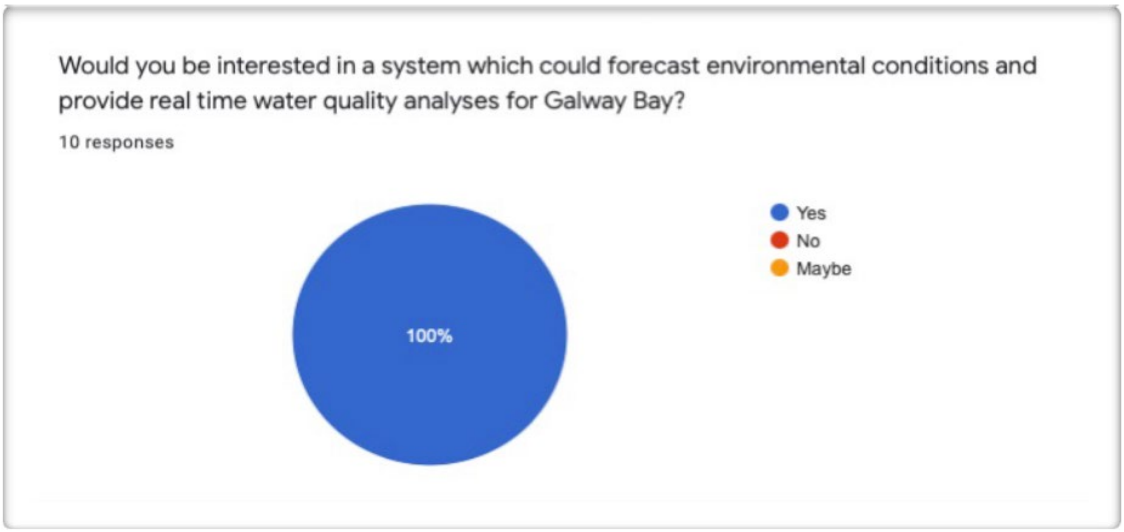


Figure 8. Questionnaire feedback from additional users identified in Pilot 5 Ireland oyster reef restoration.

2.1.3.2 Specific Needs

The potential to restore native oyster populations is closely linked to present and future environmental characteristics at restoration sites. Choosing sites and areas within sites for restoration does not simply involve looking historically at distribution but futureproofing against changes in the environment expected due to climate change and human activities and development. There is a market need to understand the following physical characteristics at or close to the seabed:

- Sediment Composition
- Sediment Mobility and Suspension
- Sedimentation
- Turbidity - Reflecting Particulates in Suspension
- Current Strength and Seabed Stress
- Salinity Concentration and Temperature
- Water Circulation - (Circulation patterns will control the retention or dispersal of larvae from spawning sites)

The value of achieving this information will help in 'Site Selection for Native Oyster Reef Restoration'. When the minimum and maximum levels for the desired physical and biochemical parameters for reef restoration are within favourable conditions the likelihood of reef restoration is drastically improved. Accordingly, knowing this information will save costs in substrate deployment and monitoring which are usually the largest costs in ORR projects. Also, the information is extremely valuable in that it will inform whether an oyster reef is capable to survive and thrive in the chosen site for reef restoration.

Parameters	**Units of measurement**	**Minimum levels**	**Maximum levels**	**Life of historical process**
Bed shear stress	N/m^3	1	10	Survival
Seabed mobility	cm/day	0	0.8	Survival
Sediment composition	mg/L	0	50	Growth & survival
Temperature (mature)	°C	3	30	Growth & survival

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

Temperature (larvae)	°C	18	30	Larval development & settlement
Turbidity	Nephelometic Units	/	/	Suspended solids & irritate oyster gills
Salinity	g/L or ppm	25	35	Feeding, growth & survival
Chlorophyll a	µg/L	1.68		For spawning to occur
Circulation patterns	-Direction in ° -Velocity in m/s	/	/	Retention of larvae or delivery of larvae to suitable areas for settlement

Table 2. Minimum and Maximum Levels for the desired physical characteristics to be recorded.

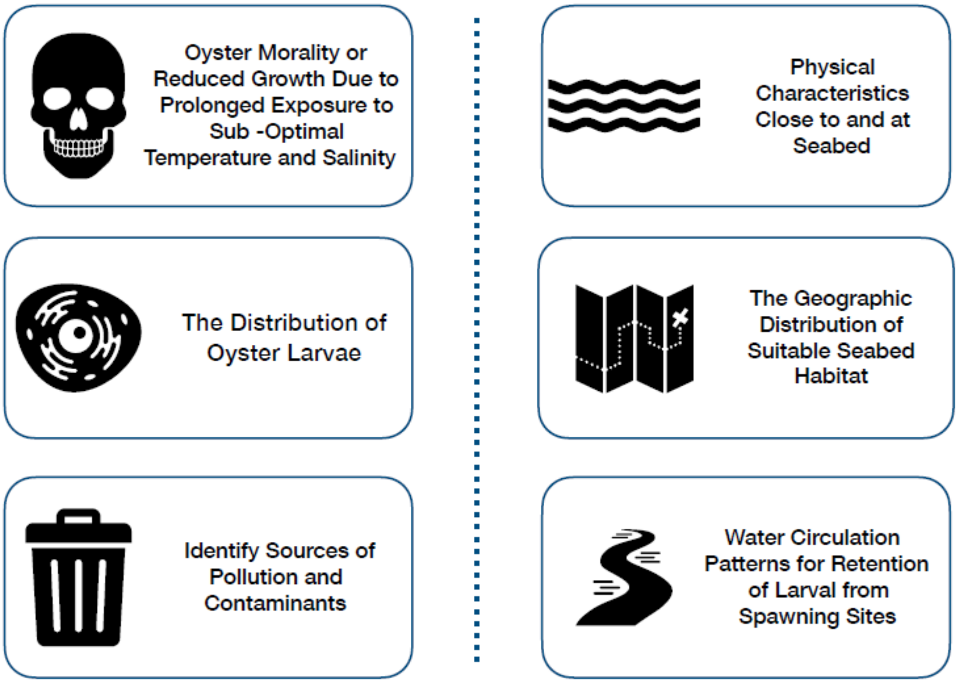


Figure 9. Oyster Reef Restoration Marine Condition Monitoring Requirements

The stakeholders engaged in ORR projects include Community Groups (e.g., Cuan Beo Environmental CLG), Environmental Conservation Bodies (e.g., London Zoological Society), State Institutions (e.g., Bord Iascaigh na Mhara), Scientific Institutions (e.g., Marine Institute), Fishery Co-Ops (e.g., Tralee Oyster Fishery Co-operative), Universities (e.g., University of Bangor) and large private companies (e.g., Belgian Offshore Wind Farms). The different groups engaged in ORR are generally grouped together in a project structure where a number of work packages are designed to achieve the primary objective of oyster reef restoration, but also additionally objectives such as marine biodiversity

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

enhancement, improving marine spatial planning, generating research, advancing marine education, and facilitating community engagement are also considered to be project objectives.

The oysterground restoration sector is another sector highly dependent on water quality information as well as the physical conditions of the water environment. Therefore, water quality prediction plays an important role in modern oysterground restoration activities, planning and management. In this case, the sectorial user requirements have been gathered mostly from the inputs of Pilot 5, in Galway Bay. Knowing that special interest should be put in update these requirements with the exchanges with other users in the sector during the lifetime of the project.

i. To **assess the disease status of native oysters by tracing viruses and bacteria** from known point insources is key to identifying the main risks associated with restoration projects. It is also key to identify inputs that are detrimental to mariculture and to bring these issues to policy and decision makers. The main cost of inaction in this aspect will be related to a decline in the quality of habitats for native oysters
ii. To provide **environmental data and short-term forecasts for parameters that may affect production** (mortality and growth). Historical data series and statistical analysis of observational data and short-term forecasts of parameters that can be used as proxies for virus and bacterial contamination, detritus, etc are needed. A key aspect is to identify seasonality in primary productivity and scope for the growth of bivalves in mariculture and wild populations. The main cost of inaction in this aspect will be related to a decline in the production of bivalves due to unfavourable conditions.
iii. To **provide data on the status (distribution and biomass) of native oyster stocks** using synoptic maps is key to identifying locations most suitable for native oysterground restoration and avoiding resourcing restoration in the wrong location. The main cost of inaction in this aspect will be related to the poor capacity to restore native oyster grounds.
iv. To determine the **distribution of suitable habitats for native oysters** using synoptic maps of salinity, temperature, and chlorophyll is key to identifying areas of high primary productivity in the area for bivalve mariculture. The main cost of inaction in this aspect will be related to the poor conservation status of habitats if detrimental inputs continue or increase.

At this moment current actions are simply based on market conditions and readiness for harvest. At the moment, the available information is river and groundwaters inputs (but these need to be improved) and outputs from an ocean circulation model but with a too low resolution and point estimates of SST. The main gaps are the lack of tools/data for tracking viral and bacterial inputs, the improvement of the spatio/temporal resolution of the data and its integration of data to a single point access platform. Ideally, this platform should be easily available showing critical parameters in a synoptic way and producing reliable short-term forecasts.

The market need for oyster reef restoration is generally uniform and standard for every ORR group as the activities undertaken and challenges faced are the same. The market needs can be grouped under a comment title of 'Habitat Suitability and Potential to Restore' which refers to the potential of a particular area of the shore for oyster reef restoration. A detailed list of the market need for this can be found in the above market need section, but they can be summarised to include (a) Water Quality Analysis and (b) Larval and Particle Dispersion and Trajectory. Providing a service that can meet these market needs would be widely desired in the ORR community.

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

2.2 Bivalve Aquaculture

2.2.1.1 Introduction

Worldwide seafood demand for bivalves continues to grow. The different species of shellfish produced in aquaculture include Mediterranean mussel, Blue mussel, Pacific cupped oyster, Venus clams nei, See mussels nei, Grooved carpet shell, and others. The main species of shellfish produced are Mediterranean mussels counting for 50% of total production, Blue mussel and Pacific cupped oysters, as well as Venus clams nei for 5% (FAO, 2018).

Seventeen Member States (still including the UK) are involved in the EU shellfish sector in 2018. In the EU-producing countries, total production increased up to 675 thousand tonnes in 2018, versus 2017 production of 668 thousand tonnes, with a total value of €1.30 billion, compared with 2017 production value of €1.26 billion, corresponding to an increase of 1% in weight and 3% in value. This production is particularly important because it is mainly produced by small-scale farms, with high employment and therefore has increasing importance for social-economic reasons.

The number of enterprises diminished to 7,250 units in 2018, versus 7,322 units in 2017, while the number of total employees increased from 34,856 in 2017 to 37,010 employees in 2019. The leading countries are Spain with 2,701 enterprises and 14,905 employees (FTE 4,125), France with 2,455 enterprises and 13,710 employees (8,363 FTE), Italy with 400 enterprises and 3,703 employees (1,361 FTE), and Portugal with 820 enterprises and employees 1,337 (FTE 495).

Data submitted by MS show an increase of GVA from €773.6 million in 2017 to €794.6 million in 2018, and an EBIT value of €249.8 million in 2018, decreasing from € 257.2 million in 2017.

2.2.1.2 EU-market for Oyster farming

Since the FORCOAST project has oyster producers within its consortium and is the main produced species in Pilot 1, a more detailed overview of this production is included in this section.

Oyster farming has a long history and is much more important than oyster fishery in most producing regions (farmed oysters provided 98% of the world's production of oysters in 2014, according to FAO). Commonly farmed oysters include the Eastern oyster (*Crassostrea virginica*), the Pacific oyster (*Crassostrea gigas*, the most-farmed oyster species worldwide), Belon oyster (*Ostrea edulis*), the Sydney rock oyster (*Saccostrea glomerata*), and the Southern mud oyster (*Ostrea angasi*)

In the EU, the culture of the native flat oyster (*Ostrea edulis*) is limited, despite stable production in recent years, as overexploitation and disease have led to its depletion. The Pacific cupped oyster, native to Japan, was brought to Europe in the 1970s after the depletion of the Portuguese oyster (*Crassostrea angulata*). Thanks to its rapid growth and adaptability to different surroundings, it is now the most widely reared oyster worldwide.

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

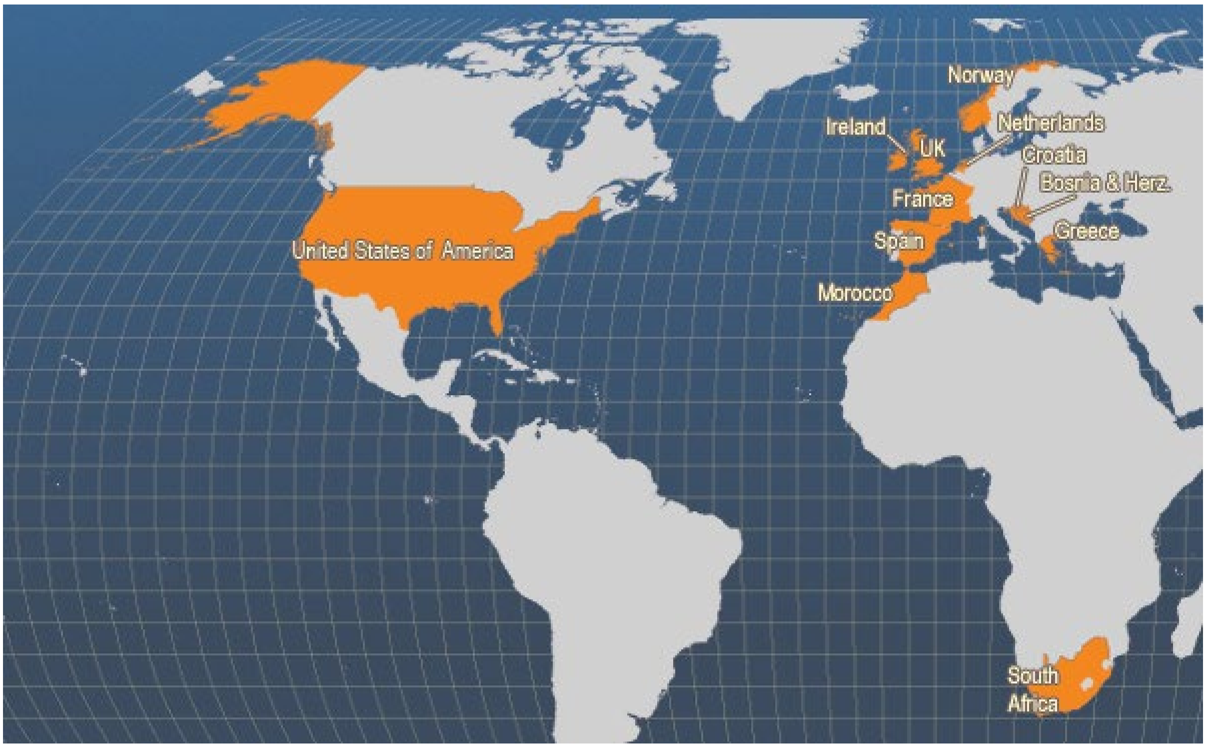


Figure 10. Main producer countries of European flat oyster (FAO Fishery Statistics, 2006)

Figure 11. Main producer countries of Pacific oyster (FAO Fishery Statistics, 2006)

Oyster production in Portugal had always been very volatile and fragile. The production was mainly of the “Pacific oyster” species but in recent years, there was an increase in the farming of the “flat oyster” and the so-called “Portuguese oyster”. Although the oysters were of Portuguese heritage, they were not traditionally consumed on a regular basis and their introduction was a long process as most people associated them with a luxury consumption good.

EU oyster production depends strongly on French production and its consumer market. After several years of decreasing production caused by the 2008 disease outbreak in French oyster farming areas,

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

production has increased again since 2014. The key market is France, but a few niche export markets for high-range products have emerged.

According to FAO, EU production amounted to 93.103 tonnes in 2014, providing approximately 2% of the world's supply. France (82% of EU production), Ireland (11%) and the Netherlands (3%) were the main producers. Other notable EU producers are the UK, Portugal, and Spain.

In 2015, according to the European Mollusc Producers Association (EMPA), the EU production of oysters was 108.910 tonnes. Pacific cupped oysters accounted for 97,5% and flat oysters for 2,5%.

Much of the production of the major producing countries is absorbed by domestic markets and is supplemented by imports from adjacent countries and trading partners (e.g. trade within the EU, where France imports surplus from other EU countries such as the United Kingdom and Ireland). The relatively short shelf life of this species is an impediment to large-scale global trade for fresh products, and consumer preference is often for live, half shell oysters or freshly shucked meats.

Worldwide aquaculture production of the Pacific cupped oyster continues to expand steadily, having expanded from 156,000 tonnes in 1950 to 437,000 tonnes by 1970, and 1.2 million tonnes by 1990. The expansion was very rapid in the 1990s, rising to 3.9 million tonnes by 2000. Expansion is continuing, reaching nearly 4.4 million tonnes by 2003. Production is likely to continue to expand, albeit at a slower rate due to coastal urbanisation and the increasing need to share the common coastal resource with other users.

EU catches, which were above 10.000 tonnes at the end of the 1960s, followed then a decreasing trend to less than 1.000 tonnes in 2018. In 2018, EU catches represented only 0.4% of global oyster catches. The European flat oyster (*Ostrea edulis*) is the main caught species within the EU (FAO). Wholesale prices show an increasing trend (EUMOFA, Figure 12). Pacific cupped oysters registered a slight increase from 2016 €4.2 per kg to €4.4 per kg in 2017, maintained in 2018.

Country	Number of enterprise		Total sales volume		Turnover		Employment		FTE		Average wage	
	number		thousand tonnes		million €		number		number		thousand €	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Croatia	19	17	0.0	0.0	0.2	0.1	22	19	7	8	19.8	20.0
France	2,043	2,043	115.2	123.5	502.6	534.1	11,574	11,574	6,992	6,992	23.2	25.5
Ireland	159	158	10.1	10.4	45.0	45.9	1303	1338	603	655	22.3	27.8
Netherlands	21	21	2.6	2.6	12.9	13.7	50	50	50	50		
Portugal	62	72	2.0	3.2	12.4	20.8	199	200	138	129	11.9	19.0
Spain	48	51	1.1	1.7	3.6	4.2	432	569	91	108	18.4	15.4
United Kingdom	89	93	2.3	2.2	8.9	8.0	280	273	197	192		
Other none DCF			0.0	0.0	0.0	0.0						
Total DCF reported	**2,441**	**2,455**	**133.3**	**143.6**	**585.6**	**626.9**	**13,860**	**14,023**	**8,078**	**8,135**	**22.9**	**25.4**
Total EU			**133.3**	**143.6**	**585.6**	**626.9**						

Source: EU Member States DCF data submission, 2021

Figure 12. Economic indicators for the EU oyster aquaculture: 2017-2018

France, as the main contributor to the oyster sector, demonstrates an increase of 13% in GVA with €291 million and a 28% increase in EBIT with €59.9 million. Ireland and Spain demonstrate decreases in all economic indicators while Portugal demonstrated over 90% increase in both GVA and EBIT.

In general, the EU oyster aquaculture sector demonstrated an 11% increase in both GVA and EBIT in 2018, and also a rise in labour productivity while the indicators ROI and Capital productivity deteriorated slightly.

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

Country	GVA		EBIT		ROI		Labour productivity		Capital productivity	
	million €		million €		%		thousand €		%	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Croatia	0.1	0.2	0.0	0.0	-26.4	15.0	18.3	20.3	181.2	87.9
France	258.1	290.6	46.9	59.9	6.3	7.1	36.9	41.6	34.5	34.4
Ireland	32.6	26.1	16.0	4.1	22.3	5.1	54.1	39.8	45.4	32.9
Portugal	8.8	16.9	6.9	13.8	67.5	78.1	63.5	130.4	85.5	95.8
Spain	2.9	2.7	1.1	0.9	75.8	35.1	31.6	24.8	197.1	104.2
Total EU	302.5	336.4	70.9	78.6	8.5	8.3	37.4	41.4	36.4	35.7

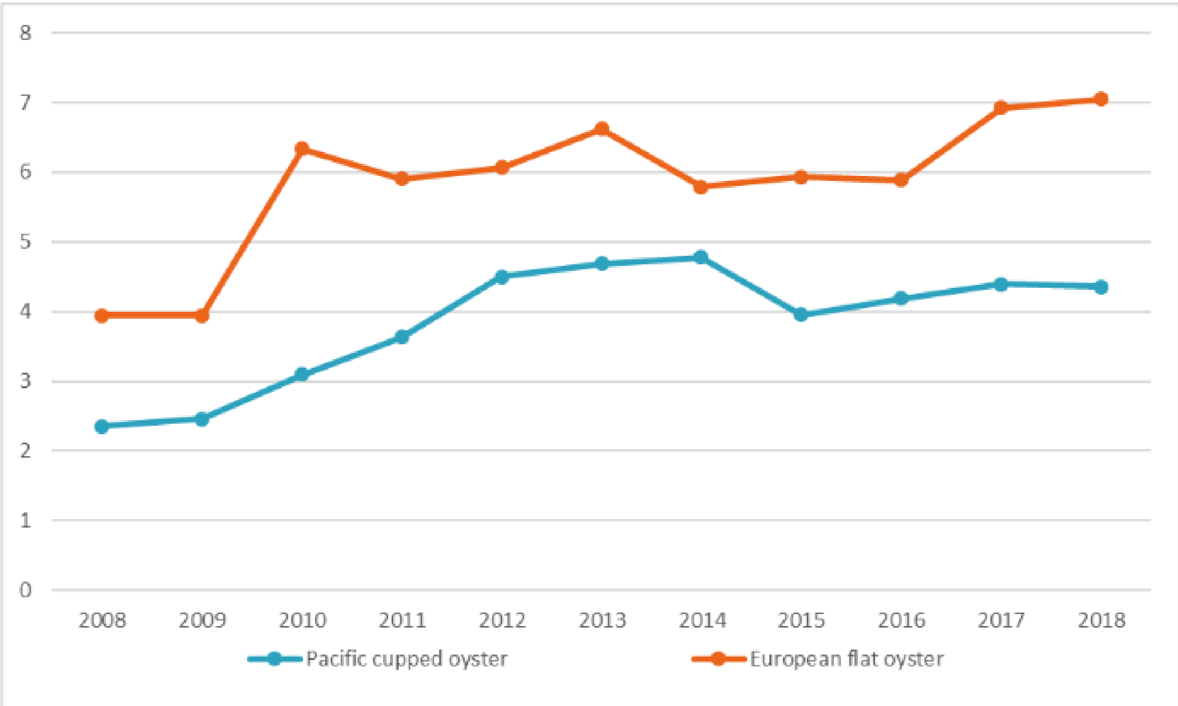
Source: EU Member States DCF data submission, 2021

Figure 13. Economic Performance indicators for the EU oyster aquaculture: 2017-2018

From 2008 to 2018, EU prices of reared Pacific cupped oysters and European flat oysters show a common increasing trend. Concerning Pacific cupped oysters, the decrease in production translates into an increase in the sales price of 54% between 2010 and 2014.

From one year to the next, price changes partly reflect the level of oyster supply (prices increase when volumes decrease). The availability of different sizes of oysters and ranges of oysters (refined or not) that make up the average price influence the price level each year. Price variations can also result from the relationship between the types of suppliers (shellfish farmers, shippers) and customers (wholesalers, restaurants, fishmongers, supermarkets, etc.).

Pacific cupped oyster price is stable between 2017 and 2018 (€4.4 per kg). With a price over €7 per kg, European flat oyster prices increased in 2018 by 2% compared to 2017. The scarcity of flat oysters results in a price that is €2.7 per kg higher than Pacific cupped oysters.



Source: EU Member States DCF data submission, 2021

Figure 14. Price evolution of the main species of oyster group: 2008-2018

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

PRICES ALONG THE SUPPLY CHAIN (EUR/kg)

First-sale (live/fresh)

First-sale prices are presented for European flat oyster (the main caught oysters' species), for which Denmark is the main producer, and Pacific cupped oyster (the main famred oysters' species), for which France is the main producer.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Source
France (European flat oyster)	2,54	3,26	3,59	2,89	3,22	3,43	3,76	3,17	2,00	1,54	EUMOFA
France (Pacific cupped oyster)	2,16	3,30	4,14	4,23	n.a.	n.a.	n.a.	3,26	2,42	2,23	EUMOFA
Denmark (European flat oyster)	2,60	3,62	5,69	7,37	7,57	6,75	6,47	6,77	5,95	5,51	EUMOFA

Wholesale (live/fresh)

Wholesale prices are presented for Spain (wholesale market of Barcelona).

Average price	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Source
Spain	8,72	9,94	10,92	11,03	11,55	12,37	12,43	11,79	11,83	12,8	Mercabarna

Figure 15. Flat oyster price evolution

2.2.1.3 European market for Mussels

The target species the Pilot 7 SM focuses on is the black mussel (*Mytilus galloprovincialis* Lamarck, 1819). The European market for mussels is estimated to be slightly below 600,000 tonnes in equivalent live animal weight. The popularity of mussels differs from country to country, where per capita consumption varies from less than 200 g to nearly 4 kg per year (FAO statistics). The overall production of mussels in Europe peaked at nearly 750,000 tonnes in the late 1990s and has since declined to about 550,000 tonnes in the past few years. On a global scale, Europe is a major contributor to mussels, supplying over a third of the total production. Aquaculture is by far the main source of mussels and is responsible for over 90% of total landings. Three countries are responsible for two-thirds of all European mussel production. Spain is very clearly the largest producer, with over 200,000 tonnes per year, followed by France, with stable production of around 80,000 tonnes. Italy is the third main producing country, with 65,000 tonnes. Most of the supplies from all three countries come from aquaculture. At the production level, a number of external risks may alter the overall output on sales, in particular unreliable seed resources and poor water quality, pollution, biotoxins, and finding spaces for future sites. At the market level, challenges exist relating to the low price of imports, which could pose a threat to local production, expensive transport and logistics and consumer reluctance to eat molluscs (http://www.fao.org/in-action/globefish/fishery-information/resource-detail/en/c/338588/).

2.2.1.4 Niche market operation planning & security

Grow-out is almost entirely sea-based. Growth is rapid between 15–25 °C and at salinities between 25 and 32 g/kg. It is dependent on the rate of replenishment of the natural phytoplankton food supply. A variety of bottom, off-bottom and suspended culture methods are used, depending on the environment (e.g. tidal range, shelter, water depth on leases, water exchange rates in bays and estuarine inlets, the nature of substrates, etc.) and tradition. In the off-bottom culture, seeds are contained in mesh bags or perforated plastic trays of various types attached by rope or rubber bands to wood frames or rebar steel trestles on suitable ground in the low intertidal zone. Such systems are sometimes located sub-tidally but this adds to handling costs. In 2017 and 2018, total operating costs

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

increased significantly compared to 2016 (JRC, 2021). FORCOAST Service Module A1 aims to optimise the handling costs while improving the planning and the security of the operations at sea.

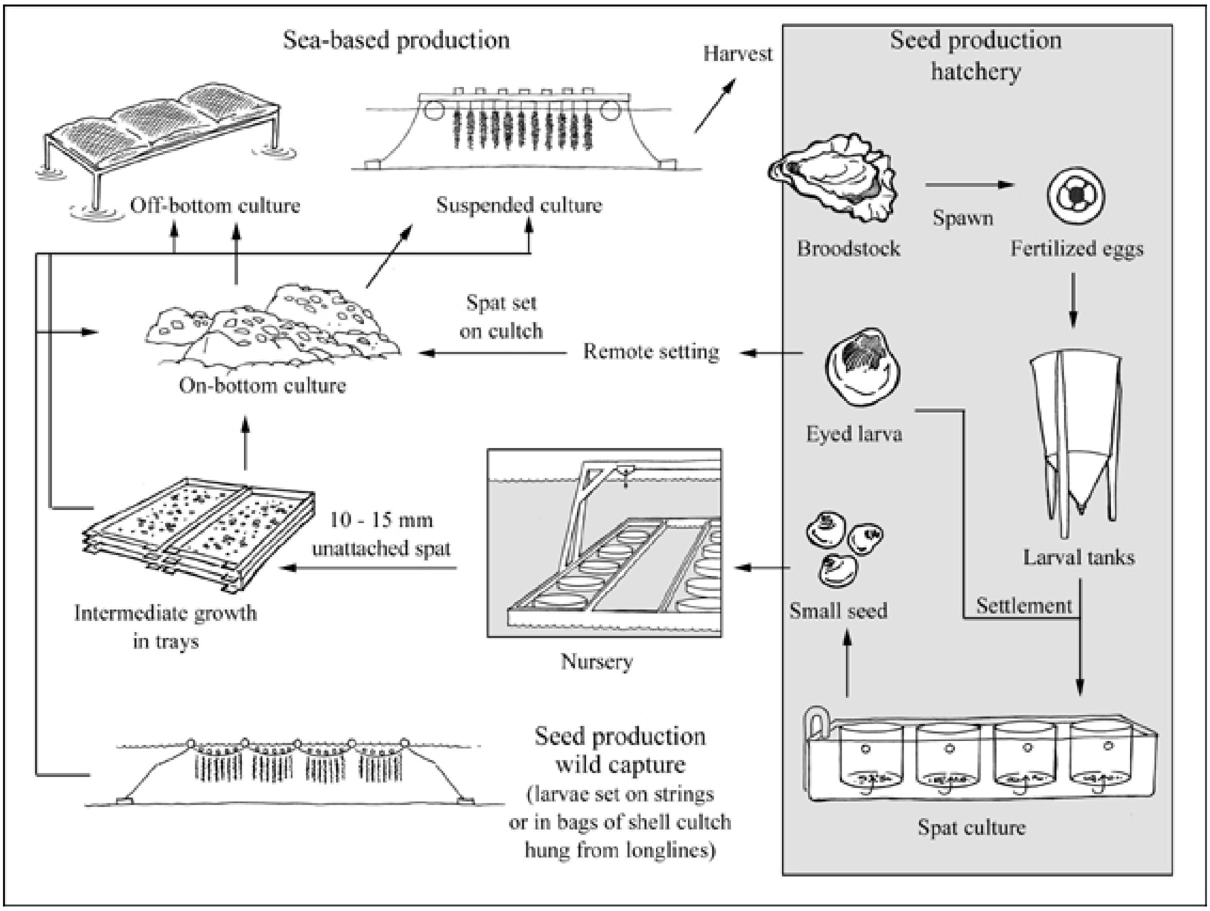


Figure 16. Oyster production cycle (FAO)

2.2.1.5 Niche market pollutant warning

This Service Module A2 can be of great importance to any shellfish farmer, especially for those with shellfish production areas that are nearshore or in the estuary, with a high risk of land discharge exposure. It is estimated that the number of potential end users may exceed 1,000, *e.g.* in 2015, there were in France alone more than 3,000 shellfish farmers producing oysters (EUFOMA, 2017).

The European market for flat oysters has dwindled to a fraction of its original volume due to failing supplies and with a consequent persistent rise in unit prices (see also Service Module A4 – Assistance for spat capture). The current market deficit is estimated at 3000 t annually.

Blue mussels may provide an alternative to agricultural proteins with a much lower carbon footprint. Additionally, Blue Mussels may remove vast amounts of nutrients from the water column. The industry is picking up momentum and the Danish industry muster an annual production above 10000 t.

European market of bivalves

Oyster farming is the second next important bivalve aquaculture activity in Europe. In 2018, the EU farmed 109.039 tonnes of oysters with a total value of EUR 457 million. Pacific cupped oyster (*Crassostrea gigas*) is by far the main oyster species farmed in the EU. Since the 1950s, there has been a steady decline in flat oyster production in Europe from 30 000 tons in 1961 to just under 2000 tons in 2016 (Figure 17). This decrease is due to the import of diseases, including *Bonamia*, which has

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

caused a strong decimation of natural resources. Therefore, to keep the production of oysters going in Europe, the Pacific oyster (*Magellana gigas*, formerly *Crassostrea gigas*) was introduced, which was resistant to the *Bonamia* parasite. However, due to climate change (warming of the North Sea), the species has started to massively reproduce and competed with the native European flat oyster.

Oysters

Since 2008, the European oyster culture suffered great losses due to the infection with the herpes virus OsHV1 (Pacific Oyster Mortality Syndrome - POMS), which causes high mortality in young Pacific oysters. As of 2012, a new infection emerged, *i.e. Vibrio aestuarianus*, which mainly affects adult Pacific oysters. These infections weakened the economic profitability of many European oyster farms until 2015. Although production has not yet fully recovered, high sales prices saved the industry from collapsing. Today oyster farming in the Netherlands continues to struggle due to the occurrence of the herpes virus and a new parasite of the oysters, namely the Japanese oyster borer, a small predatory snail that drills holes in the young oysters and eats the meat (http://www.zeevruchtengids.org/nl/oester).

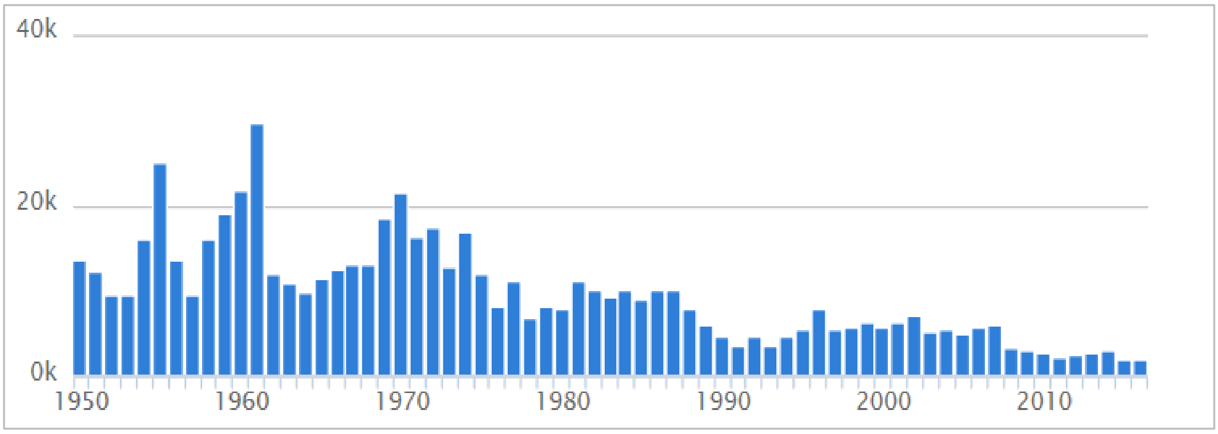


Figure 17. Evolution in production of the European flat oyster (Ostrea edulis) (www.fao.org/ fishery/culturedspecies/Ostrea_edulis/en)

The top five countries for flat oyster production are France (40.5% - 1,612 tons), Ireland (15.7% - 627 tons), Croatia (14.2% - 566 tons), Spain (11.8% - 468 tons) and the Netherlands (8.8% - 350) (https://www.tridge.com/intelligences/oyster/production).

There is only one oyster farmer present in Belgium, which is located in Ostend and uses the water from the Spuikom for the cultivation of both hollow and flat oysters.

In 2016, 1940 tons of oysters were imported into Belgium, of which 60% came from Dutch and 40% from French oyster farms. 70% was imported live, including 162 tons of flat oysters and 1200 tons of Pacific oysters, a ratio of 1:7.4, but with a difference in price in favour of the flat oyster of 3-5x. The remainder was imported frozen, smoked and otherwise processed oysters. About half of the production of Dutch oyster farming (in the Oosterschelde and Grevelingenmeer in Zeeland) is destined for the Belgian market.

Furthermore, wild oyster populations became very rare due to overfishing of the natural oyster beds including the Hinderbanks of Belgium (Gercken and Schmidt, 2014; Houziaux et al., 2008), the introduction of beam trawling destroying the natural oyster beds, severe winter periods (i.e. 1962/1963). Nowadays, patches of wild European flat oysters are only found in estuaries around the North Sea, especially at locations that are protected from beam trawling, e.g., Limfjorden in Denmark,

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

Lake Grevelingen and the Oosterschelde in the Netherlands, several inlets on the coast of the British Isles, Ireland and Norway. Some European flat oysters have been found recently in the BPNS (Kerckhof, 2018; Personnel observations in Westdiep).

There is therefore a strong need to restore native oyster populations, in order to increase the biodiversity and their function in coastal defence. These so-called eco-services are difficult to assess in value, but when looking into coastal defence, measures for coastal protection are increasingly required as coastal zones are under the duress of climate change (sea level rise, intensification of storms, increasing beach erosion, etc.) and under enhanced anthropogenic pressure (demographic evolution, loss of habitats, economic expansion, etc.). The combination threatens the ecosystem and significantly reduces the resilience of the coast. Current engineering approaches – both hard and soft measures – come short in efficiently and cost-effectively protecting the coast. In Belgium alone, the annual costs for coastal defence amount to several millions of euros and that is for only 67 km of coastline. A study by Van der Biest et al. (2017) quantifies and estimates the value of ecosystem services of bivalve reefs in the Belgian Part of the North Sea (BPNS). The identified ecosystem services were identified as shrimp production, carbon retention, water quality regulation, coastal protection and recreational diving. The yearly added benefits (sum of five ecosystem services) of one hectare of a bivalve reef in comparison with one hectare of unstructured, sandy foreshore (typical for the Belgian coast) are estimated at 85.9 x 10^3 €, indicating an important potential added value in terms of ecosystem services.

2.2.1.5 Niche market spat collection

The Service Module gives an insight into the best period to employ the spat collectors and the distributions of the spat pinpointing the areas with the highest densities. This means that the Service Module can be used by bivalve farmers (for the moment only for blue mussels and European flat oysters, but it is believed that this Service Module can be easily adapted for the Mediterranean mussel, *Mytilus galloprovincialis* and the Pacific oyster) that are depending on spat collected from the wild with spat collectors, and end users that are involved in oyster reef restoration and rely on natural recruitment. Table 4 lists a few of the potential end users, but not all. It is expected that the number of potential end users exceeds 150 within Europe.

2.2.2 Future Developments

The bivalve mariculture aquaculture sector will need to support increases in European demand for seafood products, as the wild fishery sector is not expected to make any dramatic shifts in the coming period, but rather to remain at fairly consistent levels. Bivalve mariculture is considered extractive and therefore sustainable up to certain levels/intensity. Moreover, it is characterized by a low carbon footprint. Aquaculture is highly specialised at regional and country levels and is strongly influenced by geography and the natural habitat of species. As such, in EU Black Sea waters (Romania and Bulgaria), mussel aquaculture is practised using equipment fitted to the environmental specificities of the area. Local demand is expected to increase in the future, as consumers are open to including mussels (and other types of seafood) into their diet (http://www.marine-research-journal.org/index.php/cmrm/article/view/210/175).

On the other hand, the growth of European bivalve aquaculture has been hindered by the occurrence of viruses and parasites, reducing the commercial output, mainly in Europe (see above). It is possible that in the future, more viruses and parasites occur, making the growth of bivalve aquaculture, such as oyster production difficult. The aquaculture sector is currently growing in the Sado estuary and

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

surroundings. In the last five years, new areas were delimited and approved by the competent authorities for Oyster and fish aquaculture.

Demographic	Economic	Sociocultural
Portugal's population is continuously growing as well as the Setubal region's population	The Portuguese economy has been steady, expanding continuously since the third quarter of 2014. However, external factors can affect the current situation	Efforts are made for more local consumption of marine products other than traditional (salted cod and sardine). The organisation of events for promotion are common nowadays.
Technological	**Ecological**	**Political and Legal**
Currently, there are no technological barriers	The production areas are located in direct contact with the estuary and thus subject to alterations in the ecosystem due to pollution or climate change actions	The political and legal support can be improved to reduce the uncertainty of aquaculture producers.

Table 3. Aquaculture sector aspects

2.2.3 Customer Identification

2.2.3.1 Characteristics

The sector of bivalve mariculture is represented in Pilots 1, 4, 6, 7, 8 and 5. In these pilots, 11 intermediate users are active, being a combination of research/technological centres working in applied research and SMEs experts in the development of products and services for the aquaculture and mariculture sectors. Three final users are also part of the consortium: two oyster farmers and one specialist on nearshore aquaculture of blue mussels. Then, among the external users, an extensive list of aquaculture, mariculture of oysters and mussels SMEs and NGOs have been identified (Table 4).

Potential customers 'Assistance for Spat Capture' service

	End user	**Activity**
Belgium		
	Brevisco	Mussel farmer
	Codevco V	Bivalve farmer
	DEME Dredging International	Mussel bed enhancement for coastal protection
	FOD Environment	Government involved in MRP & concessions for maritime activities
	Geo XYZ	Maintenance of mussel farming & oyster reef restoration projects
	ILVO	Knowledge institute involved in project on bivalve farming & bivalve reef restoration
	Jan De Nul	Partner in Belgian Pilot of project United: culture and oyster reef restoration on scour material in offshore windfarms
	OD Nature	Knowledge institute

	Parkwind	Partner in Belgian Pilot of project United: culture and oyster reef restoration on scour material in offshore windfarms
	University of Ghent	Knowledge institute
	Aquacultuur Oostende – De Oesterput	Oyster farmer
Bulgary		
	Smart Farm AS, Bulgary	Mussel farming
Croatia		
	University of Dubrovnik (Mali Stone Bay)	Main research body working in Mali Stone Bay which is the largest native oyster aquaculture production area in the Mediterranean
	Plasma Saal	Holistic medicine & Partner in Native Oyster Reef Restoration Ireland (NORRI)
Denmark		
	Musholm farm	Longline mussel farm
France		
	CRC Bretagne Nord	Partner in FOREVER – Flat Oyster REcoVERy
	CRC Bretagne Nord	Partner in FOREVER – Flat Oyster REcoVERy
	ESITIC Caen	Knowledge institute & Partner in Marineff project & Partner in FOREVER – Flat Oyster REcoVERy
	IFREMER	Knowledge institute & Partner in
	Ports de Normandie	Maritime Industry & Partner in Marineff project
	TPC	Civil engineering & Partner in Marineff project
	University of Caen - Normandy	Knowledge institute & Partner in Marineff project
	VINCI Construction Maritime and Fluvial	Civil engineering & Partner in Marineff project
Germany		
	AWI	Knowledge institute & Partner in Proceed - Seed Oyster Production for Ecological Restoration & RESTORE I
	Federal Agency for Nature Conservation	Government & Partner in Proceed - Seed Oyster Production for Ecological Restoration
	Kieler Meeresfarm	Longline mussel farm
Ireland		
	Achill Oyster Group	Oyster Fishery Management
	Clarinbridge Oyster Co-op Society Ltd	Oyster Fishery Management
	Comharchumann Sliogeisc Chonamara Teo	
	Galway Bay Oyster Restoration	Restoration of native oyster habitats

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

	Project (Cuan Beo)	
	Lough Swilly Wild Oyster Society Ltd	Oyster Fishery Management
	Loughs Agency	Oyster Reef Restoration in Lough Foyle
	Marine Health Foods Ltd	Producer of marine products & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Native Oyster Reef Restoration Ireland	Training and educating local community about biomimetic restoration
	NexLoop	Partner in Native Oyster Reef Restoration Ireland (NORRI)
	North Mayo Oyster Development Co-op Society Ltd	Oyster Fishery Management
	Tralee Oyster Co-op Society Ltd	Oyster Fishery Management
Spain		
	Spanish Institute of Oceanography	Knowledge institute & Partner in the Mar Menor Oyster Project
	Smart Farm AS, Spain	Mussel farming
Sweden		
	East Sweden Aquaculture Centre (ERAC)	Longline mussel farm
	Bohus Havsbruk	Longline mussel farm
The Netherlands		
	Barbé Yerseke	Suspended mussel farmer & partner of 100% Zeeuws
	Firma NL. en L. de Keijser	Suspended mussel farmer & partner of 100% Zeeuws
	Hoogerheide Delimossel	Suspended mussel farmer & partner of 100% Zeeuws
	Marinecultuur Oosterschelde BV	Suspended mussel farmer & partner of 100% Zeeuws
	Mosselhangcultuur Landa	Suspended mussel farmer & partner of 100% Zeeuws
	Neeltje Jans Mosselen	Suspended mussel farmer & partner of 100% Zeeuws
	Shell	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Van Oord	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Eneco	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Diamond Generating Europe	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Partners Group	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Ark Natuurontwikkeling	Partner in Borkum stones, Voordelta & Wadden Sea

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

	WWF Netherlands	Partner in Borkum stones, Voordelta & Wadden Sea
	Wageningen Marine Research	Partner in Borkum stones, Voordelta & Wadden Sea
	Bureau Waardenburg	Partner in Borkum stones, Voordelta & Wadden Sea
	Sas Consultancy	Partner in Borkum stones, Voordelta & Wadden Sea
Outside the European Union		
Canada		
	ATLANTIC AQUA FARMS LTD	Blue mussel farmer
	BADGER BAY MUSSEL FARMS LTD.	Blue mussel farmer
	FANNY BAY OYSTERS	Pacific oyster farmer
	MAISON BEAUSOLEIL	Oyster farmer
	MAC'S OYSTERS LTD.	Pacific oyster farmer
	K'AWAT'SI SHELLFISH COMPANY	Pacific oyster farmer
United Kingdom		
	Ardfern Yacht Centre	Recreational sailing & Partner in Seawilding Restore the Native Oysters in Loch Craignish
	Blue Marine Foundation	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI) & Solent Oyster Restoration Project & Wild Oyster Project
	Bournemouth University	Knowledge institute & Partner in Marineff project
	British Marine	British Marine is the trade association for the UK leisure, superyacht and small commercial marine industry & Partner in Wild Oyster Project
	CEFAS	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Colchester Oyster Fisheries	Oyster Fishery Management & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	CROMACH	Local volunteer association & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Environmental Agency	Government & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Glenmorangie Compagny	Partner in the Dornoch Environmental Enhancement Project (DEEP)
	Heart of Argyll Wildlife Organisation	Nature Protection & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Heriot Watt University	Knowledge institute & Partner in The Dornoch Environmental Enhancement Project (DEEP)
	IFCA	Government & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Institute of Aquaculture	Knowledge institute & Partner in Seawilding -

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

		Restore the Native Oysters in Loch Craignish
	Marine Conservation Society	Partner in the Dornoch Environmental Enhancement Project (DEEP)
	Native Oyster Network –UK & Ireland	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Natural England	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Nature Conservacy	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	River Roach Oyster Company	Oyster farmer & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Scottish Association of Marine Sciences	Knowledge institute & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Stirling University	Knowledge institute & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Tollesbury & Mersea Native Oyster Compagny LTD	Oyster Fisheries & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Ediburg	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Essex	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Exeter	Knowledge institute & Partner in Marineff project
	University of Southampton	Knowledge institute & Partner in Marineff project
	Wildlife trust	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Zoological Society of London (ZLS)	Partner in Essex Native Oyster Restoration Initiative (ENORI) & Wild Oyster Project
Norway		
	Smart Farm AS, Norway	Mussel farming
United States of America		
	Refanala - High Vibrational Living Solutions	Health & Beauty & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Biomimicry New England	Biomimicry & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Chesapeake Bay Foundation	Restoring the native oyster, Crassostrea virginica in Chesapeake Bay, Maryland, Virginia
	Duke University	Oyster reef restoration in Australia
	Georgia Department Of Natural Resources	Oyster Reef Restoration projects in Plantation Creek, Florida Passage, Oatland Island, Skidaway River, Altamaha River, Jekyll Island Boat Ramp, Oyster Creek, Jointer Creek, Turtle and South Brunswick, Bellville Boat Ramp & Overlook Park

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

	Institute for Applied Ecology (IAE)	Oyster Reef Restoration Projects in the Gulf of Mexico
	NOAA Restoration Center	has funded more than 70 oyster restoration projects in 15 states
	Norwegian University of Science and Technology – NTNU-Trondheim	Mussel farming technologies
	The Nature Conservancy (TNC)	Pensacola East Bay Oyster Habitat Restoration Project & South Carolina Oyster Reef Restoration
Australia		
	Flinders University, SA	
	The Centre for Tropical Water and Aquatic Ecosystem Research - TropWATER	

Table 4. List with potential customers of Service Module A4 – Assistance for spat collection and distribution per country.

Potential customers per Pilot

P	Location	INTERNAL USERS		EXTERNAL USERS
		Intermediate	Final	
1	Atlantic	IST (Research)	ExporSado (SME, Oyster farmer)	APA (Portuguese Association of Aquaculture, https://www.facebook.com/Associação-Portuguesa-de-Aquacultores-673407849366733/)
4	Southern North Sea	ILVO, RBINS (Research)	Brevisco (SME, Nearshore aquaculture and fishing)	Colruyt group (https://www.colruytgroup.com) UGENT (https://www.ugent.be/en) Jan de Nul Group - Offshore Renewables (www.jandenul.com) DEME (www.deme-group.com) + Dutch, UK and North of France equivalent At sea nova
6	Limfjorden	DMI, AU (Research)	Oyster boat (SME, Oyster production)	Jeka Group, Havnen (https://jeka-group.com/contact/) Vilsund Blue (Blue mussel fishing) https://vilsund.com/en/
7	Black Sea	ULiege, NIMRD (Research) Jailoo (SME)	-	SC MARICULTURA SRL
8	Adriatic Sea	CNR, OGS (Research)	-	AMA - Associazione Mediterranea Acquacoltori (www.a-m-a.it)
5	Galway Bay	Marine Institute (Research)	Cuan Beo (SME, Restoration)	Irish Native Oyster Fisheries Forum (INOFF) (No Website - organization coordinated by Bord Iascaigh na Mhara) Irish Packer's Group (No Website - organization coordinated by Bord Iascaigh na Mhara) Irish Farmers Association Aquaculture https://www.ifa.ie/sectors/aquaculture/ Marine Spatial Planning Unit (Dept of Housing)

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

				https://www.housing.gov.ie/planning/maritime-spatial-planning/maritime-spatial-planning-directive/maritime-spatial-planning Bord Iascaigh na Mhara http://www.bim.ie/about-us/contact-us/galway/ Sea Fisheries Protection Authority https://www.sfpa.ie/ Inland Fisheries Ireland https://www.fisheriesireland.ie/ National University of Ireland Galway http://www.nuigalway.ie/ Galway Mayo Institute of Technology https://www.gmit.ie/

Table 5: Detail on users inside the consortium (intermediate or final) and sectorial final users for the Bivalve mariculture sector

This service focuses on bivalve aquaculture producers to validate the concept. It also focuses on areas where the tide is a relevant limiting factor. However, it can be exported to other aquaculture producer areas and add other variables as desired, i.e. in open areas replacing tide levels with waves. Recent data, from 2019, listed 3619[14] and 1265[15] active fisheries and aquaculture enterprises respectively in Portugal.

Potential customers 'Land Pollution' service

The main customer segment identified for the Land Pollution service module (A2) is represented by the owners/managers of aquaculture farms(s) or consortium/syndicates of such actors organized at regional levels. Additionally, the institutions regulating or promoting marine aquaculture products and activities might use the service (for instance, the National Agencies for Fisheries and Aquaculture, the National Sanitary-Veterinary and Food Safety Authorities, and the Waters National Administrations). To some extent, research institutes can use some data, for specific case studies or actions.

List of local Consortia and Producers' Organisations operating in the North Adriatic Sea (Friuli-Venezia-Giulia, Veneto, and Emilia-Romagna Italian regions) with potential interest in the service:

Region	Name of Company/consortia	Website/Address
Friuli-Venezia-Giulia	CO.L.M.I. S.C.a r.l.	Villaggio del Pescatore, 34011 - Duino-Aurisina (TS)
Friuli-Venezia-Giulia	Ittiomar Soc Coop a r.l.	Via Machiavelli, 28 - 34132- TRIESTE

14 https://www.pordata.pt/Portugal/Empresas+da+Pesca+e+Aquicultura+total+e+por+escal%c3%a3o+de+pessoal+ao+servi%c3%a7o-3444

15 https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=506923022&PUBLICACOESmodo=2

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

Friuli-Venezia-Giulia	Emiliano Crosara	Via Battisti, 20/a – 34015 - Muggia (TS)
Friuli-Venezia-Giulia	MI.MAR. Soc Coop a r.l.	Via Argonauti,18 - 34074- Monfalcone (GO)
Friuli-Venezia-Giulia	Roberto Pesel e C. S.n.c.	Via Brigata Casale, 120 - 34149- TRIESTE
Friuli-Venezia-Giulia	Ittica DAG S.a.s.	Via San Poletto, 31 - 34074- Monfalcone (GO)
Friuli-Venezia-Giulia	FRAMAR S.n.c.	Villaggio del Pescatore, 134 – 34011 - Duino-Aurisina (TS)
Friuli-Venezia-Giulia	PELOSA S.n.c.	Via Commerciale, 47/3 - 34134- TRIESTE
Friuli-Venezia-Giulia	ALMAR - Soc Coop agricola a r.l.	Via Gerolamo Raddi, 2 - 33050 - Marano Lagunare (UD)
Friuli-Venezia-Giulia	Shoreline S.Coop. a r.l.	Padriciano,99 - 34012- TRIESTE
Friuli-Venezia-Giulia	Laudamar	https://www.facebook.com/Nuova-Laudamar-Pescaturismo-Mitilicoltura-577949099285948/?ti=as
Veneto	Societa' Agricola Adriamar Sas	22 Lungo Mare S. Felice, Cavallino-treporti, VE 30013
Veneto	Clodia Scrl	Via S. Felice, 7, 30015 Chioggia VE
Veneto	Mitil Pesca Srl	http://www.mitilpesca.com/
Veneto	Pescatori Sile Scrl	https://pescatorisile.altervista.org/
Veneto	Genesi Srcl	via Busetti 110 - Venezia
Veneto	Moceniga Pesca Az. Agricola	https://www.moceniga.it/
Veneto	Villaggio Pescatori Scrl	Via Curtatone, 30 – Pila (VE)
Veneto	Cooperativa Pescatori “Po”	Via Roma, 207 – Scardovari (VE)
Veneto	Cooperativa Pescatori “PILA” – O.P. Soc.Coop. a r.l.	http://www.mercatopila.it/
Veneto	Mitilicoltori Sacca degli Scardovari Scrl	https://www.scardovari.org/
Veneto	Cooperativa Pescatori ”ADRIATICO”	https://www.facebook.com/cooperativa.adriatico/
Veneto	Cooperativa Pescatori Delta Padano	https://www.facebook.com/deltapadanopresidente/
Veneto	Societa' Cooperativa Pescatori S. Giulia	https://www.informazione-aziende.it/Azienda_SOCIETA-COOPERATIVA-PESCATORI-SGIULIA
Veneto	Cooperativa Pescatori “ALBA”	Via Pineta, 13 – Rosolina (RO)
Veneto	El Piocio Societa' Cooperativa	https://www.informazione-aziende.it/Azienda_EL-PIOCIO-SOCIETA-COOPERATIVA
Emilia-Romagna	Adriamar Di Pari Giancarlo	https://www.informazione-aziende.it/Azienda_ADRIAMAR-DI-PARI-GIANCARLO

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

Emilia-Romagna	Azzurra - Societa' Cooperativa A Responsabilita' Limitata	https://www.informazione-aziende.it/Azienda_AZZURRA-SOCIETA-COOPERATIVA-A-RESPONSABILITA-LIMITATA-2F4DD
Emilia-Romagna	Pro.mo.ittica Societa' Cooperativa A Responsabilita' Limitata	https://www.informazione-aziende.it/Azienda_PROMOITTICA-SOCIETA-COOPERATIVA-A-RESPONSABILITA-LIMITATA
Emilia-Romagna	Copralmo Societa' Cooperativa A Responsabilita' Limitata	Viale CABOTO 11, 47042 - Cesenatico,
Emilia-Romagna	Societa' Cooperativa Marinara	VIA TORRE, 71, 47814, Bellaria-igea Marina, Rimini
Emilia-Romagna	Imarr - Societa' Cooperativa Agricola	https://www.informazione-aziende.it/Azienda_IMARR-SOCIETA-COOPERATIVA-AGRICOLA
Emilia-Romagna	La Fenice Societa' Cooperativa A Responsabilita' Limitata	https://www.informazione-aziende.it/Azienda_LA-FENICE-SOCIETA-COOPERATIVA-A-RESPONSABILITA-LIMITATA-94EEF
Emilia-Romagna	Tecnopesca - Societa' Cooperativa	https://www.informazione-aziende.it/Azienda_TECNOPESCA-SOCIETA-COOPERATIVA
Emilia-Romagna	Cooperativa Gente Di Mare SOC. COOP. A R.L.	https://www.coopgentedimare.it/
Emilia-Romagna	Sviluppo Marittimo - Societa' Cooperativa	https://www.informazione-aziende.it/Azienda_SVILUPPO-MARITTIMO-SOCIETA-COOPERATIVA
Emilia-Romagna	Consorzio Pescatori Di Goro Società-Cooperativa organizzazione Di Produttori	https://www.copego.it/
Emilia-Romagna	Mitilcoop Societa' Cooperativa Agricola	https://www.informazione-aziende.it/Azienda_MITILCOOP-SOCIETA-COOPERATIVA-AGRICOLA
Emilia-Romagna	Allevamenti In Acque Marine Societa' Cooperativa	https://www.informazione-aziende.it/Azienda_ALLEVAMENTI-IN-ACQUE-MARINE-SOCIETA-COOPERATIVA
Emilia-Romagna	Sol Levante - Societa' Cooperativa	https://www.informazione-aziende.it/Azienda_SOL-LEVANTE-SOCIETA-COOPERATIVA-F6778
Emilia-Romagna	Cooperativa Armatori E Operatori Della Pesca	Via Magrini n. 29/B, 47042 Cesenatico (FC)
Emilia-Romagna	REAMAR. SOC. COOP. A R.L.	http://www.reamar.it/
Emilia-Romagna	Societa' Cooperativa Futuro Del Mare	https://www.informazione-aziende.it/Azienda_SOCIETA-COOPERATIVA-FUTURO-DEL-MARE

Table 6. Local Consortia and Producers' Organisations operating in the North Adriatic Sea

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

Potential customers 'Marine Conditions' service

The Service Module is primarily relevant to the shellfish primary producers and the processing industry. Secondarily authorities, consultants, academia, nature conservation organisations and philanthropic investors may be interested. Authorities regulate the shellfish business and may impose environmental restrictions depending on environmental impact or public health issues.

List of potential users in the Sado Estuary region:

#	Company	Type of production
1	Exporsado	Oyster production
2	Aquanostra	Oyster production
3	Best Fish	Oyster production
4	Ostra Ribeiro	Oyster production
5	Ea Aquicultura Dú Sado	Oyster production
6	Probival	Oyster production
7	3s - Marine Portugal	Oyster production
8	Neptunpearl	Oyster production
9	Bivalsete	Oyster production
10	Herdeiros De Adelino	Oyster production
11	Shellset	Oyster production
12	Quadrado Selvagem	Oyster production
13	Salina Greens	Oyster production
14	Peschicultura Boa Água	Oyster production
15	Valentim Cavaco Rodrigues	Oyster production
16	Piscicultura Moinho	Oyster production
17	Ostras 3.0	Oyster production
18	Sapalsado	Oyster production
19	Cardinal Habitual	Oyster production
20	Bivalsado	Oyster production
21	Oysterworld	Oyster production
22	Marvellous Wave	Oyster production
23	Global Pinhal	Oyster production
24	Lopolândia	Oyster production
25	Modesto e Cordeiro	Seabass and seabream
26	Aquacultura do Texugo	Seabass and seabream
27	Piscintacta	Seabass and seabream

Table 7. Sado estuary aquaculture producers

Potential customers 'Site Prospection' service

List of potential users in the Danish area, covering the Baltic Sea and Limfjord region:

#	Company	Net profit (×1000) DKK	#	Company	Net profit (×1000) DKK
1	Rederiet Ruth A/S	185 098	27	Royal Danish Fish A/S	225

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

#	Company	Net profit (×1000) DKK	#	Company	Net profit (×1000) DKK
2	Gitte Henning A/S	94 633	28	Shellfish Limfjord ApS	87
3	Astrid Fiskeri A/S	77 986	29	Britta Brock E443 A/S	85
4	Asbjørn A/S	31 530	30	Sten Kjær ApS	52
5	Cattleya A/S	19 375	31	Vestjydske Dambrug ApS	18
6	Jette Kristine E 727 ApS	17 930	32	BRØDRENE OLSEN. RØDVIG FISKERI ApS	9
7	Frea A/S	13 034	33	SEA ApS	- 20
8	Aquapri A/S	12 220	34	Funderholme Dambrug A/S	- 77
9	Kjærsgaard Hirtshals A/S	8 121	35	HM 120 Astoria ApS	- 89
10	Aquapri Denmark A/S	7 232	36	John Hansen. Glyngøre ApS	- 112
11	HJ FISKERI HARBOØRE ApS	6 420	37	Karen Nielsen ApS	- 115
12	Fiskeriselskabet Pondus ApS	5 476	38	Sejbæk Dambrug ApS	- 148
13	Seafood Limfjord ApS	4 836	39	Fonden Danmarks Center For Vildlaks	- 327
14	Partsrederiet Albatros ApS	2 548	40	BORNØ ApS	- 616
15	Lingbank Fiskeri ApS	2 493	41	Credo Fish ApS	- 698
16	Fiskeriselskabet Borkumrif ApS	2 090	42	Løvlund Dambrug ApS	- 1 076
17	FISKERISELSKABET HOUNISEN ApS	1 692	43	Fn 234 Canopus Aps	- 1 156
18	Brejnholm Dambrug ApS	1 554	44	HG 352 Polaris ApS	- 2 149
19	Ny Kingfisher A/S	1 353	45	Volstrup ApS	- 2 773
20	T 138 Poseidon A/S	1 290	46	Danaqua ApS	- 3 026
21	Kærhede Dambrug ApS	878	47	Danish Salmon A/S	- 3 269
22	Smidt Nissen Jøker & Co., A/S	436	48	Maximus A/S	- 6 055
23	Hanstholm Samlecentral A/S	391	49	Amy ApS	- 6 276
24	Løjstrup Dambrug A/S	312	50	Hjarnø Havbrug A/S	- 11 187

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

#	Company	Net profit (×1000) DKK	#	Company	Net profit (×1000) DKK
25	SSO ApS	271	51	Atlantic Sapphire Denmark A/S	- 46 398
26	Pedersen Aqua ApS	229			

Table 8. Danish Fisheries and Aquaculture companies and their net profit

In general, two customer segments could be identified. On the one side, there are the oyster reef restoration operators and on the other side, the bivalve farmers rely on natural spat settlement. According to the live cycle of the target species, however, the latter can be split further into two groups: *i.e.,* the mussel farmer (the blue mussel has two reproduction/settlement peaks in a year) and the flat oyster farmer (the European flat oyster has one short window of reproduction/settlement once a year).

Relations between the three Customer Segments can be linked to each other. But in some cases, the relation between the three Customers Segments is none existing, as some suspended mussel farmers rely on the fishing of young mussels from natural settling grounds (*e.g.,* some suspended mussel farmers in the Easter Scheldt sock mussel spat from the Wadden Sea), while oyster reef restoration operators rely on juveniles and adult flat oysters from farmers.

A further potential sector exists out of scientific and research institutes. Offshore bivalve culture is still under development, which means that in these projects the main end users are situated in the academic world. Once offshore bivalve culture is proven to be successful, industrial entrepreneurs will be involved in offshore activities. As conditions in the open sea are of a different dimension, in comparison with in- and nearshore aquaculture (smaller boats, no dpi obligation, small crew, etc.), other end users will be involved.

2.2.3.2 Specific Needs

The bivalve mariculture sector is represented by a significant number of intermediate and final users within several pilots inside FORCOAST. In this case, finding commonalities between the requirements gathered for the different users and regions was challenging and special efforts will be needed to ensure convergence towards services/products useful for different areas and activities.

The main common drivers for the development tailored of services and products are summarized in the following.

i- Operation planning at short temporal scales for the operational design of the work plan for the following day, or the next days. To have an accurate forecast of currents/wave height/meteorological conditions (wind)/tides (surface elevation)/temperature), for one to five following days (and for the recent past days) is key for deciding whether to go out to the field or not, due to the met-ocean conditions, planning or adapting short-term or daily operations in the farm or site, deciding on harvesting and localizing lost gears. The main cost of inaction or wrong action related to lack of the needed information is in general coupled with increased farming costs. These can be directly related to costs associated with workers' workday, when conditions are not appropriate for on-site work (for instance work hours lost due to low/high tide under/overestimations due to the lack of reliable information), potential losses related to field safety, the potential cost to losses in the production due to abnormal conditions (e.g., abnormal temperature). In the case of the lost gears, the cost should be computed as a trade-off between gear loss and searching cost, so an accurate forecast of gear location is key to deciding on gear recovery.

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

Today, a decision is based on available daily forecasts of marine and/or meteorological conditions (e.g., wind guru or national weather forecast services, DMI weather and SL forecasts) or empirical estimations based on available data. The available forecasts usually lack spatio-temporal resolution of precision (e.g., bias on SST or errors in locating a lost gear) and of key variables for the operation and harvesting (like a good prediction of currents, SST and river loads). The estimations obtained from available data for some cases are not able to reflect the conditions at the farm/site of exploitation (e.g., tide gauge in the Sado Estuary does not reflect what happens deep inside the estuary, which can lead to errors on high and low tides up to 30 min) or at much lower temporal resolution (e.g., in-situ temperature measurements only available several times a year). Thus, the main gaps to be filled by FORCOAST products and services are: more accurate and high-resolution met ocean conditions, namely on surface elevation, temperature, currents (drift of potentially lost gears), wind conditions, solar radiation (to determine the possible working hours) time series in a window of 1-5 days around the operation day.

ii-planning of special protection or mitigation measures in case of special events. A special case for operational planning and short time scales has been raised in several of the pilots; this is the building of an **operational warning or alert system** which could help **planning measures in case of special events** in order to minimize the risk of loss of production and ensure the growth rates and the quality and homogeneity of the harvest.

The list of key information and variables for bivalve aquaculture is extended and includes monitoring/forecasting storms, waves, sea surface TS conditions and chlorophyll concentration, dissolved oxygen (DO, mg O_2/L) and hypoxia, total suspended matter, water quality, eutrophication, contaminants including chemicals and oil spills, toxic algae or faecal bacterial contamination (wastewater discharges and spatial extension).

The selection of suitable thresholds for these variables is also key to the effectiveness of the warning systems. For instance, for preventing mussel death some of the thresholds can be set to detect:

- High temperature (>30 ºC)
- Very low salinity (below 6 PSU), which can occur because of a massive freshwater input
- DO concentrations below 2 mg O2/L, which cause the closing of valves and the subsequent impossibility of feeding and ultimately death of mussels.
- High probability of wastewater discharge reaching the mussel farm (potential bacterial contamination).
- High wave height

Today, the decisions are based on data from local monitoring and weather forecasts (sometimes not validated) and experience or the combination of all of these. Usually, the absence of a coherent alert system leads to a delay in obtaining usable information from data-holding institutions. While with a coherent alert system special protection or mitigation measures could be planned like: preventive fast harvesting, the submersion of long lines for protection (e.g. in case of high wave heights it could be needed to submerge the installations from 2 m depth to 4-7 m depths) or perform *E. coli*/other bacterial contaminants analyses. Even if the occurrence of these special events is low for most cases (from a few times in a decade or a year), the main benefits of an accurate alert system can be key to reducing (a) Production losses (for instance in conditions causing the death of mussels, to recover and market at least some of the harvest can be more cost-effective than to leave the entire harvest to die since the costs of harvesting live/dead mussels from the installations are the same) and (b) incomes loss and risks for human health and the sustainability of the exploitation in case of contaminated mussels.

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

iii- Operation planning at mid-term temporal scales. To have accurate mid-term to long-term forecasts or climatological information on Chlorophyll surface and vertical distribution, temperature and nutrients are key to ensure/monitor food availability and optimize mussels/oysters growth rates and health conditions, though actions required at monthly to seasonal timescales, for instance, decide long-term harvesting plans (to guarantee the proper size for commercialization) or adapt the depth of mussel bags. Again, these actions have direct consequences on the production costs and benefits, and presently decisions are taken mostly based on experience since for some cases there is no data or for others, the climatology or forecasts available are not accurate enough. Thus the main gap to be filled by FORCOAST in terms of services is to use and, where needed, to produce ocean and biogeochemical hindcast data to build climatologies of these variables, as a basis for the decision or to feed Dynamic Energy Budget (DEB) models in order to determine and improve if possible the production yield.

iv- Determine habitat suitability and planning of new locations or determine the distribution of suitable habitats for oysters. The availability of long-term hindcast or climatologies of the following variables: temperature, salinity, currents, Chl-a, turbidity, and nutrients is again key for decisions on whether the habitat is sufficiently healthy for oysters, finding suitable locations for cultivating oysters and in general optimal siting for aquafarming. Thus, again the production of the ocean and biogeochemical hindcast data to build reliable climatologies of these variables would be the main gap to be filled by FORCOAST.

v- Other specific requirements have been identified for some of the pilots:

- (Pilot 1) Determination of cause for oyster green colouration
- (Pilot 4) Additional requirements on available information is related with their co-production of seaweeds, like light availability or nutrients, and to the prediction the arrival of oyster spat (i.e., a decision tool to maximize the collection of spat and lowers production cost related to the purchasing of seeds). FORCOAST services can be likewise designed in a way that allows adaptations for different type of productions (mussels, oysters, seaweeds, fishes).
- (Pilot 8) hindcast/forecast of cloud cover and/or river runoff to prevent the risk of pollution due to wastewater treatment plant by-passes and bacterial dispersion related to heavy rains and river floods. This information can be derived from both satellite data (L3 products) and model forecasts.
- (Pilot 6) OysterBoat conducted a phone survey with the 5 top primary producers and whole sale dealers in Denmark, 9 key parameters are identified, which are listed below in descending priority:

1 – Water temperature over the water column

2 – Advance icing information

3 – Oxygen over the water column

4 – Hypoxia, release of H2S

5 – Algy, shellfish nutrition

6 – Venomous algae leading to shell closure and non-feeding

7 – E. coli

8 – Marteilia and Bonamia

9 – Spatfall of blue mussels and oysters

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

In addition, the wave forecast was also mentioned as an important service indicator in a FORCOAST user workshop in June 2022. Especially for Limfjorden, the shellfish primary producers need to know about icing, waves and hypoxia. Ice formation is governed by hydrography and meteorological condition while hypoxia additionally includes oxygen, phytoplankton and detritus deposits. The primary producers cannot abandon locations but may lower or hoist their cultures to avoid havoc or mortality.

2.3 Wild Fishery

2.3.1 Current Situation

2.3.1.1 European market big fish

According to The State of Mediterranean and Black Sea Fisheries, 2020, the fish resources in the Black Sea are under threat due to overfishing, climate change, and alien species. The total direct fishery revenue in the Black Sea countries is estimated to be USD 3.6 billion. The wider economic contribution of fisheries in the region, including both the direct revenue and indirect impacts, is estimated at USD 9.4 billion. The top 3 commercial species by value are European anchovy (USD 275,784,853); Whiting (USD 19,658,866) and Horse mackerel (USD 19,578,874). The report indicates the fishery is evolving in the right direction, but many challenges remain: catches are lower than in the 1980s, exploitation rates are mostly still too high, management plans need to be extended, discards and bycatch must be reduced, and an ageing fleet and workforce require renovation and new flow. In Bulgaria, the total domestic catch is about 8,600 metric tons (MT) since 2017.

According to Fish and Seafood Market Brief – Bulgaria, 2020, (Report Number: BU2020-0021), Bulgaria's Black Sea fishing industry is fragmented along its 300 km of coastline. In 2018, the Black Sea catch increased by 9.9%. It consisted of European sprat, red mullet, blue fish, Black Sea horse mackerel, and turbot. Conch accounts for the highest percentage of the Black Sea catch at about 41%. In 2018, the conch catch reached 3,515 MT, a 2.8% decrease over 2017. The soft-shell clam catch reached 600.5 MT, a 27% decrease. The blue mussel catches slightly increased by 11%, reaching 12.5 MT. Traditionally, the European sprat catch accounts for a big portion of Bulgaria's total Black Sea catch. In 2018 it reached 3,188 MT, a 3.2 MT increase over 2017. Bulgaria's 2018 red mullet catch increased by 59% to 595 MT. The other Black Sea species caught by Bulgarian anglers included bluefish (261 MT), Black Sea horse mackerel (197 MT), turbot (56 MT), and other species. The Bulgarian fishing fleet is small, with about 2,000 vessels.

In 2018 the total catch from marine fisheries in Bulgaria reached almost 8,600 tonnes, slightly decreasing from the previous catch production of around 10,000 tonnes. Marine fisheries in Bulgaria originate from the Black Sea. According to the report of the Fishery Division of the Food and Agricultural Organization to the United Nations in 2017, the Bulgarian fishing fleet consisted of 1 880 registered vessels, of which 1,295 were active. The active fleet had a combined gross tonnage (GT) of 5 thousand tonnes, an engine power of 41.2 thousand kilowatts (kW) and an average age of 25 years. The Bulgarian fishing fleet consists mainly of small fishing vessels: the majority of the fleet was less than 12 m in length and used passive gears. The segmentation according to Vessel Length (VL) is as follows (the numbers refer to 2016): VL <6 m - 415; 6m<VL<12m - 703; 12m<VL<18m - 61; 18m<VL<24m - 15; 24m<VL<40m - 12.

In Romania, in recent years there has been a considerable decline in marine catches, from 14,000 tonnes in 1989 to 6,200 tonnes in 1990 and 1200 tonnes in 1991, 2,122 tonnes in 2002. In 2002, 21 private companies were authorized to carry out the commercial fishery. A number of more than 4,500

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

fishermen operated in this type of fishery and used 880 boats, 40-pound nets, 1,260 turbot gillnets/trammel nets, 11 beach seines and 9,030 rodlines.

In summary, the fishing sector is composed mostly of SMEs and individual fishermen, who could benefit from the Service Module at an affordable price. An approximate estimation of the potential end-users would be the total number of vessels with VL>6 m, e.g. ~1500. Another important category of potential users is represented by national regulatory agencies, which could use the service as a working tool for issuing fishing licenses, for example. This could generate a shift in the initial business model approach, from a one-time (possible renewable) subscription to a monthly/annual one.

2.3.1.2 European market of small pelagics

Between 2000 and 2013, small pelagic fisheries represented over 50% of the landings in the Mediterranean and the Black Sea; these species accounted for 17% of the EU catches in 2015 (Schickele et al, 2020). The EU market contains a large number of vessels and fisheries. Understanding each fishery or metier is fundamental for growth. Even though there are different types of metiers for targeting these species, the main metier used is the purse seine. In addition, these vessels are usually equipped with computers and receive satellite communications when they are far from the coast and as such, they do not obtain a 4G signal. On the other hand, an artisanal fleet that also catches small pelagics operates very close to the coast where this service module is less accurate and usually, they are not enough equipped for supporting this type of technology. Therefore, we will focus herein on purse seiners fishing small pelagics.

The Spanish fishing fleet is composed of 8,839 vessels operating in four different fishing grounds: national (95% of the fishing vessels), European (1%), international (1%) and unified census of surface longline (2%). Within the national group, there are four fishing grounds: Canary Islands, Cantabrian and NW Spain, Bay of Cadiz and Mediterranean. Pilot 2 is focused on the Cantabrian Sea (see in Table 1 the main PO of this fishing ground within the Spanish coast) and the NW Iberian Peninsula fishing ground. There are 4,643 fishing vessels registered to operate in this fishing ground, among them the main fleet is the artisanal fleet which accounts for 91% of the total fleet. 88% of the total fleet belongs to the Galician autonomous community, while 12% are from Asturias, Euskadi, and Cantabria communities. Even though the number of purse seiners contributes only to 6% of the total fleet, these vessels reach 39% of the gross tonnage within this fishing ground and 30% of the total engine power.

Summarizing (Table 8), the potential users of this Service Module are 253 vessels where Pilot 2 is focused (coverage of the oceanographic model). If the Service Module is applied to other models' outputs covering the rest of the Spanish coast the potential users could be 540 vessels.

Galicia	Euskadi	Asturias	Cantabria	Total Cantabrian Sea and NW Iberian Peninsula	Total Spain
152	58	6	37	253	540

Table 9. Number of purse seiners per autonomous community fishing in the Cantabrian Sea and NW Iberian Peninsula and total purse seiner fleet in Spain

Concerning the European fleet, in 2018 it was composed of 63,593 active vessels. Greece, Italy and Spain were the countries with the highest number of boats and Spain with the highest gross tonnage (Prellezo et al., 2020). The EU large-scale fleet comprises 15,344 vessels and covers 75% of the total gross tonnage, among these vessels there are vessels fishing large and small pelagics and a country-by-country analysis should be done to clarify the percentage of these vessels fishing on small pelagics. But these data can provide us with an estimate of the potential users at the European level.

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

2.3.1.3 Niche market suitable fishing areas

The Service Module gives information on the areas suitable for fishing, taking into account the conditions favourable for specific fish species; the upwelling areas are known as favourable zones for the fish catchment. The wave height is an essential oceanographic parameter for the adequate planning of the operations at sea.

In order to scale the service to the European level, an adaptation of regional models would be required. Thus, since this is not a foreseen activity in the frame of the project, the service model will be marketed only regional, with a focus on the Bulgarian and Romanian potential clients. The potential end-users are estimated at around 1,500.

Other potential users refer to the rest of the Black Sea fishing fleet that might have the right to fish in the area of interest of the service. In this regard, the Turkish vessels would represent a priority for marketing strategies. According to the "State of Mediterranean and Black Sea fisheries" report, published by FAO (Food and Agricultural Organization of the United Nations), Turkey had, by far, the largest overall catch in the 2016-2018 period, of almost 274,000 tonnes (23.3 % of the total catch in the Mediterranean and the Black Sea basin). This amount was possible due to the 15,352 fishing vessels, thanks to which Turkey leads the list in the region. Also, Turkey represents 82.1 % of the total fleet in the Black Sea.

2.3.2 Future Developments

Fisheries still dominate the EU seafood market, accounting for 76% of the total per capita consumption; fish prices grew significantly in recent years (+ 10% between 2013 and 2017) (European Market Observatory for Fisheries and Aquaculture Products, 2018). Future growth will require continued progress in strengthening fisheries management regimes, reducing loss and waste, and tackling problems like illegal fishing, pollution of aquatic environments, and climate change, the report adds. But also more efficient fishing operations. Here FORCOAST reaches out with two Service Modules to help the fishermen.

2.3.3 Customer Identification

2.3.3.1 Characteristics

The sector of wild fisheries is present in Pilots 2 and 3. In these two pilots, four intermediate users are active, two of them are research/technological centres working in applied research and two of them SMEs experts in the development of products and services for the wild fishery sectors (and aquaculture in the case of TERRASIGNA). The final users for this case are all external: the Purse Seine fleet in the Bay of Biscay, which has already collaborated with AZTI in the framework of different regional/national projects, and the Bulgarian Fisheries companies.

Potential customers 'Fish Suitability Index' service

P	Location	INTERNAL USERS		EXTERNAL USERS
		Intermediate	Final	
2	Bay of Biscay	AZTI (Research) Marine Instruments (SME)	-	Purse Seine fleet
3	Black Sea	Terrasigna (SME) USOF (Research)	-	Bulgarian Fisheries companies

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

Table 10: Detail on users inside the consortium (intermediate or final) and external users for the Wild Fisheries sector

The potential customers could be separated into two big categories: 1) wild fishery industry operating in the open sea and 2) customers with activity in the coastal area or near shore. The first category could be further split into large fishing companies, mid-size fishing firms and individual fishermen. The second category includes merchants of seafood, fishing stationary nets operators, catchers of bottom organisms, dragging vessels, and trawlers. There is also a third category, not directly related to fishing activities: these are customers with an interest in SCUBA diving and underwater photography, marine sports and maintenance of tourist attractions.

The main customer segment identified for this Service Module is the wild capture fisheries sector, more specifically those focusing on small pelagic species.

2.3.3.2 Specific Needs

For the wild fisheries sector these are the main drivers that should be considered for the development of services and products:

i - To **determine the distribution of suitable habitats for small pelagic fisheries** and avoid other non-target species. Information on the environment (synoptic maps of salinity, temperature, chlorophyll (Chl-a), Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Mixed Layer Depth (MLD), Sea Surface Height (SSH), O_2, Primary Productivity (PP), Euphotic Zone Depth (ZEU) is key to provide an overview of the potential habitat of the target species. Together with the information on the ocean conditions (next point), the environmental information will support the decision for defining the next fishing grounds. With the final purpose of reducing the costs associated with days at sea (person-work, fuel, fungible...); thus, optimizing the operations in the sea and port cost. Nowadays this decision (fishing grounds) is taken based on their historical experience (previous fishing campaigns) and the climate background and weather forecast. The marine weather forecast services give frequent information but, it is mostly for the atmosphere, i.e. there is a lack of data for the sea. There are also onboard met-ocean tools (e.g. MarineView) that give operational daily information on the met-ocean conditions. In the framework of FORCOAST, integrating this high-priority information as proxies for the fishing suitability in the area of interest will be a priority, using a single platform, easy to use and hourly or daily updated with 3 days forecast.

ii - To **inform about the ocean conditions** (currents, stokes drift, maximum crest height, maximum wave height, momentum and energy fluxes, atmosphere state variables…) **for planning operational activities** (where/when to target fishing effort). This information about the met-ocean conditions will support the decision on where/when to target fishing efforts and to plan routine operations for the following days. The economic cost associated with the decision are those related to days at sea, on the other hand, it will also impact the safety and working comfort on board. Nowadays, in order to make this decision they look for online information on met-ocean forecast services for the next 1 to 3 days. In the framework of FORCOAST, we foresee covering this high priority information for this sector in an easy-to-use single platform updated hourly or daily and with 3 days forecast.

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

3 Competition Analysis

3.1 Competition overview Oysterground Restoration (ORR)

There are very few services available to meet the specific market needs for ORR as outlined in the above ‘Market Need ’section, however, there are two options available for ORR groups to conduct marine environmental condition analysis. These are to; a) Deploy remote sensors and record data manually and calculate how the data affects ORR works or; b) Subscribe to a service that will record marine environmental data and calculate how the data affects ORR works. Neither of these services meets the specific requirements for ORR. Alternatively, they are designed either for monitoring marine conditions or aquaculture farm management and are simply the closest thing available to a marine environmental condition monitoring service for ORR. Below is contained a list of the most suitable sensors and services currently on offer to assess the ORR industry, listing their advantages and disadvantages. For a detailed description of each of the items listed, an exhaustive list is present in Annex1 – Detailed Competition Analysis.

Sensing + Aqua

System advantages	System shortcomings
Remote sensing	No ocean modelling
Meteorological arrays/weather forecasting	No Geographical Distribution of Suitable Seabed Habitat
Data dashboard	No Distribution of Oyster Larvae
Low user input required	No Sedimentation Modelling
Data sharing	No Particle Tracking
Software support team available	No Oyster Mortality Analyses due to Prolonged Exposure to Sub Optimal Temp/Salinity
Mobile app available	No Physical Characteristics Close to and at the Seabed
Web portal available	No Water Circulation Patterns for Retention or Dispersal of Larvae from Spawning Sites
No set-up data required	No Retrieving Source of Contaminants No dissolved Carbon/Nitrate Detection

Table 11. Sensing + aqua suitability for achieving oyster reef restoration market needs

Tech Works Marine

System advantages	Systems shortcomings
Software support team available	No Oyster Mortality Analyses due to Prolonged Exposure to Sub Optimal Temp/Salinity

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

Software system available	No Physical Characteristics Close to and at the Seabed
Large network of data sharing	No Water Circulation Patterns for Retention or Dispersal of Larvae from Spawning Sites
No set-up data required	
Ocean modelling available	
Turbidity monitoring available	
Dissolved carbon, oxygen, nitrate detection	

Table 12. Tech Work Marine buoys suitability for achieving Oyster Reef Restoration market needs.

Ocean Seven 310 CTD Multi-parameter probe

System advantages	Systems shortcomings
Software support team available	No Oyster Mortality Analyses due to Prolonged Exposure to Sub Optimal Temperature/Salinity
Software system available	No Physical Characteristics Close to and at the Seabed
Large network of data sharing	No Watter Circulation Patterns for Retention or Dispersal of Larvae from Spawning Sites
No set up data required	
Ocean modelling available	
Turbidity monitoring available	
Dissolved carbon, oxygen, nitrate detection	

Table 13. Ocean Seven 310 CTD Multi-parameter probe suitability for achieving Oyster Reef Restoration market needs.

Libelium-SmartVillage Smart water solution kit Sigfox

System advantages	Systems shortcomings
Remote Sensing	No Retrieving Source of Contaminants
Software System Available	No Geographical Distribution of Suitable Seabed Habitat
Data Dashboard	No Distribution of Oyster Larvae

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

Dissolved Carbon, Oxygen, Nitrate Detection	No Sedimentation Modelling
No Set Up Data Required	No Particle Tracking
Software Support Team Available	No Oyster Mortality Analyses due to Prolonged Exposure to Sub Optimal Temp/Salinity
	No Physical Characteristics Close to and at the Seabed
	No Water Circulation Patterns for Retention or Dispersal of Larvae from Spawning Sites
	High User Input Required
	No Ocean Modelling Available

Table 14. Libelium-SmartVillage Smart water solution kit Sigfox suitability for achieving Oyster Reef Restoration market needs.

3.2 Competition Overview Bivalve Aquaculture (BV)

Also in the bivalve aquaculture sector, there are only a few services available. They are mainly based on remote sensing datasets and in most of the cases the products are not officially released or publicly available (demos and documentation can be accessed upon request).

AquaSpace (http://www.aquaspace-h2020.eu/)

System advantages	System shortcomings
Use of CMEMS remote sensing data	No 3D ocean modelling
Maps of suitability index	No water circulation patterns for tracking particle/pollutant dispersions
Socio-economic driver analysis	No mussel mortality analyses due to prolonged exposure to sub optimal ocean conditions
Low user input required	Static analysis (non-operational products)
Ecophysiological models for Mediterranean mussel	
Software support team available	
FiCIM model for estimation of local environmental impact	
Results available on GIS platforms	
Spatial multi-criteria evaluation tool	

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

Table 15. AquaSpace suitability for achieving mussel aquaculture market needs

AquaX (https://www.aquaexploration.com/)

System advantages	System shortcomings
Use of high-resolution remote sensing data (Sentinel + CMEMS)	Lack of publicly available validation
Tools for water quality management	Demos and documentation available upon request
3D ocean modelling	
Machine learning approach	
Simple / easy to use platform	
Alert system for HABs	

Table 16. AquaX suitability for achieving mussel aquaculture market needs

AquaGIS (ISPRA)

System advantages	System shortcomings
Web App	Limited to Italian coasts
Tools for identifying the Allocated Zones for Aquaculture (AZAs)	Not officially released/publicly available yet
Integration of several informative layers (e.g., bathymetry, model outputs, restricted areas)	

Table 17. AquaGIS suitability for achieving mussel aquaculture market needs

FORESHELL-CHyM (CETEMPS)

System advantages	System shortcomings
Hydrologic model for bacterial diffusion forecasting	Limited to Italian coasts
	Not officially released/publicly available yet

Table 18. FORESHELL-CHyM suitability for achieving mussel aquaculture market needs

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

Rheticus Aquaculture (https://www.rheticus.eu/it/servizi-rheticus/rheticus-aquaculture/)

System advantages	System shortcomings
Remote sensing based	No 3D ocean modelling
Continuous monitoring of environmental parameters	Lack of publicly available validation
Assess the optimal time for harvesting and selling products	Demos and documentation available upon request
Risk evaluation/mitigation	

Table 19. Rheticus Aquaculture suitability for achieving mussel aquaculture market needs

3.3 Competition overview Wild Fisheries (FI)

CatSat (https://www.catsat.com/)

The most widespread commercial product that could be a potential competitor to Front Detection is CatSat.

System advantages	Systems shortcomings
Integrate fleet, buoy, mobile tracking, catch report data, advanced navigation, within the CATSAT interface.	Only desktop application
Compressed data download format to reduce satellite communication costs and flexible data selection.	
World-renowned sales and technical support, including training and dedicated fisheries experts available to advise you seven days a week.	
High-quality and high-resolution ocean and weather data available	
Follow fleet movements thanks to AIS data.	

Table 20. CatSat advantages and disadvantages for wild fishery sector needs

3.4 SW-Analysis of Competitors

3.4.1 Oysterground Restoration

Strengthens	Opportunities
• Results available on GIS platforms • Platform support team	• Up and running toolbox frameworks

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

• Integration of CMEMS dataLow user input required	• Likely, growing interest from the growing user community • The introduction of smart farming will stimulate use of service models
Weaknesses	**Threats**
• Static analysis (instead of operational) • No direct access to ocean models • No tracing tools (spats, pollutants) • Providing very basic to no data/information • Not suited to the geographical area of interest • Lack of scientific knowledge and technical capacity to expand their spectrum of services to their users • Inability to integrate and interpret external sources of data to provide relevant information towards actionable insights.	• Loss of relevance in future time (static results) • Scepticism of the producers and lack of freely and publicly available demos and documentation to increase the attractiveness

3.4.2 Bivalve Aquaculture

Strengths	**Opportunities**
• Results available on GIS platforms • Platform support team • Integration of CMEMS data • Simple and easy-to-use tools • Low user input required • Ecophysiological model for Med. Mussels	• Up and running toolbox frameworks • Likely, growing interest from the growing user community • The introduction of smart farming will stimulate use of service models
Weaknesses	**Threats**
• Static analysis (instead of operational) • No direct access to ocean models • No tracing tools (spats, pollutants) • Providing very basic data • Data not always suited to the geographical area of interest • Lack of scientific knowledge and technical capacity to expand their spectrum of services to their users	• Loss of relevance in future time (static results) • Scepticism of the producers and lack of freely and publicly available demos and documentation to increase the attractiveness • Farmers are not willing to pay for such service modules

• Inability to integrate and interpret external sources of data to provide relevant information towards actionable insights.	

3.4.3 Wild Fishery

Strengthens	Opportunities
• High resolution information • Local hydrodynamic models • Integration of existing knowledge by using CMEMS • Platform support team • User friendly • Information available for mobile phones (Telegram). No need of a computer or download apps.	• Use and disseminate of Copernicus Marine services • Validate in situ the usefulness of this integrated information
Weaknesses	**Threats**
• Providing very basic data • Data not always suited to the geographical area of interest • Lack of scientific knowledge and technical capacity to expand their spectrum of services to their users • Inability to integrate and interpret external sources of data to provide relevant information towards actionable insights. • Some fleets pay for integrated solutions, others are reticent to pay for these services and others take the advantage of free-of-charge services	• Model data not available • Trust in new services by the end-users

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

4 FORCOAST Positioning

4.1 SW-Analysis

The following initial SWOT analysis for FORCOAST services was done.

Strengths	Opportunities
• High resolution information • Integration of existing knowledge by using Copernicus Marine Services • Sustainable data provision • Cost effectiveness of data provision • Targeting the demand of the market • Highly motivated and skilled consortium. • Operational products (daily updated information and services). • Strong scientific expertise in the consortium • Multidisciplinary consortium (data analysis, physics, front-end development…) • Simple, easy to use • Services custom-made based on user needs and gaps • User-friendly information to interact with. • Giving the user a powerful decision-making tool	• Creating sustainable business and job opportunities • Provide value to existing EU programs and projects • Use and dissemination of Copernicus Marine services • Contribute to sustainable fishery and oyster restoration activities. • Central architecture of the platform is designed as open and evolutive: capacity to ingest and disseminate new services. • More need for site selection in the future • Providing our services to other sectors (e.g. offshore) as well
Weaknesses	**Threats**
• FORCOAST service is partially dependent on satellite and global and local model data availability and its continuity. • Need of maintenance of the platform • Market readiness level of the different services • Ecosystem readiness • Consortium after the end of the project	• Entities perform similar service • Sustainability of existing services used in the supply chain platform; • Trust in new services by the end-users • Unconsolidated consortium beyond the project's lifetime • Free-to-use service providers • Pioneering the market of information services • Are sea farmers willing to pay for these services?

4.2 Target user/customer per sector

The demand for marine information services is increasing as the marine-related business has been observed to be growing in economic value. This value depends on the efficiency and effectiveness of

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

the operations and productivity while decreasing the pressures on the marine and coastal environment. The increasing availability of data and technological advancements will contribute to a better and deeper understanding of the surrounding environment. Europe in particular, through programs such as Copernicus, has been making significant investments to make data publicly available that can make important contributions to the productivity of the operations in different sectors.

The purpose of FORCOAST is to make data available for the end user in an understandable manner and, even more important, in an applicable way in the form of Service Modules.

4.2.1 Oysterground Restoration

Irish Pilot

Sectorial Final Users

- Irish Native Oyster Fisheries Forum (INOFF)
- Native Oyster Network
- Tralee Oyster Co-op
- Lough Swilly Co-op
- Clew Bay Co-op
- Achill Co-op
- Cuan Beo Galway Oysters
- Kilkieran Co-op
- Clarin Bridge Co-op
- Native Oyster Restoration Alliance (NORA)
- Irish Oysters Packer Group
- IFA Aquaculutre
- Bord Iascaigh na Mhara
- Tralee Oyster Society
- BIM Clare
- BIM (Galway)
- Marine Spatial Planning Unit (Dept of Housing)

Maritime Safety Users

- Royal National Lifeboat Institution
- Irish Coast Guard
- Oranmore Maree Coastal Search Unit

Water Pollution Concerned Users

- Sea Fisheries Protection Authority
- Health Service Executive - Bathing Waters
- Marine Institute

Offshore Energy

- Marine Renewables Industry Association
- Department of Communications, Climate Action and Environment

Tourism and Recreation

- Galway Bay Sailing Club
- Galway Hookers Association

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

- Galway Bay Boat Tours
- Swim Buddies

Coastal Protection Users

- Galway County Council
- Clare County Council
- Inland Fisheries Ireland
- Marine Institute
- Office of Public Works
- National Parks and Wildlife Service
- Irish Whale and Dolphine Group
- Department of Planning Housing and Local Government

Port and Shipping

- Port of Galway

Sustainable Marine Living Resources

- Inshore Fisheries Forum
- HABS Marine Institute

Weather and Climate

- Met Eireann

Basic and Applied Ocenography

- National University of Ireland Galway
- Galway Mayo Institute of Technology

Customers in Europe

The end users that could benefit from the Service Module – Retrieve sources of contaminants includes all bivalve farmers, and end users that are involved in oyster reef restoration and rely on natural recruitment.

Table 20 lists the potential customers for the Service Module – Retrieve sources of contaminants.

	End user	Activity
Ireland (9 ORR groups)		
Galway Bay Oyster Restoration Project (Cuan Beo)	Galway Bay, Co. Galway, Ireland	The project aims to restore native oyster habitats through strategic cultch deployment to promote the larval settlement, to identify the distribution of critical habitat for native oysters including modelling of temperature and salinity, develop spatial management of fisheries that will include closed areas for oyster reef development, to gain a more in-depth knowledge of native oyster habitat restoration through practical research, to

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

		monitor the prevalence of Bonamia and to improve coastal water quality in Galway Bay.
Clarinbridge Oyster Co-op Society Ltd	Clarin Bridge, Co. Galway	Oyster Fishery Management
Clarinbridge Oyster Co-op Society Ltd	Clarin Bridge, Co. Galway	Oyster Fishery Management
Loughs Agency	Lough Foyle, Co. Derry	Oyster Reef Restoration in Lough Foyle.
Tralee Oyster Co-op Society Ltd	Fenit, Co. Kerry	Oyster Fishery Management
North Mayo Oyster Development Co-op Society Ltd	Belmullet, Co. Mayo	Oyster Fishery Management
Achill Oyster Group	Achill Island, Co. Mayo	Oyster Fishery Management
Lough Swilly Wild Oyster Society Ltd	Buncrana, Co. Donegal	Oyster Fishery Management
Comharchumann Sliogeisc Chonamara Teo	Kilkieran, Co. Galway	Oyster Fishery Management
Native Oyster Reef Restoration Ireland	Arklow, Co. Wicklow	Training and educating local community about biomimetic restoration.
Belgium (1 ORR group)		
Belgian pilot of UNITED	Belgium	Belgian United is combining the culture of flat oyster and sugar kelp and compares the characteristics of sugar kelp grown nearshore and offshore.
Croatia (1 ORR group)		
University of Dubrovnik (Mali Stone Bay)	Mali Stone Bay, Croatia	The University of Dubrovnik is the main research body working in Mali Ston Bay which is the largest native oyster aquaculture production area in the Mediterranean.
France (1 ORR group)		
Flat Oyster Recruitment and Growth (FOREVER)	-Brest, France -Quiberon, France	The project consists of three complementary actions. The first action aims to inventory the main populations of wild flat oysters in Brittany and to describe their health and genetic characteristics.

		The second action focuses on the ecology and the dynamics of the two remarkable beds still remaining in the bays of Brest and Quiberon. The last action promotes restoration and management measures for these beds in partnership with local actors (fisheries and shellfish farming bodies, regional authorities, and environmental management organizations such as Natura 2000).
Germany (2 ORR groups)		
Seed Oyster Production for Ecological Restoration (PROCEED)	Helgoland, Germany	PROCEED is engaged in implementing an oyster hatchery on the German offshore island Helgoland to establish a healthy broodstock and sufficient seed oyster production for ecological restoration.
Ecological Restoration of the Native Oyster Species *Ostrea edulis* (Restore)	Borkum Reefground, Germany	Restore involves the construction of a pilot oyster reef in the Natura 2000 site Borkum Reefground.
Spain (1 ORP group)		
Knowledge and Tools for a Future Oyster Restoration Action (Mar Menor)	Mar Menor, Spain	The project aims to gain knowledge about the feeding physiology of the oyster and its nutrient capability throughout a phytoplankton bloom and to develop the necessary tools for a future oyster restoration action.
Sweden		
The Bilvalve Project	Sweden	Identification of existing pressures on Swedish oyster populations, knowledge development for best management structures, initiate stock enhancement strategies.
The Netherlands (2 ORP groups)		
Blauwind and the Rich North Sea Oyster Pilot	Nederland	The Rich North Sea and Blauwwind have joined forces to expand this plan to gain more understanding of the influences of habitat conditions

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

		on biodiversity and how we to stimulate flat oyster reef development.
Voordelta, Wadden Sea, Brokum Stones Restoration Projects	- Voordelta - Wadden Sea - Brokum	3-D printing of reef structures and other hard substrate material and starting a Bonamia-free *Ostrea edulis* population.
Outside the European Union		
United Kingdom (7 ORR groups)		
Essex Native Oyster Restoration Initiative (ENORI)	Blackwater, Essex, England	ENORI is a collaboration between the oystermen, scientists, conservationists and the UK government to restore native oysters in Essex UK.
Marine Infrastructure Effects Initiative (Marineff)	English Channel, England	The MARINEFF project was selected under the European cross-border cooperation Programme INTERREG VA France (Channel) – England co-funded by the ERDF and involves 9 French and British partners. The project aims to demonstrate new biomimetic marine structures to improve the ecological status of inshore waters, as well as to involve professionals and stakeholders in the project.
Solent Oyster Restoration Project	Solent, England	The Solent Oyster Restoration Project, spearheaded by the Blue Marine Foundation (BLUE), is restoring native oyster populations on a large scale on England's south coast.
Wild Oyster Project (Self-sustaining populations of Native Oysters for the UK Seas)	- Conwy Bay, Wales - Firth of Clyde, Scotland - Tyne&Wear, England	The Wild Oyster Project is a new three-year restoration project that launched in June 2020, developed as part of a new collaboration between the Zoological Society of London (ZSL), Blue Marine Foundation (BLUE) and British Marine. The aim of the project is for the UK seas have self-sustaining populations of native oysters which provide clean water, healthy

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

		fisheries, plentiful biodiversity and on land there is a re-ignited national love of this iconic species.
The Dornoch Environmental Enhancement Project (DEEP)	Dornoch Firth, Scotland	Oyster reef restoration in Dornoch Firth.
Ecological Restoration, Rewilding, Preservation (Kilchoan Estate)	Kilchan Estate, Scotland	Kilchoan Estate has been working with Seawildng to create a native oyster restoration project at the head of Loch Melfort.
Restore the Native Oysters in Loch Craignish (Seawilding)	Loch Craignish, Scotland	Oyster reef restoration in Loch Craignish.
United States of America		
Billion Oyster Project	New York, America	Restoring oyster reefs in new york harbor through public education initiatives
Cheasapeake Bay Foundation Cooks Point Sanctuary Reef, Maryland	Cooks Point Sanctuary Reef, Maryland, America	Restoring oyster reefs in Chesapeake Bay
Australia		
Australian Shellfish Reef Restoration Network	-Australia -New Zealand	The Australian Shellfish Reef Restoration Network is a community of practice that brings together organisations and individuals interested in shellfish reef education, conservation, restoration and management

Table 21. List with potential customers of Service Module R1 – Contaminants Source Retrieval per country

4.2.2 Bivalve Aquaculture

At Pilot sites

The pilot site is one of the major areas of bivalve production in Portugal with 14 firms producing oysters. In addition to ExporSado, other aquaculture companies in the Sado estuary include Neptunpearl, Bivalsado, Oysterworld and Aquanostra.

The main customer segment identified for the Land Pollution service module (A2) in Pilot 7 is represented by the owners/managers of aquaculture farms(s). Additionally, the institutions regulating or promoting marine aquaculture products and activities might use the service (for instance, the National Agencies for Fisheries and Aquaculture, the National Sanitary-Veterinary and Food Safety Authorities, and the Waters National Administrations). To some extent, research institutes can use some data, for specific case studies or actions.

- Maricultura Ltd. / Pescaria lui Matei Ltd.

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

- Authorities: National Agency for Fisheries and Aquaculture, the National Sanitary-Veterinary and Food Safety Authority, the Romanian Waters National Administration
- Research institutions: NIMRD for future research purposes

For Limfjorden Pilot Site, the Service Module is primarily relevant to the shellfish primary producers. OysterBoat is the project partner which uses hydrography and biogeochemical information for its oyster cultivation business. Other aquaculture companies in Limfjorden include Blå Biomasse A/S, Seafood Limfjord ApS, Shellfish Limfjord ApS, MytiLine ApS, Vilsund Blue A/S and Muslingeriet

Company	Activity
Oyster Boat	Oyster farmer
Venøsund Fisk og Skaldyr ApS	Larviculture Limfjorden
Vilsund Blue	Muslinger farming
AQUAPRI Denmark A/S	Sea farm
DTU-MSC	Siting
AquaProcess	Consultation
Blå Biomass ApS	Blue mussels
Association Muslingeerhvervet	Blue mussels

Table 22. Shortlist of potential users in the Limfjord area

This Service Module - Assistance for spat capture was originally designed for the Belgium Pilot. This Pilot is located at Westdiep and investigates the possibilities of integrated aquaculture (blue mussels, flat oysters and sugar kelp) and passive fisheries (project SYMAPA). During the former project Value@Sea (at the same location), it became clear that finding of juvenile flat oysters of good quality and disease-free was very difficult. Therefore, the possibility of capturing flat oyster spat is investigated in the ongoing project SYMAPA. Mussel culture also relies on the availability of mussel spat from nature. Therefore a model was constructed by RBINS to aid the SME (**Brevisco**) involved in bivalve farming in the project.

As the interest in mariculture in Belgium is increasing, several other SMEs are following. For example, at the end of 2020, the SME **CODEVCO V** received a used environmental permit to establish an integrated mariculture farm (105 ha), first with blue mussel and later onwards with European flat oyster and sugar kelp (MD of 23 December 2020). **DEME Group** is a shareholder in the first Belgian commercial sea farm for the production of mussels. **Geo XYZ** is a company specialising in hydrographic and topographic services, provides services to local authorities dredging industry, marine & offshore industry engineering companies and research centres, and is also interested in mariculture.

But also the Belgian industrial partners within the project UNITED are potential customers of this Service Module: **Parkwind** (offshore windfarm operator) and **Jan De Nul** (dredging, offshore energy

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

market & environmental works) and the latter are interested in the commercial culture of flat oysters and oyster reef restoration. (Table 1).

However, during the project period of FORCOAST it became clear that the use of the Service Module A4 – Assistance for spat capture, was not only limited to the sectors of the Bivalve Aquaculture and Oyster Reef Restoration but can also be of benefit in the use of biogenic bivalve reefs. In Belgium, the consortium COASTBUSTERS is performing experiments to enhance the development of bivalve reefs with the use of aquaculture techniques. Within this consortium, two major players are active that are active in coastal protection worldwide: **DEME Group** (is a world leader in the highly specialised fields of dredging, land reclamation, marine infrastructure, offshore energy and environmental remediation worldwide) and **Jan De Nul** Group (specialised in dredging and the production of offshore energy, land reclamation, prevention of pollution and marine infrastructures) Both companies are interested in the use of such artificial enhanced biogenic mussel beds for coastal protection, not only for the Belgian coast but all over the world. This is a multi-billion market. Therefore, it is important that the spat collectors for mussels are installed timely, to ensure maximum efficiency and yield. and For these activities, the Service Module A4 - Assistance in spat capture is of great importance to further develop their activities in coastal protection, bivalve culture and oyster reef restoration. As both companies are active worldwide, the extension of the Service Module A4 to other species and areas could be of great importance.

The Adriatic Sea is, at present, the most important Mediterranean area in terms of mussel production in longline systems (22 metric tons in 2013, ~33.6% of the Italian production, MiPAAF 2014), and represents an area for potentially developing oysters' cultivation up to 6 km offshore (Bertolini et al., 2021; Roncarati et al., 2017). In such a context, the bivalve fisheries in the Northern Adriatic region is considered a fully successful system because of the deep and virtuous interaction between local consortia and Producers' Organisations in resource management (Rodriguez et al., 2021). This feature is reflected by a large number of companies and consortia (fifty-eight) that operate in the bivalve field (Section 2.2.3). In particular, the "top-level" farmers' associations should be targeted, in order to reach the local producers more effectively and with the proper approach. With respect to this, more targeted "literacy" and dissemination activities would be surely beneficial.

Customers in Europe

List the most important end users that could benefit from the Service Module in Europe and explain how the Service Module could be of benefit to them.

Other end users in Europe could start by exporting the SM to the other FORCOAST pilots and trying to reach the market through the European Aquaculture Association (EAS).

Customers in the rest of the world

At this level of development, it is complicated to explore the world's end users. But in theory, it can be exported to any other location in the world if the requirements are met.

Customers in Europe

Maricultura Ltd. / Pescaria lui Matei Ltd. (Romania), Smart Farm AS, Bulgaria (Bulgaria), Musholm farm (Denmark) are all mussel farms that may trigger management actions as a follow-up of early warning of potentially microbiologically contaminated waters reaching the farm site.

Customers in the rest of the world

Smart Farm AS, Norway is a mussel farm that may trigger management actions as a follow-up of early warning of potentially microbiologically contaminated waters reaching the farm site.

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

Table 22 is a list of potential customers of the Service Module per county (this list can be longer than the end users described in the text above).

End user	Activity
Romania	
Maricultura Ltd. / Pescaria lui Matei Ltd.	Mussel farming. Trigger management actions as a follow-up of early warning of potentially microbiologically contaminated waters reaching the farm site
National Agency for Fisheries and Aquaculture, the National Sanitary-Veterinary and Food Safety Authority, the Romanian Waters National Administration	Policy and decision-making
NIMRD	Future research activities
Bulgaria	
Smart Farm AS, Bulgaria	Mussel farming
Denmark	
Musholm farm	Mussel farming
Outside the European Union	
Norway	
Smart Farm AS, Norway	Mussel farming

Table 23. List with potential customers of Service Module per country

Customers in Europe and the rest of the world

This is the Danish Pilot and there is no knowledge available on other European Primary Producer needs, nor in countries outside Europe. LTA, Lower Trophic Aquaculture is poorly developed in Europe. Reliable Service Module information may boost the development of LTA in Europe.

Customers in Europe

The end users that could benefit from the Service Module – Assistance in spat capture include all bivalve farmers that are depending on spat collection from the wild with spat collectors, and end users that are involved in oyster reef restoration and rely on natural recruitment.

The blue mussel farmers are all the farmers that use the suspended mussel culture with seed collected from the water column (excluding all farmers that uses mussel seed that is fished on natural mussel beds), almost all mussel farmers in Norway and Denmark, and part of the mussel farmers in The Netherlands and France.

The number of customers could however substantially be increased when the Service Module would be adapted for two more species: the Mediterranean mussel (*Mytilus galloprovincialis*) and the Pacific oyster. It is believed that this Service Module can be easily adapted for these species, as the cue parameters for reproduction and spat settlement are already well known.

For the flat oyster farmers, the number of customers is limited, as most of the flat oyster culture relies on spat that is produced in hatcheries. It is however believed, that the number of flat oyster farmers that will collect oyster spat will spat collectors will increase in the future with the introduction and expansion of oyster reefs through restoration (more availability of natural spat) and stricter regulations on the transfer of oysters between locations within and from outside the European Union to prevent the spreading of invasive species and diseases.

For the oyster reef restoration operators, it is believed that with the increase of initiatives and the EU funding for oyster reef restoration projects, the number of customers will grow in the near future. Deliverable 6.1 Initial Market Analysis identified 19 Oyster Reef Restoration (ORR) groups in Europe and 3 large ORR groups outside of Europe. The industrial partners, knowledge institutes, as well as environmental organisations that are involved in oyster reef restoration are potential customers.

Table 23 lists the potential customers for the Service Module - Assistance for spat capture.

	End user	Activity
Belgium		
	Brevisco	Mussel farmer
	Codevco V	Bivalve farmer
	DEME Dredging International	Mussel bed enhancement for coastal protection
	FOD Environment	Government involved in MRP & concessions for maritime activities
	Geo XYZ	Maintenance of mussel farming & oyster reef restoration projects
	ILVO	Knowledge institute involved in project on bivalve farming & bivalve reef restoration
	Jan De Nul	Partner in Belgian Pilot of project United: culture and oyster reef restoration on scour material in offshore windfarms
	OD Nature	Knowledge institute
	Parkwind	Partner in Belgian Pilot of project United: culture and oyster reef restoration on scour material in offshore windfarms
	University of Ghent	Knowledge institute
	Aquacultuur Oostende – De Oesterput	Oyster farmer
Bulgaria		
	Smart Farm AS, Bulgaria	Mussel farming
Croatia		
	University of Dubrovnik (Mali Stone Bay)	Main research body working in Mali Stone Bay which is the largest native oyster aquaculture production area in the Mediterranean
	Plasma Saal	Holistic medicine & Partner in Native Oyster Reef Restoration Ireland (NORRI)
Denmark		
	Musholm farm	Longline mussel farm
France		
	CRC Bretagne Nord	Partner in FOREVER – Flat Oyster REcoVERy
	CRC Bretagne Nord	Partner in FOREVER – Flat Oyster REcoVERy
	ESITIC Caen	Knowledge institute & Partner in Marineff project & Partner in FOREVER – Flat Oyster REcoVERy

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

	IFREMER	Knowledge institute & Partner in
	Ports de Normandie	Maritime Industry & Partner in Marineff project
	TPC	Civil engineering & Partner in Marineff project
	University of Caen - Normandy	Knowledge institute & Partner in Marineff project
	VINCI Construction Maritime and Fluvial	Civil engineering & Partner in Marineff project
Germany		
	AWI	Knowledge institute & Partner in Proceed - Seed Oyster Production for Ecological Restoration & RESTORE I
	Federal Agency for Nature Conservation	Government & Partner in Proceed - Seed Oyster Production for Ecological Restoration
	Kieler Meeresfarm	Longline mussel farm
Ireland		
	Achill Oyster Group	Oyster Fishery Management
	Clarinbridge Oyster Co-op Society Ltd	Oyster Fishery Management
	Comharchumann Sliogeisc Chonamara Teo	
	Galway Bay Oyster Restoration Project (Cuan Beo)	Restoration of native oyster habitats
	Lough Swilly Wild Oyster Society Ltd	Oyster Fishery Management
	Loughs Agency	Oyster Reef Restoration in Lough Foyle
	Marine Health Foods Ltd	Producer of marine products & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Native Oyster Reef Restoration Ireland	Training and educating local community about biomimetic restoration
	NexLoop	Partner in Native Oyster Reef Restoration Ireland (NORRI)
	North Mayo Oyster Development Co-op Society Ltd	Oyster Fishery Management
	Tralee Oyster Co-op Society Ltd	Oyster Fishery Management
Spain		
	Spanish Institute of Oceanography	Knowledge institute & Partner in the Mar Menor Oyster Project
	Smart Farm AS, Spain	Mussel farming
Sweden		
	East Sweden Aquaculture Centre (ERAC)	Longline mussel farm
	Bohus Havsbruk	Longline mussel farm
The Netherlands		
	Barbé Yerseke	Suspended mussel farmer & partner of 100% Zeeuws
	Firma NL. en L. de Keijser	Suspended mussel farmer & partner of 100% Zeeuws

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

	Hoogerheide Delimossel	Suspended mussel farmer & partner of 100% Zeeuws
	Marinecultuur Oosterschelde BV	Suspended mussel farmer & partner of 100% Zeeuws
	Mosselhangcultuur Landa	Suspended mussel farmer & partner of 100% Zeeuws
	Neeltje Jans Mosselen	Suspended mussel farmer & partner of 100% Zeeuws
	Shell	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Van Oord	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Eneco	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Diamond Generating Europe	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Partners Group	Partner in Blauwwind and The Rich North Sea Oyster Pilot
	Ark Natuurontwikkeling	Partner in Borkum stones, Voordelta & Wadden Sea
	WWF Netherlands	Partner in Borkum stones, Voordelta & Wadden Sea
	Wageningen Marine Research	Partner in Borkum stones, Voordelta & Wadden Sea
	Bureau Waardenburg	Partner in Borkum stones, Voordelta & Wadden Sea
	Sas Consultancy	Partner in Borkum stones, Voordelta & Wadden Sea
Outside the European Union		
Canada		
	ATLANTIC AQUA FARMS LTD	Blue mussel farmer
	BADGER BAY MUSSEL FARMS LTD.	Blue mussel farmer
	FANNY BAY OYSTERS	Pacific oyster farmer
	MAISON BEAUSOLEIL	Oyster farmer
	MAC'S OYSTERS LTD.	Pacific oyster farmer
	K'AWAT'SI SHELLFISH COMPANY	Pacific oyster farmer
United Kingdom		
	Ardfern Yacht Centre	Recreational sailing & Partner in Seawilding Restore the Native Oysters in Loch Craignish
	Blue Marine Foundation	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI) & Solent Oyster Restoration Project & Wild Oyster Project
	Bournemouth University	Knowledge institute & Partner in Marineff project
	British Marine	British Marine is the trade association for the UK leisure, superyacht and small commercial marine industry & Partner in Wild Oyster Project
	CEFAS	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)

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

	Colchester Oyster Fisheries	Oyster Fishery Management & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	CROMACH	Local volunteer association & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Environmental Agency	Government & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Glenmorangie Compagny	Partner in the Dornoch Environmental Enhancement Project (DEEP)
	Heart of Argyll Wildlife Organisation	Nature Protection & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Heriot Watt University	Knowledge institute & Partner in The Dornoch Environmental Enhancement Project (DEEP)
	IFCA	Government & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Institute of Aquaculture	Knowledge institute & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Marine Conservation Society	Partner in the Dornoch Environmental Enhancement Project (DEEP)
	Native Oyster Network –UK & Ireland	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Natural England	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Nature Conservacy	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	River Roach Oyster Company	Oyster farmer & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Scottish Association of Marine Sciences	Knowledge institute & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Stirling University	Knowledge institute & Partner in Seawilding - Restore the Native Oysters in Loch Craignish
	Tollesbury & Mersea Native Oyster Compagny LTD	Oyster Fisheries & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Ediburg	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Essex	Knowledge institute & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	University of Exeter	Knowledge institute & Partner in Marineff project
	University of Southampton	Knowledge institute & Partner in Marineff project
	Wildlife trust	Nature protection & Partner in Essex Native Oyster Restoration Initiative (ENORI)
	Zoological Society of London (ZLS)	Partner in Essex Native Oyster Restoration Initiative (ENORI) & Wild Oyster Project
Norway		
	Smart Farm AS, Norway	Mussel farming

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

United States of America		
	Refanala - High Vibrational Living Solutions	Health & Beauty & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Biomimicry New England	Biomimicry & Partner in Native Oyster Reef Restoration Ireland (NORRI)
	Chesapeake Bay Foundation	Restoring the native oyster, Crassostrea virginica in Chesapeake Bay, Maryland, Virginia
	Duke University	Oyster reef restoration in Australia
	Georgia Department Of Natural Resources	Oyster Reef Restoration projects in Plantation Creek, Florida Passage, Oatland Island, Skidaway River, Altamaha River, Jekyll Island Boat Ramp, Oyster Creek, Jointer Creek, Turtle and South Brunswick, Bellville Boat Ramp & Overlook Park
	Institute for Applied Ecology (IAE)	Oyster Reef Restoration Projects in the Gulf of Mexico
	NOAA Restoration Center	has funded more than 70 oyster restoration projects in 15 states
	Norwegian University of Science and Technology – NTNU-Trondheim	Mussel farming technologies
	The Nature Conservancy (TNC)	Pensacola East Bay Oyster Habitat Restoration Project & South Carolina Oyster Reef Restoration
Australia		
	Flinders University, SA	
	The Centre for Tropical Water and Aquatic Ecosystem Research - TropWATER	

Table 24. List with potential customers of Service Module A4 – Assistance for spat collection and distribution per country.

Customers in Europe

The most important end users that could benefit from the Service Module in Europe and, in particular, in the Adriatic Sea are:

- Co.Giu.Mar. – Consorzio Giuliano Maricolture (www.legacoopfvg.it/cooperative/consorzio-giuliano-maricolture-cogiumar/)
- O.P.I Fasolari (www.fasolari.it)
- Consorzio Cooperative Pescatori del Polesine (www.scardovari.org)
- Consorzio Pescatori di Goro (www.copego.it/)
- Consorzio Mitilicoltori dell'Emilia-Romagna (www.cozzaromagnola.it)
- A.M.A. – Associazione Mediterranea Acquacoltori (www.a-m-a.it)

These users are particularly sensitive to physical and biogeochemical conditions that are related to river runoffs and inland inputs. Therefore, they would get benefits from the Front Detection, Marine Conditions, Land Pollution Services, which should be able to provide the necessary monitoring, prognostic, and diagnostic tools for the assessment of biogeochemical and physical stressors impacting the farming sites.

Customers in the rest of the world

Among the users, we listed above, the A.M.A. – Associazione Mediterranea Acquacoltori (www.a-m-a.it) operates all over the Mediterranean Sea and thus in those non-EU countries where the bivalve fishery system is particularly important (e.g., Tunisia and Marocco).

4.2.3 Wild Fishery

At Pilot sites

The Service Module is designed to work for the western part of the Black Sea and can not be directly applied/transferred in other areas of the world ocean or even in the Black Sea. Thus the main customers to take advantage of this Service Module would be the inhabitants of the Bulgarian and Romanian Black Sea coast. The service offers information on typical marine species in the area, as well the events like upwelling, which is strongly dependent on local conditions. The table below summarizes the potential customers, following the categories described in the segmentation.

Service Module Fronts Detection has been developed to answer some needs identified in pilot 2 (Deliverable 2.1 Stakeholders Interests and Needs) focused on giving service to the wild fisheries sector. Small pelagic species in the pilot area are the following ones: Atlantic horse mackerel (*Trachurus trachurus*), European pilchard (*Sardina pilchardus*), Mackerel (*Scomber scombrus*) and European anchovy (*Engraulis encrasicolus*), with the latter being the most appreciated due to its economic value. According to the Working Group on Stock Assessment of Small Pelagic Species (WGSASP) 2019 report (http://www.fao.org/gfcm/technical-meetings/detail/en/c/1274635/), the Northern Spain fleet operating on small pelagics during 2019 was composed of 104 vessels of different sizes (<12 m, 12-24 m and >24 m length). These target customers are listed in the first rows (Spain) of Table 1.

The French fleet also operates partially at the pilot site, and as such two POs fishing on small pelagics have been included in the table.

Finally, since this Service Module is mainly addressed to the fisheries sector and the main inputs to this Service Module are global remote sensing data, partners within the consortium, especially Pilot 3 (Bulgaria and Romania) and its end users (Raykov, 2020) could also benefit from this Service Module.

Customers in Europe and the rest of the world

Other potential customers are the passing in the area fishing vessels from the other Black Sea countries (Turkey, Ukraine, Russia, Georgia) who could take advantage of the distributed information. In general, the developed know-how in the Service Module could be applied to support the wild fishery in other regions in the European seas and the world ocean, but the local specifics are to be taken into account and the algorithm should be tested and tuned to work in other areas.

	End user	Activity
<u>Bulgaria</u>		
	"Black Sea Sunrise" Marine Fishery Association	organization of professionals in the field of sea fishing in the Black Sea
	BG-Fish	Bulgarian Association of Fish products producers

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

	Morski ribolov Nesebar Ltd	trade in fish and seafood, fish and seafood processing, commercial fishing
	Elekta Sea products	SME for processing of seafood and rapana
	Dalboka mussel farm	cultivation of ecologically clean Black Sea mussels
	Department of Meteorology and Geophysics – Sofia University St. Kliment Ohridski	Research and numerical modelling of oceanographic processes
	Institute of fish resources - Agricultural Academy	fish stocks studies and monitoring of the dynamics and structure of the food base of industrial marine fish species.
	Institute of oceanology, Bulgarian Academy of Science	Research and statistics of biodiversity in the Black Sea
Romania		
	National Agency for Fisheries and Aquaculture	Governmental/regulatory agency
	Terrasigna	Business of Earth Observation data processing.
	Interfrig Fish	Fishing company
	Sea Sharks	Fishing company
	Rompescador ltd	Fishing company
Outside the European Union		
Georgia		
		Fishing operators in the western part of the Black Sea
Russia		
		Fishing operators in the western part of the Black Sea
Turkey		
		Fishing operators in the western part of the Black Sea
Ukraine		
		Fishing operators in the western part of the Black Sea

Table 25. List with potential customers of Service Module per country

Customers in Europe

In other to look for more end users at the European level, DG-MARE published a "List of recognised producer organisations and associations of producer organisations" (https://ec.europa.eu/oceans-and-fisheries/fisheries/markets-and-trade/seafood-markets_en). Among them, it would be necessary to search for each producer organization focusing on small pelagics and with enough technology on board to support this type of application.

Customers in the rest of the world

Finfish is the main group of marine species fished worldwide (85% of the total marine catches supposes about 7.9 million tonnes). Among them, the most fished ones are the small pelagics (FAO, 2020). The most fished species worldwide is the Peruvian anchoveta (*Engraulis ringens*), whose production represented 10% of the finfish production in 2018 (7,045 thousand tonnes). Among other species in the top list of species worldwide there is the Atlantic herring (*Clupea harengus*) which

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

supposes 3% of the total finfish production (fourth position in the ranking) in 2018 (1,820 thousand tonnes) followed by the European pilchard (*Sardina pilchardus*), which accounted for the 2% (1608 thousand tonnes), Pacific chub mackerel (*Scomber japonicus*), with 1557 thousand tonnes caught contributing to a 2% of the global production and Atlantic mackerel (*Scomber scombrus*), Japanese anchovy (*Engraulis japonicus*) and Sardinellas nei (*Sardinella spp.*) accounting each of them with 1% of the total production with catches of 1047, 957 and 887, respectively. These geographically widespread species can be classified into two groups depending on their final production. The biggest species (*e.g.* mackerel, horse mackerel) are utilized for human consumption and the smaller ones (*e.g.* Peruvian anchoveta) are more typically converted into fishmeal or fish oil for use as feed (for aquaculture and livestock).

	End user	Activity
Spain		
	OPEGUI	Fisheries producer organizations
	OPESCAYA	Fisheries producer organizations
	ARVI	Fisheries producer organizations
	OPROMAR	Fisheries producer organizations
	Organización de productores Puerto de Celeiro, S.A.	Fisheries producer organizations
	OPLUGO	Fisheries producer organizations
	OPACAN	Fisheries producer organizations
	Future fisheries producer organization from Asturias	Fisheries producer organizations
France		
	Coopérative des artisans pêcheurs d'Aquitaine	Fisheries producer organizations
	Les Pêcheurs de Bretagne	Fisheries producer organizations
Bulgaria		
	Black Sea Sunrise	Fishery associations
	BG Fish	Fishery associations
Rumania		
	Terrasigna	Business of Earth Observation data processing.
	Interfrig Fish	Fishing company
	Sea Sharks	Fishing company
	Rompescador ltd	Fishing company
Outside the European Union		
Chile		
	Asociación de Industriales Pesqueros del Norte (ASIPNOR)	Industrial fishing association
	Agrupación de Industrias Pesqueras del Sur Austral (FIPES)	Industrial fishing association
	Asociación de Industriales Pesqueros A.G. (ASIPES)	Industrial fishing association
	Sociedad Nacional de Pesca (SONAPESCA).	Industrial fishing association

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

Peru		
	Federación de Integración y Unificación de los Pescadores Artesanales del Perú (FIUPAP)	Artisanal fishermen organizations
	Asociación Nacional de Empresas Pesqueras Artesanales del Perú (ANEPAP)	Artisanal fishermen organizations

Table 26. List with potential customers of Service Module per country.

4.3 Value Proposition per service

4.3.1 Service Module R1 – Contaminant Source Retrieval

Service Module identification

The Service Module - Retrieve sources of contaminants will show the trajectory particles move through the water, how long they remain in a particular area and where they are most likely to have originated from. This is a valuable service module for all coastal users for whom good water quality is a concern, however, it is particularly useful for coastal users who are located close to flood drainage plains, wastewater treatment, stormwater overflows, urban areas, areas of large scale agricultural production and other potential sources of harmful substance pollution.

The Service Module - Retrieve sources of contaminants will allow the end user to show how the above-mentioned polluting activities affect their coastal activity and can allow them to take actions to;

- → Mitigate against these challenges,
- → Show policy makers how a polluting activity is affecting their coastal activity,
- → If possible seek compensation for losses.

Service Module purpose

The Service Module – Retrieve sources of contaminants will allow an end user to cast a hind-cast of the trajectory harmful particles travelled in the water to show where they likely originated from and determine whether or not they remained in a particular area for a significant period of time to cause damage to seafood production, marine life or human health.

- This service module is particularly useful to Oyster Reef Restoration groups for a number of reasons, these include;
- Understanding why a particular site is not performing well for oyster reef restoration.
- Showing regulators how a marine polluting activity can directly impact oyster health.
- Influence coastal planning decisions by highlighting how a planned development could potentially lead to increased pollution of coastal waters.
- Showing the areas of the coast where the lowest level of contamination takes place and thus allowing Oyster Reef Restoration groups to select the best site for reef restoration.

Cross-sectorial

Wild Fisheries: The service module could potentially explain why a particular area of the wild fishery is in decline owing to pollution from land-based activities.

Bivalve Aquaculture:

- Understanding why a particular site is not performing well for seafood production.
- Showing regulators how a marine polluting activity can directly impact bivalve health.

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

- Influence coastal planning decisions by highlighting how a planned development could potentially lead to increased pollution of coastal waters.
- Showing the areas off the coast where the lowest level of contamination takes place and thus allowing aquaculture producers to select the best site for reef restoration.

4.3.2 Service Module A1 – Marine Conditions

Service Module identification

The Service Module provides a forecast on meteo-oceanographic conditions and near real-time data that is distributed to the end user in a friendly way using mobile phone existing applications. The main objective is to plan the activities by having updated local information on the limiting environmental conditions. In addition, recent operational observations of environmental variables (meteorological, hydrodynamic, biogeochemical, river discharges,..) will be distributed by the same channel.

IST has started developing this service taking into consideration the requirements by ExporSado to develop a diagram that includes the most limiting factors for planning their activities:

- Tide
    - Time and height of the high and low tide
    - Optimum tide level for their activities
- Daylight hours (sunrise and sunset)
- Wind conditions
- Rain conditions

The service is distributed on a daily (including the next two days' forecast) and weekly basis (including next week's best forecasts). The service was presented in the Portuguese Aquaculture Association (APA, on its Portuguese acronym) and was well received but still, we have to demonstrate this concept with more end-users. Our next step is to approach directly other Sado estuaries aquaculture producers and to gather their interest. In addition, the tool will be exported to other pilots to evaluate the response of other aquaculture areas to this product.

Service Module purpose

This service module aims to contribute to better and safer management of the production areas. Since producers receive daily updated metocean environmental conditions for their area. This information allows them to better decide which activities they will be performing according to the environmental conditions.

Cross-sectorial

This information is relevant for other sectors that operate in the same area such as fishermen, port administration and tourist operators including dolphin-watching activities. This service module can be also of interest to local authorities and other industries present in the area.

Service Module purpose

The marine environment forecast service in Limfjord is not available in the Copernicus service. The only forecast available is from DMI, on coarse resolution and mainly focusing on storm surge warnings. FORCOAST developed high-resolution fjord forecasting system to provide a 5-day forecast on hydrodynamic conditions, with significantly improved quality on SST, stratification and resolution. This provides users with a unique value in knowing extreme water conditions, e.g., warm or cold days which relate to oyster and mussel growth conditions and potential oxygen depletion. Unfortunately, wave and ice forecasts were not planned in the project. Currently, the wave and ice forecasts are available from the models but have to be validated and improved in order to meet the user's needs.

Thus in the future, it is possible to develop the wave and ice forecast in the service, and probably hypoxia, the largest risk in Danish shellfish farming.

Cross-sectorial

Environmental studies of hydrography and marine biology may benefit greatly from accurate and detailed models. Authorities, consultants, academia, nature conservation organisations and philanthropic investors may commission specialised studies.

4.3.3 Service Module A2 – Land Pollution

Service Module identification

Aquaculture farmers have no or low means to assess the risk of exposure to harmful land discharges. Along with the lack of information regarding the oceanographic variables, the main problem is the lack of information regarding the outflows from the on-shore wastewater treatment plants. For instance, in Pilot 7, the emerging aquaculture farms are placed somehow close to the Constanta city wastewater treatment plants, which sometimes, during summer-touristic periods - may outflow untreated water, containing possibly some bacterial inputs, such as *E. coli.*

SM-A2 targets aquaculture farmers as main users. It is built on the flexible assumption that users only have limited means to characterize the source of pollutants. A thorough description of these sources would include the location of the source, the nature of the discharge and temporal variations in the outflow. As a first approach we consider that users won't be able to gather sufficient knowledge regarding nature, and temporal variations, but should have the means to characterize at least the location.

Also, SM-A2 uses surface circulation hindcast and forecast model data to provide an estimate of the potential risk of being affected by user-identified sources of pollution, i.e. to assess if the local marine conditions are such that an effective release at the pollution source has a significant probability to reach the farm. A constant watch is set, updated daily to consider the most recent circulation conditions. As the best proxies attainable within this context, alarms are raised based on the relative concentration and age of the released substance. That is, users are notified if a substantial fraction (1) of the release may reach the farm in a relatively short time (2). (1) and (2) respectively correspond to "Fraction" and "Age" thresholds, that the user may modify to parameterize notification.

Service Module purpose

The knowledge that marine conditions are such that releases from pre-identified sources have large chance to reach the farming area (and notification of when this risk arises at least three days in advance) could trigger actions from the farm managers. This includes early harvest (if the model predicts a sufficient time period until potential contamination), delayed harvest (allowing the mussels to self-purify, after the contaminated water has passed the farm area), or extra/enforced quality control procedures in order not to threaten public health.

Cross-sectorial

SM-A2 may match with some requirements of the Oyster Ground Restoration sector in the cases where 1) fixed sources are known in advance, 2) a regular watch may be beneficial concerning the potential influence over a predetermined area. However, it seems unsure that the short forecast timescales required for the Aquaculture sector are of relevance for the Oyster Ground Restoration sector.

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

4.3.4 Service Module A3 – Site Prospection

Service Module identification

The purpose of the service module is to identify areas with the highest growth potential and lowest mortality for flat oysters, *Ostrea edulis*, and thereby increase harvest and restoration potential. Oyster farmers tend to face challenges with high spat mortality and variable growth depending on environmental conditions.

Service Module purpose

The service module contains maps of monthly means and variability (Standard deviations) of selected environmental variables important for oyster growth and survival (temperature, salinity, food, particulate organic matter (POM), hypoxia, resuspension of POM). These variables were identified by potential end-users as the most important factors for oyster growth. The environmental variables are obtained mostly from ecological model data, but some (e.g. temperature, POM) can potentially be provided by remote sensing data. The data is used to create a spatial habitat suitability index (HSI) of flat oysters based on user-specific information for the considered species. The user must provide some information about the environmental thresholds of the considered species. The thresholds are used to calculate scoring indices from 0 to 1 for each environmental variable. This information can be used in the future planning of new sites for aquaculture for farmers and managers.

Cross-sectorial

Environmental studies of hydrography and marine biology may benefit greatly from accurate and detailed models. Authorities, consultants, academia, nature conservation organisations and philanthropic investors may commission specialised studies.

4.3.5 Service Module A4 – Spat Capture Assistance

Service Module identification

This Service Module will estimate the period of blue mussel/flat oyster spat settlement and their distribution in a given area and will enable mussel/oyster farmers or flat oyster reef restoration operators:

- → to employ their bivalve spat collectors at the best period of the year, in order to enable the highest efficiency of the spat collectors
- → to employ their oyster spat collectors in the areas with the highest densities of oyster spat in a given period and area, in order to collect the highest yield of spat

According to the requirements of the Customers of this Service Module, it must generate output on two levels:

- Forecast of the time window with the highest probability of spat settlement at a specific location (farm or oyster reef)
- Forecast with distribution and density map within a specific area (Belgian part of the North, Galway Bay, Limfjorden, Black Sea, etc.)

Service Module purpose

The majority of marine bivalves reproduce by releasing large amounts of gametes into the water column where fertilisation takes place. The fertilized egg cells and the consecutive larval stages float in the water column (pelagic phase) and are transferred to other areas by currents. The reproduction is mainly driven by temperature, while the development of the larvae is mainly driven by temperature and feed availability. The higher the temperature (within the optimal range) and/or the higher density of phytoplankton, the shorter the larval development period. The growth of the shell of the larva causes the larva to sink to the bottom and start its benthic phase. This is the period that the larva needs to find a suitable substrate. In some cases, like for the blue mussel (*Mytilus edulis*), the spat can still detach itself and uses its byssal threads as a parachute in the water current to attain a better place. In the case of the flat oyster, this is otherwise (see below).

This means that the shellfish farmer must have an idea of when the spawning takes place (when the temperature threshold is reached) and how long the larval development will take (amount of temperature x hours/days) before the spat settlement will take place, in order to deploy the spat collectors (*e.g.* dropper lines, empty shells,).

Especially for the spat of the European flat oyster (*Ostrea edulis*) the condition of the substrate is important, as the spat of this species will not settle on the substrate which has already substantial fouling. This means that when the spat collectors are put into the water too long in advance of the spat settlement, biofouling organisms will have the chance to colonize the substrate, preventing the flat oyster spat to settle on the substrate. Subsequently, with low yields of spat on the collectors. If the spat collectors are deployed too late, then the farmer will miss the window of spat settlement, with subsequently low yields of spat. As the settlement of flat oysters takes place after the first settlement peak and before the second peak of settlement for blue mussels. This provides only a small window to deploy the spat collectors for European flat oysters.

Furthermore, it is also interesting for the shellfish farmer to have an idea about the distribution of the bivalve larvae in the water column. Because the farming site may be situated in an area with low bivalve recruitment due to low connectivity with natural bivalve grounds (*e.g.* mussel beds or oyster reefs). It is, therefore, necessary that the Service Modules can provide a forecast of spat distribution and density, in order to pinpoint the ideal settlement locations for a spat of the target species next to the cultural sites. In this way, spat collectors can be deployed at these locations and subsequently transfer the juveniles to the farming site(s).

Cross-sectorial

As this model could also provide valuable information on the time and quantity of recruitment of flat oyster spat, this model can also be used in the Oyster Reef Restoration project and is therefore also already used in the H2020 project UNITED, in order to find areas where spat settlement could take place naturally (with oyster larvae coming from outside the Belgian part of the North Sea, as it is believed that there are no flat oyster reefs within that area). This model can also simulate the effects of self-recruitment once a flat oyster reef is initiated or an oyster farm is in place. It was therefore decided with the FORCOAST consortium that the Service Module could also include the Irish Pilot.

4.3.6 Service Module F1 - Suitable Fishing Areas

Service Module identification

The main objective of this Service Module is to offer information about the most favourable conditions for fishing. In order to achieve this, the following information will be provided:

- Fishing Suitability Index – optimal habitat conditions for specific species
- Upwelling information – upwelling events are known to generate the most fertile marine ecosystems.
- Information on waves coming from nested wave model for the Northern Black Sea

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

Service Module purpose

The service is developed as a decision support tool for the fisheries engaged stakeholders in the north-western part of the Black Sea. It will provide access to valuable information, such as upwelling events and favourable areas for specific species, in order to help fishermen to maximize the economic efficiency of their activities. The service directly addresses multiple categories of stakeholders, from individual fishermen to mid-size and industrial fishing companies in Bulgaria and Romania.

The idea behind the Service Module is to identify favourable conditions for fishing. The Fishing Suitability Index is implemented to reflect the optimal conditions for specific species. It is similar to the already developed Habitat suitability Index (HSI) for whiting (*Merlangius merlangus euxinus*) within the SkyFISH project (http://skyfish.terrasigna.com/). Optimal conditions were identified based on literature references and with the help of the National Institute for Marine Research and Development “Grigore Antipa” (NIMRD) experts. The Fishing Suitability Index is determined from multiple oceanographic variables (with values ranging from 0.1 – less suitable to 1 – best conditions). Survey and fishery data were used to tune the parameters.

The upwelling events are identified by a strong decrease in a day-to-day tendency of the SST, as well as offshore integral Ekman transport calculated from the 3D field of the velocity in the area of interest. The input data are taken from satellite and model products available through Copernicus Marine Service.

The information on waves is coming from a nested downscaled wave model, developed for this purpose, in the NW part of the Black Sea. The existing wave models do not provide sufficient spatial resolution, thus representing the significant wave height and period in more detail. The NWS wave model is downscaled in the Copernicus configuration (CMEMS data at the open boundary).

Cross-sectorial

The information from the Service Module will be mainly of use for the industrial and private fishermen in the area of interest. Marine transport and recreational marine sports, including tourism, could also benefit from the data on waves and upwelling areas. Since the area of the Service Module covers also the coast, the Fishing Suitability Index and upwelling areas information can be used by the mussel farmers and rapana/sea-shell pickers.

4.3.7 Service Module F2 – Fronts Detection

Service Module identification

This service module will daily locate the main temperature and chlorophyll fronts within the sea surface. This information could help the small pelagic fishing fleet to have more relevant information in their search for rich fishing grounds. Any information that could reduce the search time and locate more efficient areas, will benefit the sector and the environment.

Sea fronts can be identified from remote sensing and/or model imagery. But since the fishing sector needs more processed data to take fast decisions, this Service Module has been designed for fast identification of frontal areas.

Service Module purpose

Ocean fronts are narrow areas at the sea surface, where a sharp gradient between two water masses with different hydrodynamic properties occur. Across frontal areas, there is a strong gradient in a short horizontal distance in the physical and biochemical properties of the seawater. There are different types of fronts depending on their location, persistence and size. Frontal areas play an important role

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

in the ecosystems and in different human activities, including fisheries as there is usually a higher concentration of commercial fisheries along fronts. In this service module, 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 front information together with other ocean information is useful in fisheries to search for suitable habitats for small pelagic and avoid other species. This Service Module will therefore reduce the costs associated with days at sea (person-work, fuel, fungible...) and thus, optimise the resources in sea operations. In short, the Front Detection service module is addressed to the fisheries sector by providing it with another source of information about the ocean conditions to reduce the time at sea and the distance travelled, with the final purpose of contributing to a more efficient activity.

Cross-sectorial

This Service Module can be applied to the other wild fisheries pilots within the FORCOAST consortium, *i.e.*, the Bulgarian Pilot. This service is applied to global remote sensing data provided by Copernicus and could, therefore, be useful to other areas outside both pilot areas (Bay of Biscay and Black Sea).

The spatial resolution of the resulting output is not relevant for the remainder sectors: Bivalve Aquaculture and Oyster ground Restoration (see also Deliverable 3.10 on Transferability). Nevertheless, in the future and based on the experience of the FORCOAST experts in these sectors, this Service Module could potentially help also these end users, if a higher resolution could be provided.

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

5 Service module dependencies

5.1 Key partners in the organisation of the FORCOAST value proposition

Role -------- Partner	End-User	Data Provision	Platform Exploiting	Advise Support	Others (please specify)	Comments
Deltares				X	Project-based expertise.	Deltares cannot be part of the exploitation after the project completion as a non-profit organization.
EuroGOOS				X	Communication and link to the European Operational Oceanography Community.	EuroGOOS as a non-profit organization cannot be part of the exploitation.
Instituto Superior Tecnico		X	X	X		Exploitation probably through other Instituto Superior Tecnico linked institutions and spin-offs.
Exporsado						
AZTI		X		X	Horizontal expertise and links towards different sectors of the blue economy and stakeholders managing marine and coastal resources.	
Marine Instruments						
University of Sofia		X		X	Communications to Fisheries Sector.	
TERRASIGNA		X	X	X		
Marine Institute		X		X	Can act as the first point of contact for Irish users.	Marine Institute, being a state agency, will not be involved in the exploitation.
Cuan Beo	X				Communication to Oyster Restoration Groups.	
University of Liege		X		X		Restrictions apply to the possibility to get involved in non-research activity. Need to be considered internally, depending on the foreseen final form of FORCOAST. ULiege is a non-profit organisation like Deltares. We cannot commit to providing data after the end of the project without any convention/financial support.
NIMRD				X	Communication to the emerging aquaculture sector.	NIMRD is a public research institute, 100% project-based financed, so we cannot commit to providing data after the end of the project without any convention/financial support.
Jailoo						Jailoo is a private entity specializing in research and operational services, hence continuation after the project end strongly depends on financial conditions.
RBINS	X	X		X		
ILVO	X	X		X	Additional biological parameters on spat.	
Brevisco	X	X		X	Operations at sea	Brevisco has 20 years bof experience with mariculture in the North Sea
DMI		X		X		

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

Aarhus University		X		X	Project-based expertise.	AU is a non-profit organisation like Deltares. We cannot commit to providing data after the end of the project without any convention/financial support.
Oyster Boat	X					
CNR		X		X		
OGS		X		X		

5.2 Service Module R1 – Contaminant Source Retrieval

Key Partners and their activities

- The **Marine Institute** will develop the code for Service Module R1 – Retrieve Sources of Contaminants, and will ensure the transferability to other Pilot sites within the FORCOAST project where there exists an interest in the service provided. This code will be made available to **Deltares**, which will develop the central FORCOAST platform.
- **Cuan Beo** identified as the most important customer, representing the oysterground restoration sector, will provide feedback on the features that must be present in the Service Module and on the most convenient way of user interaction with the application.
- **FORCOAST partners**.
- **TerraSigna** will exploit and maintain the FORCOAST central platform during and after the FORCOAST project, The FORCOAST central platform is the central access point to the FORCOAST information services.
- Some **FORCOAST partners** will develop the hydrodynamic models needed to predict the dispersion of contaminants at each Pilot site, while others will provide several services during and after the project (Table 2).

Key Suppliers

The Key Suppliers are

- Copernicus services: Copernicus Marine Service, Copernicus Climate Service
- The Norwegian Meteorological Institute, through the development of the OpenDrift particle-tracking model (Dagestad et al., 2018) used for tracking contaminants in the seawater.

Key Activities

Further development of the model

Any model providing 3-D currents would be suitable for this Service Module and would not need any further development.

Gathering physico-chemical data

Any physico-chemical data (e.g. river freshwater flux) needed to force the operational models needs to be collected.

Gathering meteorological data

Any meteorological data needed to force the operational models need to be collected.

Key Resources

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

Implementation of Service Module R1 – Retrieve Sources of Contaminants requires the following resources:

- Hydrodynamic currents from operational models.
- Computer resources to run the operational models and keep the service working.
- Human resources for maintenance of the service.

Barriers to Entry Overview

The primary barrier to entry facing a potential user for the FORCOAST system is their ability to provide the required 'set up data 'to run the desired service model, including its validation. ORR groups vary in their ability to provide 'set up data 'depending on their structure, capabilities and years in action.

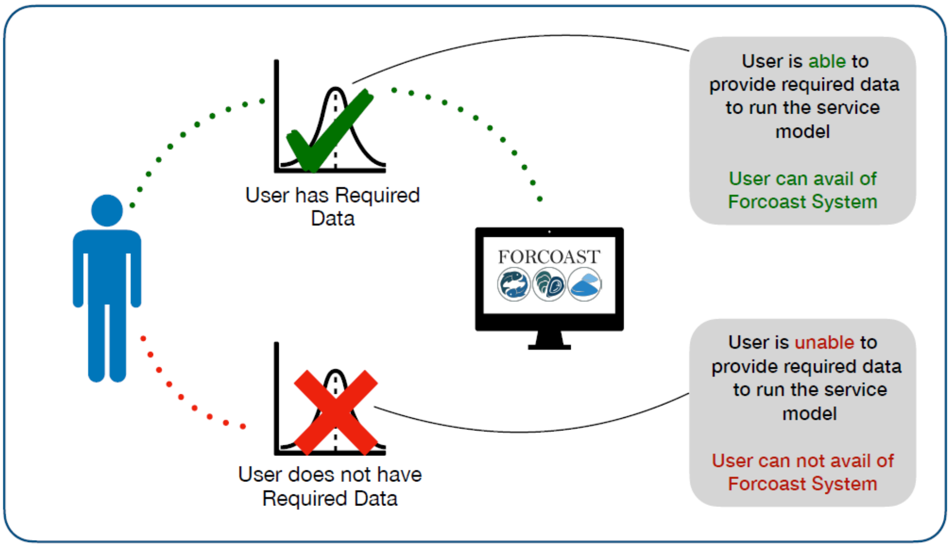


Figure 18. Set up data requirement diagram.

None of the above mention marine environmental monitoring systems outlined in the competition section requires set-up or historical data to be available for their services to be applied. This is a significant barrier to entry unique to the FORCOAST system that represents a challenge for availability.

Table 11. Forcoast Service Modules Required Set Up Data

		Target locations	Source locations	Obstacles	Waterlevel	Sunlight	Wind conditions	Waves	Water currents	Volume of pollutants	Period of pollution	Bathymetry	Temperature	Salinity	Oxygen	Turbidity	Detritus	Food supply	Chlorophyll a	Cue conditioning release events	Duration of release events		Hind cast	Forecast
F1	Suitable fishing areas											X	X	X	X	X		X		X	X		X	X
F2	Front detection											X	X	X	X	X		X		X	X		X	X
A1	Operation scheduler	X			X	X	X	±	±															X
A2	Land pollution	X	X	X			X	X	X	X	X												X	X
A3	Prospection for new sites								X			X	X	X	X	X	X	X	X				X	
A4	Assisstance spat capture	X	X					X	X				X						X	X	X		X	X
R1	Oyster ground restoration	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X

In *Deliverable D3.9 – Sector-specific Decision Workflow Synthesis* a list and extensive explanation of the different initial Service Modules listed in Table 11 can be found.

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

Pilot 5 Ireland 'Available Set Up Data' Case Sample:

- A fine scale hydrodynamic advection model has been developed for Galway Bay and is being validated with observation data on temperature and salinity.
- A sediment model is being developed and will use new sediment grain size data.
- There may be data available in literature on the relationship between cumulative degree days and gonad development for oyster so that temperature data could predict the general timing of spawning.
- Experimental data on response of oysters to range of temperatures and salinities was obtained in 2020.
- Model validation data available from CPT remote sensor loggers (2 years).

Figure 19. Case sample for Pilot 5 Ireland available set-up data.

5.3 Service Module A1 – Marine Conditions

Key Partners and their activities

- **CoLAB +ATLANTIC** for future capitalisation and exploitation activities in Portugal.
- **TerraSigna** has been identified as a suitable candidate to exploit and maintain the FORCOAST central platform during and after the FORCOAST project. The FORCOAST Central Platform is the central access point to the FORCOAST information services.
- **FORCOAST partners** will provide several services during and after the project (Table 1).
- Model developers are at DMI maintaining the Limfjord forecast products of currents, salinity, temperature, sea level, winds, etc. Regular product validation is needed to ensure the quality of the forecast.
- Additional model developments are necessary for the extension to other areas, and other parameters such as waves and sea ice.
- Scientists are available for the extension to other areas and variables in the Baltic-North Sea region.
- Internal user (Oyster Boat) is available to provide feedback on the service and how to address their needs.
- Additional potential end users (Venøsund Fisk og Skaldyr ApS, Vilsund Blue, AQUAPRI Denmark A/S, DTU-MSC, AquaProcess, Blå Biomass ApS, Association Muslingeerhvervet) have been informed about the capacity of the Service Module for the Limjorden.

Key Suppliers

The provision of meteorological forcing from IPMA and river flow from the Portuguese Environmental Agency are key for this high resolution model.

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

UNDERSEE has been subcontracted in the framework of this project to provide near real time observation in the production area.

Key Activities

Further development of the model

There is still a need to collect other sector requirements and set up graphic templates for them.

Gathering biological data

HAB information has been identified as very relevant for many aquaculture producers.

Gathering physico-chemical data

The physical and chemical data need include water level, Chlorophyll *a*, temperature, salinity and nutrients.

Gathering meteorological data

Wind and rain data are seen as key components of this Service Module. Also atmospheric pressure. Currently using a 2.5 km resolution meteorological model from IPMA.

Gathering earth observation data

Satellite SST, chl-a, SPM and optical data are needed with high resolution and accuracy in intertidal areas.

Key Resources

- Access and automatic download of high resolution meteorological forcing from IPMA for the short forecast (next 48h) and the NCEP Global Forecasting System for longer forecasts (up to 14 days)
- Access to near real time river flow from EMODnet and operational simulations of other properties from MOHID LAND applications
- Access and storage of ocean boundary conditions from CMEMS
- Data servers to store and distribute the information through ftp and threads services
- MOHID Water model to simulate the estuarine dynamics
- Scripts to convert the modelling results into the service and the graphic design that can be adapted and easy to understand by the end user.

Barriers to Entry

Getting into the market with customers is difficult since people in the sector have been in the sector forever doing their operations without these. Selling something to them about what they do their whole life is difficult.

5.4 Service Module A2 – Land Pollution

Key Partners and their activities

- **University of Liege** is responsible for the design and development of the A2 service module, in collaboration with **Jailoo**. More specifically, ULiege provided the design of the service module functionality, and the post-processing steps, I.e. deriving from a set of lagrangian tracks the diagnostic relevant to customers and ways to present them. Jailoo has ensured the pre-processing, I.e. the computation of advective tracks for given circulation conditions, relying on the Python module Ocean Parcels. Jailoo provided the various ocean data ingestion modules to adapt the service modules to ocean data provided by the different models (at the

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

different pilots). Both benefitted from expertise in the maintenance of the CMEMS BS-MFC-BIO product.
- **TerraSigna** has been identified as a suitable candidate to exploit and maintain the FORCOAST central platform during and after the FORCOAST project. The FORCOAST Central Platform is the central access point to the FORCOAST information services.
- **FORCOAST partners** provided specific test cases and user requirements specific to their area which contributed to fine-tuning of the final service module (Table 2).

To keep the service up and running, the following ecosystem stakeholders are needed:

- Model developers carrying out the development, implementation and maintenance of coastal circulation models.
- Service Module developer to keep track of updates in the OCeanPArcels dependency
- Sampling environmental data, needed for in-situ validation
- Farmer, providing feedback on the service and how it addresses their needs.

NIMRD experts are trained in local data acquisition and disposal of the local infrastructures to that aim (for the Romanian area).

Key Suppliers

The different ForCoast model producers for met-ocean data at high resolution (mainly marine current forecasts) (including Jailoo for Pilot 7).

Copernicus Marine Service: for wave forecast products and satellite SST data for hydrodynamic model validation.

Key Activities

The Service Module has been tested for two pilot sites (Romania, Pilot 7 and Ireland, Pilot 5) and or the cloud-based deployment (ie. scheduled execution from the centralized FORCOAST platform). As such it counts among the most developed SM in the catalogue.

The computation of advection tracks is inherited from the python module OceanParcels. Hence, further evolution of this third-party open-source package may require to be followed up in further development of SM-A2.

Further functional improvements are strongly dependent on the user’s capacity to characterize sources and nature of land pollutants, and on pilot models to characterize marine conditions. For instance, an extended version of SM-A2 could implement substance-specific reaction modules to be considered along particle advection tracks. Released substances would then be upgraded from a passive tracer (current formulation) to an evolutive tracer representing the growth of bacteria, or the decay of a pollutant. At this point, it made no sense to provide such development without evidence that user or external sources can be used to precise the nature of harmful substances. Another example would be to allow considering temporal variations in the release. Again, this requires the user's capacity to provide such information, or the identification of an external source able to provide this information in real time, or at least on a climatological basis.

More specific validation could be based on the drifter experiment: drifters (or dyes) could be released from the user source locations and the real trajectory compared with the simulated one. However, such targeted validation experiments may be costly and need to be justified by market perspectives.

Gathering biological data

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

In the cases where users require to develop SM-A2 for the specific aim of *E. coli* bacterial outbreak, an intensive protocol would need to be deployed to validate bacterial growth along the advection trajectory.

According to EU Regulation No. 629/2019, the risk of contamination of shellfish is evaluated by reference to the sources and types of faecal contamination (human and animal) in the vicinity of the shellfish production areas (shoreline survey), on the one hand, and the results obtained based on the indicator bacteria *Escherichia coli,* from samples taken in these areas, on the other hand. Areas are classified following a full assessment of this risk and the classification given to an area determines whether shellfish harvested in that area require post-processing treatment and, where appropriate, the level of such treatment.

Criteria for the classification of bivalve molluscs harvesting/culture areas (Table 26).

Class	Criteria for the classification of bivalve molluscs harvesting areas	Post-harvest treatment required to reduce microbiological contamination
A	Samples of live bivalve molluscs from these areas must not exceed, in 80% of samples collected during the review period, 230 *E. coli* per 100 g of flesh and intravalvular liquid. The remaining 20% of samples must not exceed 700 E. coli per 100 g of flesh and intravalvular liquid.	none
B	Live bivalve molluscs from these areas must not exceed, in 90% of samples, 4,600 MPN *E. coli* per 100 g of flesh and intra-valvular liquid. In the remaining 10% of samples, live bivalve molluscs must not exceed 46,000 MPN *E. coli* per 100 g of flesh and intra-valvular liquid	purification, relaying or cooking by an approved method
C	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three-dilution MPN test of 46,000 *E. coli* per 100 g of flesh and intravalvular liquid	relaying or cooking by an approved method

Table 27. Classification of bivalve mollusc harvesting/culture areas according to EU law Regulation (EC) 629/2019

In September 2020, the microbiological survey as per EU Regulation No. 629/2019 was completed in Romanian marine waters. After analysing the results of the samples collected and corroborating them with the shoreline survey carried out by NIMRD, the National Sanitary-Veterinary and Food Safety Authority performed the microbiological classification of all three production and relaying areas of live bivalve molluscs in the Romanian sector (namely Chituc - Perișor, Mamaia Bay and Agigea - Mangalia) in class A. As such, shellfish harvested or reared in these areas can be marketed for human consumption without further purification required. It must be underlined that classification is not permanent and, once regular monitoring indicates non-compliance with the set parameters, classification shall be suspended and the entire process must be re-run, in order to allow safe marketing on the local and European markets.

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

Gathering physico-chemical data

The data gathering for drifter-based validation of SM-A2 was designed within certain experiments in adjacent areas of the Eforie mussel farm.

Gathering meteorological data

The Pilot model is dependent on operational atmospheric forcing data, currently obtained through the ECMWF data servers.

Gathering earth observation data

Remote sensing data is required only sporadically, in the course of the validation exercise. Those are thus required upon the evolution of the pilot model, but not for daily operational production.

Key Resources

Running the service module requires the operational provision of modelled currents. Human intervention is required only in case of operational chain failures or in case of (upstream) model upgrades with changes to the forecast files. Furthermore, contrary to the operational hydrodynamic forecasting model itself, a hypothetical failure of the service module on a given day does not compromise the following cycles. Thus, the operational maintenance cost of the service module should be quite limited.

Updates to the service module may consist mainly of (1) upgrading the Ocean Parcels code to the newest version, (2) adding capabilities to consider different (new) hydrodynamic model forecast files.

Without considering these updates, and assuming no cost for the hydrodynamic forecasts, the key resources required by the service module can be summarized as follows:

- a platform able to automatically download all required forecasting files (from various THREDDS or FTP servers corresponding to different geographical sites), both for hydrodynamics and waves. The platform should have sufficient computing resources in order to perform the Lagrangian simulations,
- relatively limited human supervision in order to detect operational chain failures, rectify them; and potentially periodically perform updates and/or upgrades.

Barriers to Entry

Given uncertainties on the source location, discharges rates, and nature of pollutants, as well as operational meteorological and oceanographic forcings, it would be almost impossible to provide any kind of certified guarantees regarding the risk of contamination. Moreover for a sanitary matter that may trigger legal, or administrative implications.

5.5 Service Module A3 – Site Prospection

Key Partners and their activities

- **DMI** is developing the Service Module and generating multi-year hydrodynamic hindcast in Limfjord
- **Aarhus University** develops a hydrodynamic Limfjord hindcast model using Flexsem coupled to a biogeochemical model for Limfjord
- **TerraSigna** has been identified as a suitable candidate to exploit and maintain the FORCOAST central platform during and after the FORCOAST project. The FORCOAST Central Platform is the central access point to the FORCOAST information services.
- **FORCOAST partners** will provide several services during and after the project (Table 1).

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

Key Suppliers

Copernicus Marine Service provides open boundary conditions and remote-sensing products. The Danish National Monitoring Program provides validation data for the models.

Key Activities

Further development of the model

Ice and hypoxia forecast service have been identified by the stakeholders. However, this has not been planned in the FORCOAST project. Although the current Limfjord forecasting system can provide ice forecast in SM A1, however, there are no activities planned in FORCOAST to improve the product. A biogeochemical modelling system has been developed by AU and used to produce hindcast. However, no activities have been planned in FORCOAST to provide a forecast, including hypoxia. These issues may be further improved after the project end.

The ecological model provides three groups of algae (diatoms, flagellates, picoplankton) and detritus as food sources for bivalves. However, it is currently not possible to model the outbreak of venomous algae. The combination of machine learning, remote sensing data and ecological modelling may be able to produce this information in the future. The model includes benthic mussels but the spawning and spat fall are not currently included. By combining the ecological model with the lagrangian modelling of mussel spat dispersal and settling, this could be achieved.

Gathering biological data

Following biological data are needed according to the user survey in Limfjord: venomous algae leading to shell closure and non-feeding, spat fall of blue mussels and oysters.

Gathering physico-chemical data

The physical and chemical data need to include: hourly SST, T/S profiles, dissolved oxygen, Secchi depth or light attenuation, H_2S, Chl a concentration, algae species, distribution of benthos, and nutrients.

Gathering meteorological data

Air temperature and humidity, light irradiance, cloud cover, winds and precipitation are needed.

Gathering earth observation data

Satellite Sea Surface Temperature, Chlorophyll a, Suspended Particular Matter and optical data are needed.

Key Resources

Key resources used for developing this Service Module include:

- Hindcast data production: an 11-year high-resolution model dataset on hydrographic conditions has been produced and validated for the Limfjord by DMI (supported by FORCOAST)
- The environmental data behind the service module is generated by the 3D FlexSem model consisting of a high-resolution hydrodynamic model coupled to the biogeochemical model ERGOM developed by AU (supported by FORCOAST)
- The algorithms behind the Habitat Suitability index were developed by AU (supported by FORCOAST)
- Platform development: Deltares is developing an information platform which can display the forecast products (supported by FORCOAST)

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

Barriers to Entry

In progress

5.6 Service Module A4 – Spat Capture Assistance

Key Partners and their activities

- **RBINS** developed and maintains the larval transport model LARVAE&CO (Lacroix et al., 2013). This model was developed to assess flatfish larval dispersal, recruitment at nurseries and connectivity between spawning grounds and nurseries (Barbut et al., 2019) as well as the impact of climate change on sole recruitment and connectivity in the North Sea (Lacroix et al. 2018). This model has also been used, after some adaptations to other species such as blue mussels and flat oysters, to assess for instance the impact of artificial hard substrates on marine organism's dispersal (project UK-INSITE-UNDINE), or the possibility of oyster bed restoration (BE-Oyster restoration project). Model results of the dispersal of mussels and oysters in the Belgian waters, obtained using a very simple parameterization, are available for the period 2000-2010.
- **EV-ILVO:** will keep on providing the necessary biological data to maintain the Service Module, but also provide additional data to expand the Service Module.
- **TerraSigna** will exploit and maintain the FORCOAST central platform during and after the FORCOAST project, The FORCOAST central platform is the main access point to the FORCOAST information services, alongside the automated bulletins received via Telegram.
- **FORCOAST partners** will provide several services during and after the project (Table 2).
- **Mussel producers**, in start-up phase.
- BREVISCO: will stay to be an operational partner for data collecting related to the spat capture assistance

- Model developers are in service with RBINS and the modelling of currents, salinity, temperature, waves, etc. is part of the routine business of the personnel, this includes the sampling of environmental data via measuring buoys and routine sampling campaigns in the Belgian part of the North Sea.
- Additional model developers are necessary for the extension to other areas.
- Scientists are available for the extension to other species (collection of biological data) that are present in the Belgian part of the North Sea.
- Farmer/project partner is available to provide feedback on the service and how to address their needs.
- Additional potential end users (Covedco, GeoXYZ, Jan De Nul and DEME) have been informed about the capacity of the Service Module for the Belgian part of the North Sea.

Key Suppliers

- Copernicus services: Copernicus Marine Service, Copernicus Land Monitoring Service (CLMS), Copernicus Climate Service
- Regional data collectors
- Internet providers
- Other important key partners are organisations that can provide information on the distribution of natural oysterground, e.g. oyster fisheries, knowledge institutes, environmental protection organisations, etc. (see Table 1). This is necessary information for the model in order to pinpoint the different sources of larvae/spat.

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

- BREVISCO: will stay to be an operational partner for data collecting related to the spat capture assistance

Key Activities

Further development of the model

The model has not been validated yet due to a lack of data (in 2020 a first attempt was undertaken to analyse the settlement window in situ, but no discrimination was made between the spat of European flat oyster and Pacific oyster). It is the objective of the FORCOAST project to validate the model with data collected *in situ* (ongoing). The model will benefit from an improvement of the parameterization such as for instance the inclusion of vertical migration or prey availability. Moreover, this model will be coupled to the growth dynamics of organisms, in order to simulate several generations, and to the MIRO&CO model, which describes the biogeochemical and ecological dynamics in the English Channel and the southern North Sea, especially N, P, Si, chlorophyll a concentration and primary production. The more recent version of the 3D marine biogeochemical model MIRO&CO (Dulière et al., 2017) results from the coupling of the 3D hydrodynamic COHERENS v2 model (Luyten, 2011) with the biogeochemical MIRO model (Lancelot et al., 2005). MIRO is a biogeochemical model that has been designed for *Phaeocystis*-dominated ecosystems (Lancelot et al., 2005). The MIRO&CO model describes the biogeochemical and ecological dynamics in the English Channel and the southern North Sea. Model results of nutrients (N, P, Si), chlorophyll a concentration, primary production, etc. are available over the period 2000-2010 (grid resolution 5 km x 5 km). A model validation performed by Dulière et al., (2017) showed that the model is able to capture the geographical distribution of nutrients and in particular the strong coastal gradients (Figure 2), but it underestimates Chl a concentration in the Belgian waters (Dulière et al., 2017). To validate the seasonal dynamics of Chl a, phytoplankton species and nutrient concentrations, model results have been compared against in-situ observations at station 330 located in the centre of the Belgian waters (51°26.00’N, 2°48.50’E). The nutrient seasonal dynamics are well reproduced by the model. Chl a is well estimated on average except during spring bloom, where the peak magnitude is underestimated in the model. From a comparison with remote sensing chlorophyll observations, it has been shown that the timing of the spring bloom is delayed in the model, in particular for the Belgian coastal and central stations (Dulière et al., 2017).

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

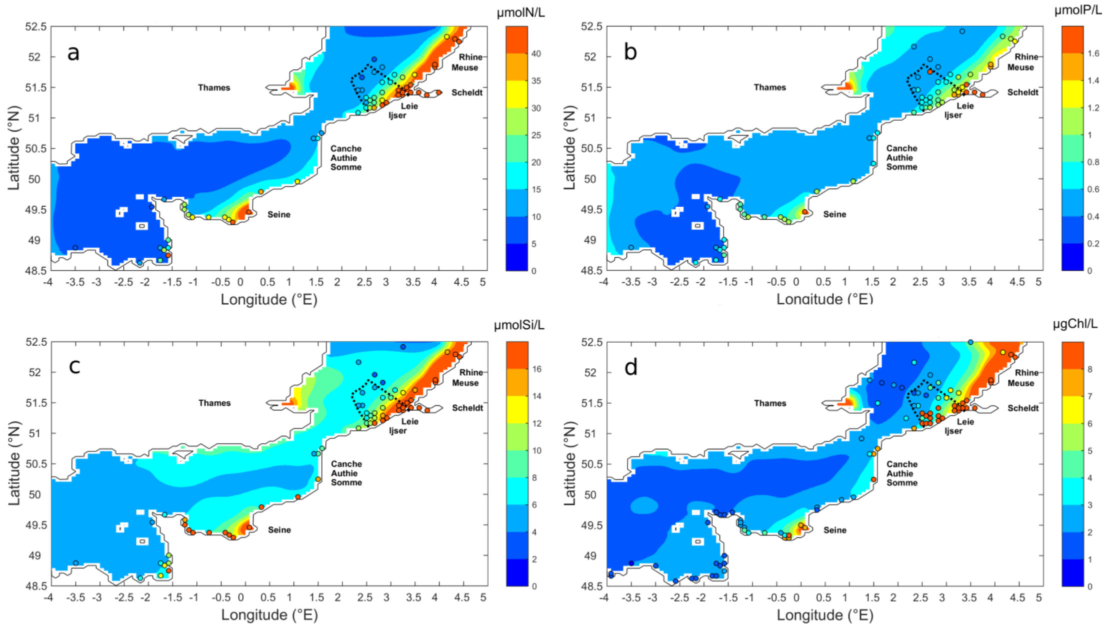


Figure 20. Spatial distribution of dissolved inorganic nitrogen (din, a), dissolved inorganic phosphorus (dip, b), dissolved silicate (dsi, c) and chlorophyll a concentrations (d). values are averaged from miro&co results over the period 2000-2010 (Dec-Feb for nutrients, mar-oct for chlorophyll a). the dotted line delineates the Belgian EEZ. superimposed dots represent in situ data (Dulière et al., 2017).

Gathering biological data

The aim of the Service Module – Assistance for spat capture is to determine the period where spat of specific species is likely to arrive in the collecting location(s). That implies having information on potential sources where the spat comes from, 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 the spat at the location. This information is given by local expertise:

- Cues for conditioning spawning events: Each species has a specific reproduction period, which can depend on the location. This information can be provided by knowledge institutes and from literature.
- 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. This information can be provided by knowledge institutes and from literature.
- Dispersal duration: The drift duration is also species specific. 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. The time period of spat settlement for blue mussel and flat oyster is investigated by EV ILVO within the FORCOAST project.

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

- Source location(s): Service Module – Assistance for spat collection and distribution 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 for example, local expertise and/or from a drift model. In the case of the Belgian Pilot, this information will be provided by a larval transport model.

Key Resources

Key Resources for the development and maintenance of Service Module – Assistance for spat capture exist of:

- Input data from physical parameters, including current, wave direction and surface & bottom temperature. The parameters are measured in situ in several locations in the Belgian part of the North Sea. These data are collected by RBINS and is an ongoing mandated assignment.
- Input data from biological parameters, including:
  - Chlorophyll-a, SPM, and turbidity are measured by RBINS and VLIZ (annual sampling campaigns)
  - Chlorophyll-a can be supplied by the remote sensing data
  - The life cycle of target organisms is provided by ILVO and the University of Ghent (this is mainly gathered on a project base)
- Input data on the distribution of the target species: this is provided by ILVO and VLIZ by ongoing sampling campaigns, and from knowledge institutes from The Netherlands, France and the UK.
- The Service Module forecast is based on a hydrodynamic model (temperature, wave) and biogeochemical model (chlorophyll) developed by RBINS. The setup of the Service Module is estimated around 10-15 working days, providing that all the required input data is available. Otherwise, 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 (at a cost of 627€/day according to the RBINS tariff applicable for services provided to for-profit organizations in Belgium and abroad in 2020). This will guarantee that the service will continuously be provided on time and, in case of an issue (ex. No meteorological forecast delivered, HPC failure), that the users will be notified. Regarding the Belgian part of the North Sea, this service will be maintained in the long-term beyond the FORCOAST project as other products provided by the Belgian Marine Forecasting center (https://odnature.naturalsciences.be/marine-forecasting-centre/). For other areas, a hydrodynamic model is needed, e.g. Marine Institute for Galway Bay (Ireland), Aarhus University for Limfjorden (Denmark). Chlorophyll-a can be supplied by the remote sensing data.

Barriers to Entry

Given uncertainties on life history traits and the adult population, uncertainties on the results of the service can be difficult to estimate. For some species in specific areas, scientific literature screening, data collection for calibration and, in the most uncertain cases, scientific studies could be needed.

The situation today strongly differs from 2018/2019 when the FORCOAST project and its objectives were developed. Due to today’s fuel prices, the mussel farmer has other problems on his mind than the service modules.

5.7 Service Module F1 – Suitable Fishing Areas

Key Partners and their activities

Give a description of the Key Partners and their activities that are needed to develop and maintain the Service Module.

- Sofia University will develop the nested wave model with high resolution for the Western Black Sea and implement the upwelling identification algorithm
- **TerraSigna** will develop the algorithm for the calculation of the Fish Suitability Index. It has been identified as a suitable candidate to exploit and maintain the FORCOAST central platform during and after the FORCOAST project. The FORCOAST Central Platform is the central access point to the FORCOAST information services.
- **FORCOAST partners** will provide several services during and after the project (Table 2).

Key Suppliers

The Key Suppliers are

- Copernicus services: Copernicus Marine Service, Copernicus Climate Service

Key Activities

Further development of the model

The nested wave model with high resolution in the western Black Sea is fully developed and will not require further effort. The algorithms for the calculation of the Fishing Suitability Index and the upwelling areas require additional tuning. Validation of the developed services is difficult as specific information on fish availability and catch is needed and is generally difficult to achieve.

Gathering biological data

Data on fish stock, habitats and migration.

Gathering physico-chemical data

Essential physical and biogeochemical parameters: temperature, salinity, currents, Chlorophyll-a, primary production.

Gathering meteorological data

At the moment meteorological data will be needed as input to the wave model, future developments forsee to integrate the information on extreme meteorological events and alert in the service.

Gathering earth observation data

Copernicus Marine Service: data from the satellite observations and models of essential oceanographic variables, such as Sea Surface Temperature, Salinity or Chlorophyll-a.

Key Resources

In order to implement an adequately functioning Service Module for Fishing suitability the main key resources are:

- Copernicus Marine Service products: Black Sea Physics Analysis and Forecast, Black Sea Monthly and 8-days Reprocessed Surface Chlorophyll Concentration from Multi-Satellite Observations + SeaWiFS Daily Climatology, Black Sea High Resolution and Ultra High Resolution Sea Surface Temperature, Black Sea Monthly, 8-Days and Daily Interpolated Surface Chlorophyll Concentration from Multi-Satellite and Sentinel-3 OLCI observations
- Adequate computer resources in order to execute the codes and store the data
- Human manpower to ensure the smooth execution of the project

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

Barriers to Entry

In progress

5.8 Service Module F2 – Fronts Detection

Key Partners and their activities

- **AZTI** is the model developer in Pilot 2 and within this institute, the Marine Technologies department is in charge of the development and operationalization of this hydrodynamic model.
- **Marine Instruments** has designed the Service Module in collaboration with Azti.
- **TerraSigna** has been identified as a suitable candidate to exploit and maintain the FORCOAST central platform during and after the FORCOAST project. The FORCOAST Central Platform is the central access point to the FORCOAST information services.
- **FORCOAST partners** will provide several services during and after the project (Table 3).

To keep the service up and running as it currently is, the following ecosystem stakeholders (without considering the stakeholder in charge of the platform maintenance, and data transferring) are needed:

- Model developers carrying out the development, implementation, and maintenance of hydrodynamic models in areas where the service is currently accessible or where it is foreseen that the service capabilities will be extended.
- End-users: shipowners, skippers, or a fleet, providing feedback on the service and how it addresses their needs and for the in-situ validation of the service.
- Researchers, for continuing researching for the improvement and validation of the service.

This service requires the following stakeholders, who are knowledgeable about the requirements:

- modellers: to keep the models updated, running, and linked to the distribution platform,
- end-users: to receive their feedback about the service,
- and researchers, to validate the service and improve it.

Key Suppliers

The main key suppliers are those that provide the datasets used to force this pilot's models:

CMEMS

IBI_ANALYSISFORECAST_PHY_005_001

- cmems_mod_ibi_phy_anfc_0.027deg-3D_PT1H-m: Hourly 3D fields of current speed components (*uo*, *vo*), temperature (*thetao*) and salinity (*so*).
- cmems_mod_ibi_phy_anfc_0.027deg-2D_PT1H-m: Hourly 2D fields of sea surface height (*zos*).

MeteoGalicia

12-hourly WRF 12km resolution 2D model output used for atmospheric forcing: Air temperature at 2m (*temp*), sea surface temperature (*sst*), relative humidity at 2m (*rh*), precipitation rate (*prec*), downward short-wave radiation (*swflx*), downward long-wave radiation (*lwflx*) and wind components at 10m (*u*, *v*).

Euskalmet

WRF 1km resolution 2D model output used for atmospheric forcing (AZTI FTP server): Air temperature at 2m (*t2m*), sea surface temperature (*tsk*), relative humidity at 2m (*rh2*), precipitation rate (*pre*),

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

downward short-wave radiation (*swd*), downward long-wave radiation (*lwd*) and wind components at 10m (*u10*, *v10*).

Key Activities

Further development of the model

To make this service module a workable service module across various sections, further knowledge and analysis are required of other fisheries and time experience of the knowledge put to use. For example, the service module is applied both to hydrodynamic model outputs and to remote sensing imagery. In the first case, it would be necessary to search for regional or coastal models covering the new areas and adapt the code to the corresponding spatial resolution. In addition, a validation of the results in each area would be advisable.

Key Resources

- Key resources are those provided by the key suppliers indicated above..

Barriers to Entry

As long as we know there is no exclusivity of this kind of service and no regulative limitations. Regarding the licensing, this SM requires a *License conditions algorithm: Apache 2.0*

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

6 Financial

6.1 Cost estimates, CAPEX and OPEX

To quantify the expenses required for the upkeep of the FORCOAST platform and services after the completion of the FORCOAST project, we distinguish between capital expenses (CAPEX) and operating expenses (OPEX). Within the context of FORCOAST these are distinguished as follows:

Capital expenses (CAPEX):

- Expenses associated with expanding the service portfolio offered from FORCOAST. Either:
  - By introducing (transferring) existing services to other areas or,
  - By introducing new services.
- Expenses associated with improving the services offered by FORCOAST. For example:
  - By improving the quality of the underlying hydrodynamic and/or water quality models as run at the FORCOAST pilot areas, through additional calibration and validation.
  - By collecting additional measurement data to support additional calibration and validation of the models.
  - By continued development of the services offered (improvements to algorithms, visualizations, etc), to improve them from prototype to TRL9.
- Expenses associated with improving the central FORCOAST platform from prototype to TRL9.

Operational expenses (OPEX):

- Day-to-day expenses are required to keep the FORCOAST platform and services up-and-running with the service levels and support required by users. (Excluding the improvements and changes mentioned under CAPEX costs.)

To quantify the OPEX costs, the following key categories are relevant:

- OPEX costs related to the maintenance of hydrodynamic and/or water quality models running at the FORCOAST pilot areas
- OPEX costs related to the FORCOAST services (Service Modules) which use the results from the hydrodynamic and/or water quality models as input. This includes any one-off efforts to activate the automated service delivery upon user request and with user specified input.
- OPEX costs related to the maintenance of the central platform from which these FORCOAST services are offered
- Other OPEX costs linked to day-to-day exploitation of the FORCOAST services (marketing, administration, etc)

6.1.1 Cost estimation process

The process to quantify the CAPEX and OPEX costs as listed in the previous section is ongoing. In this report, we will provide a breakdown and an initial estimation of key OPEX costs. Noting that these are in the process of being refined in preparation of “D6.4 - Final business plan” (to be submitted in October 2022). Estimates of CAPEX costs are only covered in the present deliverable in part, since the key initial CAPEX costs are already covered by the FORCOAST project funding during its development, and hence don’t need to be recovered by revenues created post-FORCOAST project. Furthermore, CAPEX costs associated with improving or expanding the services offered will largely be incorporated in “D5.7 - Report on applications of the platform including Roadmap for achieving TRL 9” (to be submitted in September 2022). Furthermore, based on further end-of-project user feedback, we will be able to identify those areas where FORCOAST has room for growth, and thus the highest potential for CAPEX investment to generate additional revenue based on end-user demand. Estimating the costs of the obtained list of potential improvements will be part of the activities carried out to evaluate the CAPEX costs, alongside the cost estimation of other points identified by the consortium.

For reference, Annex 1 contains the forms which are being used to collect the relevant cost estimates from the relevant project partners. Among others, input gathered in this way thus far served as the basis for the initial cost estimated in the subsequent sections.

6.1.2 Initial Operating expenses (OPEX) estimates

The continued exploitation of the FORCOAST services post-FORCOAST project relies on the partners and stakeholders involved in the exploitation strategy (Deliverable D6.5 – Initial Exploitation Strategy). Hence, to quantify these costs accurately, estimates from all relevant partners are required. The list of roles expressed per partner in the FORCOAST exploitation can be found in the 'Key Partners' points of the different Service Modules in Section 4. Noting that this process is ongoing, initial, indicative OPEX estimates have been derived based on input provided by partners and experience thus far with the various FORCOAST activities. These have been extrapolated to overall estimates in the below table.

The continued exploitation of the FORCOAST services post-FORCOAST project relies on the partners and stakeholders involved in the exploitation strategy (Deliverable D6.5 – Initial Exploitation Strategy). Hence, to quantify these costs accurately, estimates from all relevant partners are required. The list of roles expressed per partner in the FORCOAST exploitation can be found in the 'Key Partners' points of the different Service Modules in Section 4. Noting that this process is ongoing, initial, indicative OPEX estimates have been derived based on input provided by partners and experience thus far with the various FORCOAST activities. These have been extrapolated to overall estimates in the below table.

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

OPEX costs FORCOAST				
Hydrodynamic and/or water quality models at pilot sites				
Pilot area	**Category**	**Estimate (Euros/year)**		**Note**
1.1 Western Black Sea	Support and maintenance	5000		
	Infrastructure costs	1000		
1.2 Bay of Biscay	Support and maintenance	5000		
	Infrastructure costs	1000		
1.3 Galway Bay	Support and maintenance	5000		
	Infrastructure costs	1000		
1.4 Sado Estuary	Support and maintenance	5000		
	Infrastructure costs	1000		
1.5 Southern North Sea	Support and maintenance	5000		
	Infrastructure costs	1000		
1.6 Limfjord	Support and maintenance	5000		
	Infrastructure costs	1000		
1.7 Western Black Sea	Support and maintenance	5000		
	Infrastructure costs	1000		
1.8 Northern Adriatic Sea	Support and maintenance	5000		
	Infrastructure costs	1000		
Service Modules				
Service	**Category**	**Estimate (Euros/year)**	**Estimate (Euros/user)**	**Note**
2.1 Suitable fishing areas	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.2 Front detection	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.3 Land polution	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.4 Contaminant source retrieval	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.5 Marine conditions	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.6 Assistance for spat capture	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		500	
2.7 Site prospection	Support and maintenance	4000		
	Infrastructure costs	0		Infrastructure costs covered by "Central Platform"
	Setup scheduled bulletin with user input		N.A.	
Central Platform				
Central Platform	Support and maintenance	15000		
	Infrastructure costs	12000		DIAS hosting costs
TOTAL		**103000**		

The following considerations apply:

- For the hydrodynamic and/or water quality models at the pilot sites, it holds that these are often utilizing infrastructure which is also used for other (non-FORCOAST) activities by the associated partners. The same holds for the support, maintenance, organization and processes required to ensure that these models stay up-and-running continuously. Although this has already been considered in the present estimates to some extent, these cost estimates will be further refined based on an agreement on which part of these costs should be charged to the FORCOAST exploiters.
- The support and maintenance costs required for the Service Modules and the Central Platform are based on hands-on experience thus far. However, as we move from development to production, the effort required to ensure that the Service Modules are running continuously will decrease since initial start-up problems will have been resolved by that time. Also, an economy of scale might lead to a reduction in costs, which has not been considered in these estimates yet.
- The “per user” effort to set up scheduled jobs per user may decrease as the number of users increases. The economy of scale has not been considered in these estimates yet.
- Operational expenses related to service exploitation (marketing costs, administration costs, …) are not incorporated. These will be incorporated in “D6.6 - Final exploitation strategy”.

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

These considerations aside, as an initial, indicative ballpark, the OPEX costs required to keep FORCOAST services running in the state as delivered by the end of the project are presently estimated in the order of 100k Euro/year. These estimates will be refined for “D6.4 - Final business plan”.

6.1.3 Initial Capital expenses (CAPEX) estimates

The main Capital expenses (CAPEX) estimates to set up the FORCOAST platform prototype and services are incorporated into the FORCOAST project. Nonetheless, additional CAPEX costs might be required post-FORCOAST project, related to:

1. Expanding the service portfolio offered by FORCOAST
2. Improving the services offered by FORCOAST
3. Improving the central FORCOAST platform from prototype to TRL9.

Regarding these costs, indicative estimates for (3) will be derived as part of “D5.7 - Report on applications of the platform including Roadmap for achieving TRL 9”. Costs associated with (2), in so far as these are not part of (3), cannot be determined at this stage, since the relevant improvements are not known at this stage. Initial estimates for (1) are provided below, to be refined for “D6.4 - Final business plan”.

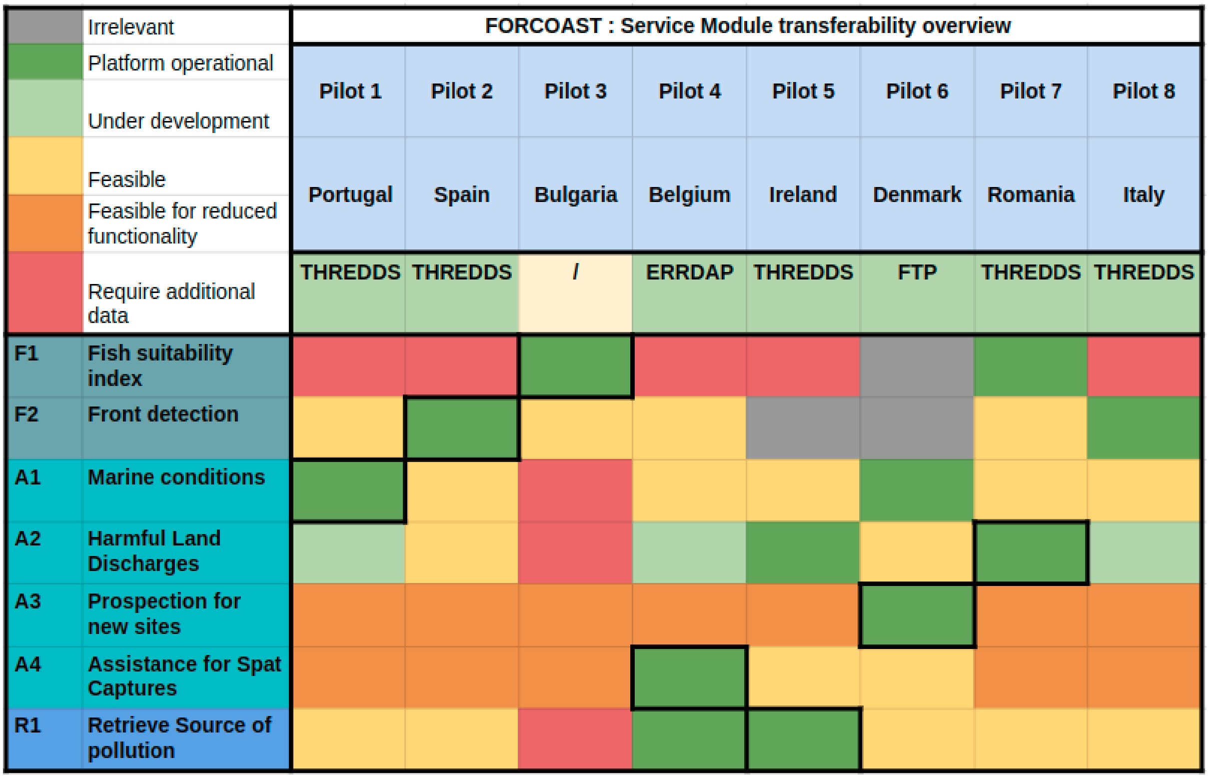
Expanding the service portfolio offered by FORCOAST can be done in several ways:

a. By introducing (transferring) existing services to other areas where the required hydrodynamic and/or water quality models required to provide input are already present,
b. By introducing (transferring) existing services to other areas where the required hydrodynamic and/or water quality models required to provide input are not present yet,
c. By introducing new services, not yet part of the FORCOAST service portfolio by the end of the FORCOAST project.

Again, costs associated with (c) cannot be estimated at this time, since the relevant services are not known at this stage.

<u>Transferring services (Service Modules) to areas where local hydrodynamic and/or water quality models are present</u>

For (a) the following table as included in “D3.10 Technical specifications for tailored products” indicates the potential transferability of the FORCOAST services (Service Modules) to other pilot areas presently included in FORCOAST (i.e. for which local hydrodynamic and/or water quality models are present).



Indicative cost estimates to transfer these services to pilot areas for which they are not implemented yet by the end of the FORCOAST project (i.e. yellow and orange cells) are as follows:

		Estimate (Euros/pilot area)	Note
F1	Fish suitability index	3000	If parameter settings for the algorithm are available for this area
F2	Front detection	3000	
A1	Marine conditions	3000	
A2	Harmful land discharges	6000	
A3	Prospection for new sites	7500	
A4	Assistance for spat captures	6000	
R1	Retrieve source of pollution	3000	

These estimates cover the technical implementation in both the back- and front-end, as well as QA on the results.

Furthermore, these estimates are based on our hands-on experience transferring these Service Modules to other pilot areas thus far. As we are moving from development to production, and as we continue building experience transferring these services to other pilot areas, these estimates will be refined for “D6.4 - Final business plan”.

Note that the cost estimate provided for F1 is conditional to the availability of the parameter settings for the algorithm used. If these parameter settings are not available and need to be derived as part of the transferral process, additional measurement data is required. Cost estimates related to this have not been included yet.

Furthermore, note that although our experience thus far is with transferring services to other pilot areas within FORCOAST, services can also be transferred to other areas where local hydrodynamic and/or water quality models are already available. If the required hydrodynamic and/or water quality model data is accessible through OGC web services for those areas, it is expected that comparable costs as those provided in the above table apply.

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

Transferring services (Service Modules) to areas where local hydrodynamic and/or water quality models are not present yet

If no local hydrodynamic and/or water quality models are present for an area of interest yet, two options are available:

1. Rely on coarser resolution CMEMS data,
2. Develop a local, high resolution hydrodynamic and/or water quality model for this area

Option 1 is possible for several of the services under development from a technical point of view at least but at the cost of local accuracy and a lower granularity (spatial and temporal) of the resulting service. In this case, cost estimates will be in a similar ballpark as those provided above for areas where local models are already available.

Option 2 is conditional to the effort invested in calibration and validation, and the necessity to collect in-situ data for model validation. Indicative estimates are provided below.

	Estimate (Euros/model)	Note
Development local hydrodynamic model	100000 - 200000	
Development local water quality model	100000 - 200000	

Note that these estimates are very coarse, in view of the uncertainty in the specifications for calibration and validation. For reference, note that some local or regional hydrodynamic or water quality models have been in continuous development for several years, with total investments exceeding 1M euros over time.

6.1.4 Refining CAPEX and OPEX costs

As described in previous sections, the initial, indicative cost estimates provided are being refined at present. The refined estimates will serve as the basis for "D6.4 - Final business plan" among others. The refinement process will rely on several key activities which are presently taking place:

- Further refinement by all project partners involved of the cost estimates which serve as the basis for the indicative estimates provided. This included an assessment of which OPEX costs should be covered as part of the FORCOAST exploitation, and which OPEX costs are already covered by other means.
- Further refinement based on hands-on experience gained with running both the models and services (Service Modules) in production, related to the effort required in support and maintenance.
- Further refinement based on hands-on experience gained when transferring services (Service Modules) to other pilot sites within the FORCOAST project.

6.2 Costs estimations and analysis per service

6.2.1 OPEX and CAPEX costs estimations per component

The OPEX and CAPEX cost estimations presented in Section 6.2.1.1 and 6.2.1.2 respectively are a result of the cost refinements of the costs presented in Section 6.1, where the consortium partners either confirmed those initial costs or expressed their refined estimates.

6.2.1.1 OPEX costs

Table 28 displays the OPEX costs related to the maintenance of hydrodynamic and/or water quality models running at the FORCOAST pilot areas, developed within FORCOAST to produce the necessary service input. This also includes the storage of the necessary model output data, used by the services as input datasets.

	Cost per Pilot area	
	Support and maintenance	Infrastructure
Pilot 1 - Portugal	5000 €/year	1000 €/year
	Comments:	Comments
Pilot 2 – Spain	5600 €/year	1000 €/year
	Comments Cost of 1 PM for the following tasks: * Adaptation to changes in forcings and configurations * Computation ** and debugging * Regular validation of operational services	Comments Average annual amortisation of a workstation (total cost >3000€)
Pilot 3 – Bulgaria	0€/year (Note: there is no model feeding the services, it is CMEMS data)	0 €/year (Note: there is no model feeding the services, it is CMEMS data)
	Comments	Comments
Pilot 4 – Belgium	5,000 €/year	1,000 €/year
	Comments	Comments
Pilot 5 – Ireland	5,000 €/year	1,000 €/year
	Comments	Comments
Pilot 6 – Denmark	15,000 €/year	1,000 €/year
	Comments AU, FlexSem model, 15,000 euro: we have higher costs in the Nordic countries, this is for setting up the HD and WQ model for a new year, collecting forcing data, running the model, quality check and generate output files in the right format to the SM DMI also has to add costs here	Comments
Pilot 7 – Romania	5,000€/year	1,000 €/year
	Comments	Comments
Pilot 8 - Italy	5,000 €/year	1,000 €/year
	Comments	Comments

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

Table 28. Costs of maintaining hydrodynamic and/or water quality models at Pilot areas per year, indicated by partners.

Table 29 displays the costs related to the FORCOAST services (Service Modules) which use the results from the hydrodynamic and/or water quality models as input. This also includes any one-off efforts to activate the automated/scheduled service delivery upon user request and with user specified input. Note that infrastructure costs are covered in the ”Central Platform” costs.

	Cost per Service	
	Support and maintenance	Scheduled bulletin setup with user input
F1 – Suitable Fishing Areas	4000 €/year	500 €/year
	Comments	Comments
F2 – Fronts Detection	2800 €/year	500 €/year
	Comments Cost of 1/2 PM for the following task: * Adaptation to changes in protocols for sending the data to the DIAS. ** Resolve data transfer issues. The Service Module requires outputs from the model, we assume that the cost of the Maintenance of the model is not included here.	Comments
A1 – Marine Conditions	4000 €/year	500 €/year
	Comments	Comments
A2 – Land Pollution	4000 €/year	500 €/year
	Comments	Comments
A3 – Site Prospection	5000 €/year	500 €/year
	Comments we have higher costs in the Nordic countries	Comments (
A4 – Spat Capture Assistance	4000 €/year	500 €/year
	Comments	Comments
R1 – Contaminants Source Retrieval	4,000 €/year	500 €/year
	Comments	Comments

Table 29. Costs of maintaining each Service (Module) per year, indicated by partners.

Table 30 displays the OPEX costs related to the maintenance of Central Platform from which these FORCOAST services are offered as demonstration.

		Preliminary costs	Estimated costs
Platform Costs	Support and maintenance	15,000 €/year	15,000 €/year
	Infrastructure (incl. DIAS costs, from which the first two years are already covered)	12,000 €/year	12,000 €/year

Table 30. Costs of maintaining the Central Platform per year, estimated from D6.3.

Table 31 displays the Marketing, User Engagement and Administration costs of each Service to promote each of them, engage with the users and cover administration costs.

F1 – Suitable Fishing Areas	750 €/year	Comments:
F2 – Fronts Detection	750 €/year	Comments: The Marketing, User Engagement and Administration actions will be adjusted to this estimation.
A1 – Marine Conditions	5000 €/year	Comments: User engagement will need a person to attend specific events and to meet the aquaculture sector in their events and in their production areas. Marketing and design of the services.
A2 – Land Pollution	750 €/year	Comments:
A3 – Site Prospection	1500 €/year	Comments: we have higher costs in the Nordic countries
A4 – Spat Capture Assistance	750 €/year	Comments:
R1 – Contaminants Source Retrieval	750 €/year	Comments:

Table 31. Marketing, User Engagement and Administration costs per Service per year, indicated by partners.

6.2.1.2 CAPEX costs

Table 32 displays the CAPEX costs of introducing (transferring) existing services to other (FORCOAST Pilot) areas, where input data is already available via models producing the necessary input or CMEMS data. In other words, costs to set up the service module to run with data available at other pilot areas, assuming relevant data is available in the appropriate way. So, this cost includes: connecting the service module to data, testing, and adding to the front-end and scheduler. Preliminary estimates based on experience thus far.

F1 – Suitable Fishing Areas	2000 €/area	Comments:
F2 – Fronts Detection	3,000 €/ area	Comments: If the data will be ready at the level of the new pilot, this action will be to implement the data flow.
A1 – Marine Conditions	3000 €/ area	Comments: It will depend also if they don't require other variables that need to change the display.
A2 – Land Pollution	6000 €/ area	Comments: price may be reduced if the model in the new domain is one already supported by the service module (currently NEMO, ROMS, MITGCM, MOHID)
A3 – Site Prospection	15.000 €/ area	Comments: we have higher costs in the Nordic countries. This is for adjusting the algorithms, and thresholds to the considered species and data availability
A4 – Spat Capture Assistance	6000 €/ area	Comments:
R1 – Contaminants Source Retrieval	3,000 €/ area	Comments:

Table 32. Costs of transferring Service (Modules) to areas with input data already available, indicated by partners.

Table 33 displays the CAPEX costs of introducing (transferring) existing services to other locations where there is no input data available for such service, neither from local models nor CMEMS, or that are outside of the original FORCOAST Pilot areas. Note that, in addition to the costs presented in Table 33 which cover the setup of the necessary model/s, costs of the previous item have to be added as well to reach a fully operational Service (Module) implementation, which is presented in Table 32.

Areas with hydrodynamic input data missing	50,000-100,000 €/model + cost of previous item	Comments: IST: I believe that our value is lower than 100k-200k. I would say that 50K-100K but will depend on the complexity of the area. The value has been adjusted to this.
Areas with water quality input data missing	50,000-100,000 €/model + cost of previous item	Comments: IST: I believe that our value is lower than this one. I would say that 50K-100K but will depend on the complexity of the area. The value has been adjusted to this.

Table 33. Costs of transferring Service (Modules) to areas without input data available, indicated by partners.

Table 34 displays the CAPEX costs of introducing new services (modules). Development of service modules scripts and algorithms targeting different users' requirements to the ones covered by the FORCOAST service catalogue. Note that, in addition to the costs presented which cover the development of a new service (module), the costs of one of the two previous items have to be added as well to reach a fully operational Service (Module) implementation.

New service (module) to an area with available input data	50,000-100,000 €/service + cost of setting up the service	Comments: We estimate a workforce of one year (8 PM), which could be approximately 44800 €/service
New service (module) to an area with no available input data	50,000-100,000 €/service + cost of setting a new model	Comments: We estimate a workforce of one year (16 PM), which could be approximately 89600 €/service

Table 34. Costs of implementing a new Service (Modules) to an area, indicated by partners.

Table 35 displays the CAPEX costs of (significantly) improving the quality of the underlying hydrodynamic and/or water quality models that run at the FORCOAST pilot areas, through additional calibration and validation.

Pilot 1 – Portugal (LISOCEAN model)	50,000-100,000 €/model	Comments: IST maybe halve of this range depending on the difficulties to improve.
Pilot 2 – Spain (Bay of Biscay model)	50,000-100,000 €/model	Comments: New model simulations and products by the improvement of one or more of the following aspects: *Coupled modelling waves and currents

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

		*Improvement of the horizontal and vertical resolution to better resolve the sub-mesoscale. *NRT data assimilation (HR satellite products and HF radar) and eventual access to non-free data * Validation of new products
Pilot 3 – Bulgaria (CMEMS – <u>not applicable</u>)	------------------------	------------------------
Pilot 4 – Belgium (COHERENS UKMO)	50,000-100,000€/model	Comments:
Pilot 5 – Ireland (Galway Bay model)	50,000-100,000€/model	Comments:
Pilot 6 – Denmark (Limfjord model)	50,000-100,000€/model	Comments:
Pilot 7 – Romania (Black Sea North-Western Shelft model)	50.000-100.000€/model	Comments: cost range depends also on collaboration with local and/or international partners
Pilot 8 – Italy (Adriatic Sea model)	50,000-100,000€/model	Comments: fine tuning of model parameters and benthic fluxes

Table 35. Costs of improving local models, indicated by partners.

Table 36 displays the CAPEX costs of collecting additional measurement data to support additional calibration and validation of the models.

Pilot 1 – Portugal (LISOCEAN model)	10000€/ data collection campaign	Comments: IST: This should be an annual value
Pilot 2 – Spain (Bay of Biscay model)	30000€/ data collection campaign	Comments: Coastal ad-hoc campaign, - Material: drifters (at least ten units: around 10000€), glider mission and ADCP with own means (associated cost of the glider mission, e.g., 10-days glider mission cost: 8000€) - Vessel daily allocation, for deployment of glider and drifters, could be around 2500 €/day

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

		in collaboration with existing open ocean regular biological campaign for having fish abundances data. *Not including the data analysis.
Pilot 3 – Bulgaria (CMEMS – <u>not applicable</u>)	------------------------	------------------------
Pilot 4 – Belgium (COHERENS UKMO)	10,000€/ data collection campaign	Comments:
Pilot 5 – Ireland (Galway Bay model)	10,000€/ data collection campaign	Comments:
Pilot 6 – Denmark (Limfjord model)	00€/ data collection campaign	Comments: we have monitoring data in this area
Pilot 7 – Romania (Black Sea North-Western Shelft model)	10.000€/ data collection campaign	Comments: price will be established by the local institute (NIMRD / Constanta, Romania)
Pilot 8 – Italy (Adriatic Sea model)	10,000€/ data collection campaign	Comments: routinary data collection is already ongoing, the cost is related to raw data organization and processing (e.g., spike removal, de-trending, etc...)

Table 36. Costs of data collection, indicated by partners.

Table 37 displays the CAPEX costs of continued development of the services offered (improvements to algorithms, visualizations, etc), to improve them from prototype to TRL9.

F1 – Suitable Fishing Areas	10,000€	Comments:
F2 – Fronts Detection	2,500 €	Comments: For ensuring the continuous service (e.g., backup input of model data in case of interruption of the high-resolution model) (Validation campaign is not included here, but in previous tables

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

A1 – Marine Conditions	5000 €	Comments: The service would need improvements to accommodate other variables and different ranges.
A2 – Land Pollution	8000 €	Comments: reaching TRL9 will also depend on the user providing actual pollutant releases. This is not (and cannot) included in the estimated cost
A3 – Site Prospection	10,000 €	Comments: would be better to also include suspended cultures in the future. Would be better to be able to choose specific months from each year (productive season) and not only a time series
A4 – Spat Capture Assistance	15,000€	Comments:
R1 – Contaminants Source Retrieval	8,000 €	Comments:

Table 37. Costs of develop the services to TRL9, indicated by partners.

Table 38 displays the CAPEX costs of expenses associated with improving the central FORCOAST platform from prototype to TRL9.

Preliminary costs	Estimated costs
150,000 €	150,000 €

Table 38. Costs of maintaining the Central Platform per year, estimated from D6.3.

6.2.2 Service Module R1 – Contaminant Source Retrieval

Cost Structures

Most important costs

Most important costs are related to the computational effort of running the operational models producing the 3-D current fields for tracking contaminants.

Most expensive Key Resources

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

Similarly, the most expensive key resources will be the computational ones.

Most expensive Key Activities

Once the models are fully operational, no particularly expensive key activities are foreseen.

Revenue Streams

Value of the Service Module

Not possible to estimate exactly as the service module is designed to increase knowledge of marine habitat as opposed to improving revenue streams. One possible estimation could be based on site selection for oyster reef restoration ground which involves deploying suitable substrate for oyster settlement. The deployment of this substrate can cost up to 6,000 euros for 200 tonnes. So possible if we knew the best location for substrate deployment which would not suffer contamination this would result in better value for cultch deployment.

Form of Revenues

Once of payment for service with possible additional payments for improvements or technical support. This is the preferred method used by remote sensor service providers.

Contribution of the Revenue Streams

In the case of the Belgian Pilot, it is for sure that in the very near future two bivalve farmers will initiate commercial activities. Depending on the incentives of the Belgian Government, it is also most likely that one ORR will start with the construction of an oyster reef. This would mean a contribution of 4500 – 9000 Euro per year for the maintenance of the service.

6.2.3 Service Module A1 – Marine Conditions

Cost Structures

Most important costs

The cost for this service consists of developing the pipeline of information and implementing the high resolution model with enough boundary conditions options so it’s not limited by those conditions. The effort in model configurations, validation and calibration are very time-consuming. Setting up the operational architecture and dissemination means from the modelling results to the service also requires some effort. However, these efforts are only needed once. The maintenance cost are relatively low compared with the implementation cost. But other costs, such as user support, marketing and communication/dissemination costs that we are not fully aware of can also increase the SM cost.

Currently, our costs are in maintaining the operational system working, continuous calibration and validation of the numerical models. However, marketing costs and customer service may increase in the future.

Most expensive Key Resources

The most expensive resource is the implementation of the model for a particular area and the monitoring station when necessary. After the implementation phase, the customer service and marketing can be the most expensive resources.

Most expensive Key Activities

Gathering information with end-users and customisation of the service can be expensive until reaching a high level of development.

Revenue Streams

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

Value of the Service Module

During the co-development of the tool with ExporSado, we estimated that arriving 15 minutes late for the adequate tides could cost around 1500€ and this situation can happen more that 6 times per month.

Form of Revenues

The revenues of this service are yet to be investigated but having all the information in one place and easy to access may be interesting for them. It could be each producer to sustain the service or it could be presented to associations or administration for providing the service to the aquaculture community

6.2.4 Service Module A2 – Land Pollution

Cost structures

Most important costs

The most important cost lies in the personnel costs associated with maintenance and update of the pilot model, required to provide met-ocean data at a local scale, and the development and maintenance of the post-processing modules. In addition, the cost of computational resources for operational data provision remains significant.

Most expensive Key Resources

A spatial extension of the service availability, across Europe or beyond, is probably the best strategy to enlarge the potential user base. This potential is already covered by the transferability principles adopted in the FORCOAST Service Design. A larger enlargement would require to secure the access to high-resolution local met-ocean forecast data, in particular concerning ocean circulations. We advice that this can be secured by incorporating local operational met-ocean data providers, external to the projects, in the data stream.

To extend the service finality (eg. addressing the nature of harmful substances explicitly) would demand significant research and development efforts, while the transferability of the produced knowledge may suffer from a lack of transferability.

Most expensive Key Activities

Key upstream activities to support the viability of SM-A2 are :

- Development and maintenance of operation met-ocean data provision. This includes the development of complex 3D hydrodynamic circulation models, which need to be coupled with atmospheric and marine conditions data at their boundary.
- Development and maintenance of the post-processing units, in particular, this involves the Python-based OceanParcels modules to compute Lagrangian tracks, and specific post-processing code to generate FORCOAST specific diagnostics and user-dedicated information.
- Regular local met-ocean in-situ data acquisition. Constant update of the local models requires a strong observational basis to support validation, and characterization of the uncertainty to be associated with the service.
- Advection specific data acquisition. Local drifters experiments would fulfill the need of specific validation of the advection module (ie. the post-processing unit). Such experiments are strictly relevant at local scales, and mostly benefits the validation of the module at each implementation site.

Revenue Streams

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

Value of the Service Module

Considering the novelty of marine aquaculture in the area no services of this type have been developed so far, consequently, the FORCOAST SM is an ice-breaking offer. The willingness to pay is impossible to assess at the moment.

Form of Revenues

No information available.

Contribution of the Revenue Streams

No information available.

6.2.5 Service Module A3 – Site Prospection

Cost Structures

Most important costs

The most important cost lies in the personnel costs associated with the maintenance and update of the pilot model in recent years (e.g., met-ocean data and boundary files) at a local scale, and the development and maintenance of the post-processing modules. In addition, user consultation, service definition, tailored product development, and improved information platform design come with a cost.

After FORCOAST, the most important cost to provide a market-oriented service includes:

- To update the service with more years (up to date)
- To further develop the service for more species and areas
- To improve model products of ecological variables
- To improve the habitat suitability index

Most expensive Key Resources

During the FORCOAST period, the most expensive Key Resources are used to support the model development, calibration and validation and to develop the service module algorithms. To extend the Service Module for a large group of users, the most expensive Key Resources will be to extend the module for other types of aquaculture with new data layers and algorithms.

Most expensive Key Activities

During the FORCOAST period, the most expensive Key Activities are model development, calibration and validation. To extend the Service Module for a large group of users, the most expensive Key Activities will still be the development of new algorithms for habitat suitability of different types of aquaculture (bottom cultures, suspended cultures) and species to meet the user requirements, as we have found that user needs on the model products can be quite different. High resolution models are needed to resolve the habitats on a scale that is relevant for planning new sites for aquaculture.

Revenue Streams

Value of the Service Module

Icing, burial by mud, food depletion, and hypoxia are “life and death” matters to shellfish primary producers and the processing industry. For the planning of new aquaculture sites, it is important to know the dominating marine conditions from previous years to assure optimal growth and low mortality. The SM provide a habitat suitability index that highlights the best area for culturing. Consequently, they carry commercial insurance against these perils. Insurance premiums in well-kept aquaculture business amount to 1-2 % of the biomass value. Assuming that half of the peril is taken out by the Danish Service Module, annual fees up to 50 k€ seem to be justified.

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

Competition and current services

Several advanced consultants run advanced hydrographic/biological models. However, currently, nobody has been able to model shallow water temperature with an accuracy below 0.5 °C. In this respect, the Service Module is second to none. Further, the consultants' models are not easily available or documented. The marine environment service in the Limfjord is not available in the Copernicus service.

Form of Revenues

Since the service is based on hind-cast model products and user settings based on local knowledge and the cultured species, the maps will only change depending on the choice of the user and when updated with new years, algorithms etc. Hence, it is not a forecasting service.

In the case of this Service Module several possible forms of revenue can be identified as:

- Service Revenue, which is generated by providing a service to the customers and is calculated based on time. For example, the number of hours of consulting services provided;
- Project Revenue, which is generated through one-time projects with existing or new customers; and
- Recurring Revenue, which is generated from ongoing payments for continuing services or after-sale services to customers. The recurring revenue model is the model most commonly used by businesses because it is predictable and it assures the company's source of revenue is ongoing. These include subscription fees and licensing content to third parties.

6.2.6 Service Module A4 – Spat Capture Assistance

Cost Structures

Most important costs

The most important debit entry in our business plan is the incorporation of new areas, the coupling of hydrodynamic models of these areas and the incorporation of other bivalve species.

Another important cost is the maintenance of the Service Module, but as the FORCOAST central platform contains several Service Modules, this cost can be divided over the total cost of maintenance of the FORCOAST central platform.

Most expensive Key Resources

When the Service Module – Assistance for spat capture would be extended to other areas, e.g. Galway Bay, Limfjorden, and Black Sea, additional work will be needed to collate the different hydrodynamical models into the Service Module. For this extra Key Resources will be needed.

Most expensive Key Activities

As mentioned above, it is our opinion that the further development of the Service Module with other areas than the Belgian of the North Sea will be the most expensive Key Activity.

Revenue Streams

Value of the Service Module

As there is not yet a commercial bivalve farmer or oyster reef restoration established in the Belgian part of the North Sea, it is still an estimate for what value the end users would pay for this service.

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

Within the project Value@Sea a business plan was made for 65 tons suspended flat oyster farm in the Belgian part of the North Sea. The annual cost for oyster seed to run this farm was 30,000 Euro. From the project SYMAPA it became clear that 86 tubes of 5m with a diameter of 20 cm filled with empty oyster shells are sufficient to capture the necessary spat of flat oysters at the Belgian Pilot site. As one longline can hold 98 spat collectors, it is enough to reserve one longline for spat capture. One longline (screw anchors, mooring lines, backbone and spat collectors) costs 14,000 Euro, with a depreciation period of 5 years and 5 700 Euro of (de-)commissioning costs. As the Service Module would enable the farmer to have an insight into what areas have the highest concentrations of larvae/spat at the time of spat settlement and gives the best timeframe for commissioning the spat collectors. This service could therefore result in an annual saving of 30,000 Euro – 3,940 Euro (longline with spat collectors) = 26,060 Euro.

A value of 5 – 10% of this cost seems to be acceptable for the end users within the Belgian Pilot. This would set the value of the Service Module at **1,303 – 2,606 Euro/year**.

Depending on the requirements of the bivalve farmer, the service requested can be different. For example, a mussel farmer has a concession on a specific location and wants to capture spat at the farming site. For this customer, the Service Module should give them a forecast on the time window with the highest probability of spat settlement, in order to deploy their dropper lines timely. On the other hand, a flat oyster farmer has a plot very suitable for growing oysters, but with low recruitment rates. However, they have a permit to collect oyster spat at six different locations in the Belgian part of the North Sea. This customer wants to have a forecast of where and when the oyster spat settlement will take place at the highest density, in order to deploy his spat collectors timely and at the best location for the highest efficiency. As the Service Module would resolve the high uncertainty in the last case, the Value of the Service Module would subsequently also be higher for this customer.

In the case of oyster reef restoration, the amount of flat oyster juveniles is even larger, with subsequently higher seeding costs. As Oyster Reef Restoration projects are mostly funded by governments and wildlife foundations, natural capture of spat for oyster reef restoration would make the Value of the Service for this activity even more acceptable.

Form of Revenues

In the case of this Service Module several possible forms of revenue can be identified as:

- Service Revenue, which is generated by providing a service to the customers and is calculated based on time. For example, the number of hours of consulting services provided;
- Project Revenue, which is generated through one-time projects with existing or new customers; and
- Recurring Revenue, which is generated from ongoing payments for continuing services or after-sale services to customers. The recurring revenue model is the model most commonly used by businesses because it is predictable and it assures the company's source of revenue is ongoing. These include subscription fees and licensing content to third parties.

The end users from the Belgian Pilot prefer to pay a subscription fee for the use of the Service Module – Assistance for spat capture. The second choice was through a one-time payment, but with the insurance, the service would continue for several years and updates would be included.

Contribution of the Revenue Streams

In the case of the Belgian Pilot, it is for sure that in the very near future two bivalve farmers will initiate commercial activities. Depending on the incentives of the Belgian Government, it is also most likely that one ORR will start with the construction of an oyster reef. This would mean a contribution of 4500 – 9000 Euro per year for the maintenance of the service.

6.2.7 Service Module F1 - Suitable Fishing Areas

Cost Structures

Most important costs

The most important cost is the cost of the human power as well as the computer processor time and storage, necessary to maintain the service alive. The communication events with the target groups are also consuming money and man effort.

As this service module was designed as a demonstration case study, further work will be required in order to make it a fully operational service. Because it is still under development, it is for the moment not yet possible to give estimations on the costs for maintenance.

Most expensive Key Resources

Significant resources will be needed to maintain the service and to relate to other interested working groups in other European and world ocean regions.

Most expensive Key Activities

Significant resources will require the organization of target users events and the development of user-friendly interface. The validation of the proposed service will require interaction with the end users and it is suggested that a discount is offered if the users agree to take part in the validation efforts.

Revenue Streams

Value of the Service Module

To estimate the Value of the Service Module, it was estimated that approximately 10% of the 1,500 potential users would subscribe to the service, with an annual subscription of 30 euros. This would come to revenue of 4,500 euros per year. Of course, much more would be at stake if national/regional agencies would use the service in their daily routine.

Form of Revenues

The most plausible form of revenue is the subscription rate to the service and activation on demand.

Contribution of the Revenue Streams

Bulgaria and Romania are countries with relatively low incomes compared to the other countries in the European Union. It can not be expected that small and medium enterprises as well as individual fishermen could afford to pay large sums for the service. It is more profitable to rely on a small subscription rate and thus increase the number of customers.

6.2.8 Service Module F2 – Fronts Detection

Cost Structures

Most important costs

The most important costs are those produced by the satellites taking images in real time. This is not supported by the FORCOAST Consortium but highlights the importance of this EO mission to keep this type of service. In addition, other important costs are the maintenance of the data servers and computational systems, as well as the analysis time.

Most expensive Key Resources

The most Expensive Key Resources are the information provided by the satellites.

Most expensive Key Activities

Most Expensive Key Activities are based on incrementing user knowledge and type of fishery knowledge. Gaining knowledge on a vast number of fisheries takes time, effort and money for research and understanding analysis.

Revenue Streams

Value of the Service Module

This type of service should be adapted to each fleet. Since their technical resources and general characteristics depending on the region and type of fish. This makes it difficult to charge the same cost to each fishery. Therefore, the value should be aligned with the result of the Profitability per Customer Segment. As an estimation for small pelagics, a Sardine vessel could be paying 100 euro or even less monthly for this type of service.

Competition and current services

The current competition is the data provided by satellite services and or other companies involved in the analysis and distribution of the information. Currently, the data received and/or provided by the satellite's services are not easy to access and/or interpret by some end-users. On the other hand, the data provided can vary in size and frequency depending on the type of data. But taking into account the usual communications onboard of a great part of this fleet, data access is costly and therefore limited. Other companies, which provide similar information after analysis, are companies like Orbimap.

Form of Revenues

Revenue streams can be associations, groups and even individual vessels and companies.

Revenues can be received either on a monthly or annual basis or even for specific single campaigns. In the case of Pilot 2, the duration of such sea campaigns takes weeks or even months during different periods of the year, as they can change the target species according to the season. So this tool could be useful for this Customer Segment for multi-species and it would therefore be preferable to program revenues at the end of each campaign.

Contribution of the Revenue Streams

It is expected that the revenue streams will increase, once the end users see the advantages/value of this Service Module and got used to the way of using the service as part of their daily work processes. Mouth-to-mouth will increment the widely use of this Service Module. The final product can be purchased monthly, per semester or yearly. Depending on the need of each end user. The method of payment can be via bank transfer prior to the use of the data.

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

7 References

Rodríguez, G., Ballesteros, H. M., Martínez-Cabrera, H., & Sánchez-Llamas, E. (2021). XXIV European Association of Fisheries Economists (EAFE) Conference: book of abstracts: Santiago de Compostela (Spain), April, 2-4, 2019. In *XXIV European Association of Fisheries Economists (EAFE) Conference* (pp. 1-233). Universidad de Santiago de Compostela.

Bertolini, C., Brigolin, D., Porporato, E. M., Hattab, J., Pastres, R., & Tiscar, P. G. (2021). Testing a model of pacific oysters'(Crassostrea gigas) growth in the Adriatic Sea: implications for aquaculture spatial planning. Sustainability, 13(6), 3309.

Roncarati, A., Felici, A., Magi, G. E., Bilandžić, N., & Melotti, P. (2017). Growth and survival of cupped oysters (Crassostrea gigas) during nursery and pregrowing stages in open sea facilities using different stocking densities. Aquaculture International, 25(5), 1777-1785.

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