FORCOAST

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

PROJECT DELIVERABLE REPORT

Deliverable Number: D5.7
Deliverable Title: Report on applications of the platform including Roadmap for achieving TRL 9
Author(s): Deltares, Marine Institute
Work Package Number: WP5
Work Package Title: Service Operationalisation, Demonstration & Validation

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	WP5
Work package title	Service Operationalisation, Demonstration & Validation
Deliverable number	D5.7
Deliverable title	Report on applications of the platform including Roadmap for achieving TRL 9
Description	This deliverable provides a report on the practical application of the platform in 8 pilots (task 5.5). The report will also summarize the outcomes of the stakeholder workshops.
Lead beneficiary	Deltares
Lead Author(s)	Deltares, Marine Institute
Contributor(s)	Pilot and Service Module Teams
Revision number	6
Revision Date	31/10/2022
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),	PU

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Confidential for consortium members only (CO))	

Document History			
Revision	**Date**	**Modification**	**Author**
0	23/08/2022	Proposed deliverable structure	Daniel Twigt, Luis Rodriguez
0	06/10/2022	Review of Section 3	Lorinc Meszaros
1	24/10/2022	Section 1 and 2 drafting, using partners contributions	Gido Stoop, Pilot and Service Module Teams
2	25/10/2022	Review	Tomasz Dabrowski, Diego Pereiro
3	27/10/2022	Overall drafting	Luis Rodriguez
4	27/10/2022	Review	Lorinc Meszaros
5	27/10/2022	Drafting, addressing comments and formating	Luis Rodriguez
6	31/10/2022	Check	Ghada El Serafy

Approvals				
	Name	**Organisation**	**Date**	**Signature (initials)**
Coordinator	Ghada El Serafy	Deltares	31/10/2022	GES
WP Leaders	Tomasz Dabrowski	Marine Institute	25/10/2022	TD

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Executive Summary

This deliverable describes (Section 2) practical applications for each of the services in the FORCOAST service catalogue. This includes examples from partner users that are benefiting from the information provided in order to support their operational activities and/or decision-making process. From the user validation of the services, the key message that can be taken from user testimonies is that the service design and implementation have been appropriate in order to attend to their necessities providing solutions to specific questions or issues in the sectors of wild fishery, bivalve aquaculture and oysterground restoration.

The deliverable also reports on (Section 3) the different user workshops that took place in mid-2022, including their structure, objectives and outcomes. These workshops were attended by relevant industry and scientific stakeholders to maximise the impact and dissemination of the FORCOAST offer to key target users. From the workshop outcomes, it can be concluded that the user satisfaction and usefulness of the of the provided services for their cases is high, which reassures the applicability of the services beyond the current partner users. The workshops and follow up communications also highlighted the difficulties the European shellfish industry faces, which in general render the uptake of scientific advances impossible or very difficult.

Lastly, the deliverable depicts (Section 4) the Technological Readiness Level (TRL) of the different components forming the FORCOAST platform ecosystem, both at the beginning of the project and at the end. The section concludes with suggested points making a roadmap to TRL9 for the post-project phase. These points range from increasing the robustness of the system and improving the quality of the underlying model outputs that feed the services to ensuring long-term data supply sustainability.

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Table of Contents

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

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

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1 Introduction

Throughout the duration of the FORCOAST project, a series of activities have been carried out to provide end-users in the three marine target sectors with information services relevant to their operational and management activities. Towards the end of the project, practical applications, and results from stakeholder workshops can be formulated from the latest user ineractions. Furthermore, an evaluation of the Technological Readiness Level (TRL) of the different components have been done, as well as drafting suggested points towards increasing the TRL to 9.

Section 2 describes practical applications for each of the services in the FORCOAST service catalogue. This includes examples from partner users that are benefiting from the information provided in order to support their operational activities and/or decision-making process. Section 3 describes the different user workshops that took place in mid-2022, including their structure, objectives and outcomes of these stakeholder workshops. These workshops were attended by relevant industry and scientific stakeholders in their area to maximise the impact and reach out of the FORCOAST offer to key target users. Lastly, Section 4 depicts the Technological Readiness Level (TRL) of the different components forming the FORCOAST platform ecosystem, both at the beginning of the project and at the end. The section concludes with suggested points making a roadmap to TRL9 for the post-project phase.

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2 Application of the Services

The services provided in FORCOAST are designed as downstream marine information services which can be used and applied in operational and decision-making situations, targeted at the sectors of wild fishery, bivalve aquaculture and oysterground restoration. The information the services provide has been devised in collaboration with user partners based on their needs and interests in the various target sectors they perform their activities (deliverable *D2.1 - Stakeholders interests and needs by sector and pilot site*). This co-design process (deliverable *D3.9 - Sector-specific decision workflow synthesis*) allows each of the final services in the FORCOAST catalogue to address one or more of these situations and needs that are encountered by the end-users in their operations. In the following subsections, practical application examples of each service for all FORCOAST Pilot areas are described.

2.1 Examples of Marine Conditions service application

The service 'Marine Conditions' is aimed at the marine sector to optimize the site operations time window based on local forecast data. The service provides present and forecast met-ocean and meteorological forecasts at the user's location of choice. These forecasts include information on the tides, as well as integrated precipitation quantity and wind information (intensity and direction).

The end users of this service frequently depend on the tidal regime for their operations. Examples of these users are oyster or fish farmers working with sluice gates. Requiring them to know when the tides are low. This can, in turn, increase efficiency and cut costs. An example of one of these end users is Exporsado in Portugal. They operate in the Sado Estuary (Figure 1). Their production process requires them to always work in intertidal areas. Fernando, one of the users of the Marine Conditions service from Exporsado says the following:

"I'm Fernando, the production manager at Exporsado's oyster farms, on the Sado river estuary, in Setúbal, Portugal. The FORCOAST Marine Conditions service helps us a lot as it determines with great accuracy the time window in which we can work in our oyster farms. Wind and atmospheric pressure have a great influence on the speed of the tide and its height and no other system or product integrates these variables in such a localized and easy-to-interpret way as this FORCOAST service. By using this service, we manage to save a lot of time and money in our day-to-day operations."

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Figure 1. Exporsado operations site in Sado Estuary

2.2 Examples of Land Pollution service application

The service 'Land Pollution' is aimed to support quality control of marine activities that are exposed or susceptible to land discharges at fixed locations, which could carry harmful substances. The 'Land Pollution' service provides a risk assessment of pollutants reaching the site of interest from known sources.

The end-users profile includes those in nearshore farming and oysterground restoration sectors. For the oysterground restoration sector, the service is used to determine an area in which oysters can best be deployed, in order to assure their survival by avoiding exposure to pollutant risks. Alec, from the non-profit oysterground restoration organization Cuan Beo from the Galway Bay area said the following about the service:

"My name is Alec, I'm an oyster farmer working in Donegal Ocean Deep Oysters and we use the FORCOAST land pollution service to identify whether any land-based pollution has reached an area of our farm, in what quantities the pollution reaches our farm and how long it remains in a particular area. Utilizing this service, we can identify the areas of our farm most directly impacted by land-based pollution and use this data to show how land-based pollution events can impact aquaculture food production."

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Figure 2. Cuan Beo staff working on one of their oysterground restoration sites in Galway Bay

In the nearshore farming sector, the service could be used to select and/or evaluate the site of operations that won't be contaminated by the land discharges from usual discharge locations. Crivăţ Mirică (Maricultura) from Romania has the following to say about the service:

"Hello, my name is Crivăţ Mirică and I am the only mussel farmer in Romania at this moment. Because the microbiological classification of water was not made, my farm was shut down in 2016. Since 2021, after the authorities made the classification, I got back in business and now the farm has just begun to operate again. We want to use the SM-A2 Land Pollution model to identify whether any land-based pollution has reached the area of our farm, and how long it remains here. By doing this, we can harvest at the right time, and avoid product contamination or need for purification."

Figure 3. Bivalve aquaculture operations at sea in the Romanian coast by Maricultura

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2.3 Examples of Site Prospection service application

The service 'Site Prospection' is aimed at identifying areas with the highest growth potential and lowest mortality for flat oysters and thereby increasing the harvest and restoration potential.

The end-users of this service are users working with bivalve farms and managers in the aquaculture sectors. The service offers possibilities to calculate index values based on user-given parameters and this allows users to set different scenarios with the variables in the model and therefore adjust it to their own case. Environmental variables are never the same, and this service provides a means of experimentation and gaining information before production activities, with the prospect of stabilizing future production. Laurits Bernitt from flat oyster production company Oyster Boat in the Limfjord area (Denmark) stated the following about the service utility in his case:

"My name is Laurits Bernitt – I´ve been an Aquaculture Manager at Oyster Boat for 14 years now. I have never seen two seasons alike, and we are spending vast resources to understand marine conditions and stabilize production. The FORCOAST Site Prospection Service and the Marine Conditions Service may provide the information we have missed so long."

Figure 4. Oyster Boat owner at his operations installations in Limfjord, Denmark

2.4 Examples of Spat Capture Assistance service application

The service 'Spat Capture Assistance' is aimed at estimating the period of mussel or oyster spat settlement. It forecasts a time window with the highest probability of spat settlement, providing a first arrival and last arrival date of the spats to an area.

The end-users of this service are in the shellfish farming sector. The service can be very valuable to them as they can gain information about when the spawning takes place and how long the larval development will take before the spat settlement. Spat collectors can't be put into the water too long

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in advance, so having a time window to operate in can lead to increased working efficiency and thus, less costs. Bert from Brevisco had the following to say about the service:

"Hi, I am Bert working in an experimental offshore oyster and mussel farm in Belgium. I find the spat capture assistance service from FORCOAST very valuable, since this will help me identify the times when spat are likely to arrive in the farm and help me to planned work on the farm and increase spat capture by avoiding too much bio-fouling."

2.5 Examples of Suitable Fishing Areas service application

The service 'Suitable Fishing Areas' provides a map with a relative indexed score of the most suitable places to catch a specific species of fish based on the bathymetry, salinity, and temperature.

The end-users of this service are in the fishing sector. The service can be used to manage the sites in which the fishing activities are carried out and subsequently increase the catch. Vio from the Institute of Oceanography had the following to say about the service and how it can be benecial to the fishing sector in that area as a whole:

"Hi, I am Vio, a marine biologist in the Institute of Oceanology – Bulgarian Academy of Science. My main focus of research is the fish resources in the Black Sea and in my opinion Suitable Fishing Areas service from FORCOAST has potential to help the various activities in the fishing sector in Bulgaria."

Figure 5. Fishing results (whiting) from activities in the Bulgarian area of the Black Sea

2.6 Examples of Fronts Detection service application

The service 'Fronts Detection' is aimed at identifying frontal areas where there is a sharp gradient in temperature and/or chlorophyll concentration in the water. These areas are characterized by higher-than-normal biological activity.

The end-users of this service are in the fishing sector. The service can be used in the fishing operation and planning cycle to reduce the time at sea and the distance travelled, contributing to a more efficient activity. Potentially, the temperature and chlorophyll fronts may also prove helpful for other adjacent sectors in which biological activity plays a role. Finally, the service can be applied to remote sensing data (e.g. provided by CMEMS) and could therefore be used beyond the pilot areas relatively easily without the need for local high-resolution model input to obtain adequate results. Fishery students

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(to become a vessel captain or to improve their education on the topic) from the Basque Country who visited the FORCOAST workshop organised for the Spanish Pilot indicated the following:

"Fisheries students from the Basque Country showed interest in the Fronts detection Service Module and its application in their future work, so they are currently receiving bulletins with this information."

Figure 6. Attendees at the Fronts Detection service workshop

2.7 Examples of Contaminants Source Retrieval service application

The service 'Contaminants Source Retrieval' is aimed at finding the most likely source location(s) of an identified contaminant. It can backtrack the contaminant to its potential and most likely source location through a simulation, providing 'heat maps' animations with outcomes from the backtracking simulation.

The end-users of this service are in the oyster restoration sector and can help oyster farmers to identify possible sources for contaminant events affecting their oyster beds and take action consequently. It can help them understand why a particular site is not performing well and can show regulators how a marine polluting activity can directly impact oyster health, among other things. A representative for Cuan Beo, partner organisation in the oysterground restoration sector said the following about the service:

"Hi, we're Cuan Beo, we work in oyster reef restoration in Galway Bay Ireland and we use the FORCOAST contaminant source retrieval service to understand how land-based freshwater inputs distribute into Galway Bay. This allows us to identify the areas of the bay most directly impacted by land-based pollution, sedimentation, and freshwater overflows. Avoiding these areas in our reef restoration activities will give us a higher yield of oyster populations restored and maximize our efforts in reef restoration."

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Figure 7. Cuan Beo performing different oysterground restoration activities

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3 Stakeholder Workshops Outcomes

From the 30th of May until the 27th of June 2022, a series of user workshops were conducted in which the services were presented to the users and in which the users could try out the services themselves and provide feedback via the 'Mentimeter' web tool. These workshops were conducted per service and per pilot area. This chapter will discuss the results derived from these various workshops.

3.1 Description of stakeholder workshops

In total, 6 workshops were conducted in 4 different pilot areas. These are:

- In Spain, the 'Fronts Detection' workshop was held.
- In Italy, the 'Fronts Detection' workshop was also held along with a workshop on the 'Land Pollution' service.
- In Denmark, the 'Marine conditions' workshop was held along with a workshop on the 'Site Prospection' service.
- Finally, in Bulgaria a workshop was held on the 'Suitable Fishing Areas' service.

There is a common agenda followed in the different workshops, although slightly modified to suit each case (e.g. accommodate two services in one meeting).
The common agenda was as follows:

- Introduction of the FORCOAST services.
- A live demonstration on how to use the service via the FORCOAST platform, also giving the participants the chance to try it.
- Questions round from the participants.
- Introducing the automatic bulletins via Telegram as the full service.
- Collection of feedback through a Mentimeter survey.
- Final round of questions from the participants.
- Ask them to provide contact information if they are interested in testing the services, receiving training and/or remaining engaged along the project.

Since the stakeholders and potential users attending these workshops have been in contact with the partners and engaged in the design and development process of the services, the main goals of the meeting were to:

- Present a use case by one of the project partners as an example of final service use.
- Gather feedback from the participants.
- Set the stage for a free test trial for the participants and assess this access alternative.

The workshops have been held both physically and in an online setting, depending on the situation and possibilities. The advantage of in person mettigns and presentations is a potentially more personal, dynamic, and active participation in the workshop. Nevertheless, most of the workshops were conducted online, to allow users to also join the workshops remote and thus lower the effort the user has to take to join the event, and reduce the amount of avoidable travelling, keeping in mind Covid-19 measures and restrictions in different countries.

3.2 Stakeholder workshop(s) Spain

This workshop was presented by representatives of AZTI and Deltares and centered around the 'Fronts Detection' service. The workshop was held in person. Most of the participants of the workshop were active in the fishery sector (13). While there was also a participant working in the management sector (1) and some participants in other sectors (2). The group consisted of a mix of students (for vessel

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captain), employees, and self-employed entrepreneurs. All participants were either based in the Basque country or Cantabria and worked in the Bay of Biscay.

Below is a table with the participants that were present at the workshop:

Table 1. Participants to the Spanish Pilot workshop

Unai Rodríguez López	Danel Fernández Etxeberria	Jose Antonio López Cerros	Alvaro Rivero Brea
.Julian Garciandia Tellería	Pello Andonegi	Xabier F	Diego Sarabia Ayesa
Beñat López Domínguez	Andrei Barba Rosie	Imanol Zabalegi	Victor Fernández Nargaes
Andoni	Alexander Barrenetxea	Hugo Comes Oms	Beñat Madariaga Carrera
Manuel	Carlos Porto Freire	Illia Zaitsev	

The participants were asked for their impression of the service. All categories scored between a 6.9 and a 7.6 (maximum score is 10), where the findability and retrievability of the infroamtion scored lowest, and the understandability scored highest.

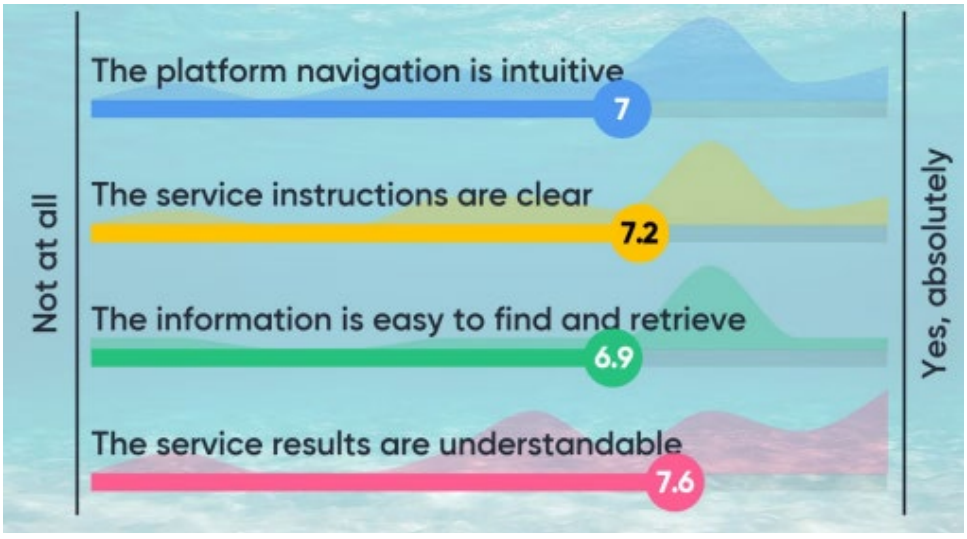

Figure 8. Participants'impression of the service - Spain

The participants were also asked if they would see value in automatically receiving an information bulletin with the most updated forecast the service provides. With a score of 8.8 out of 10, an overwhelming majority thought this feature would add value to their service experience.

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When asked if the participants would make use of the FORCOAST service, 8 out of 16 participants would subscribe to the service as it is, 5 participants would subscribe, but would like to see some changes, and three participants would not make use of the service.

The final multiple-choice question was about the market uptake. The participants were asked to estimate the potential revenue gain the service would provide on a yearly basis. The numbers were far apart. 5 participants estimated a modest gain of 0-100 euros, while other participants said it could even potentially result in a revenue gain of 10,000 to 50,000 euros. However, most participants estimated the revenue gain at about 1,000 to 6,000 euros.

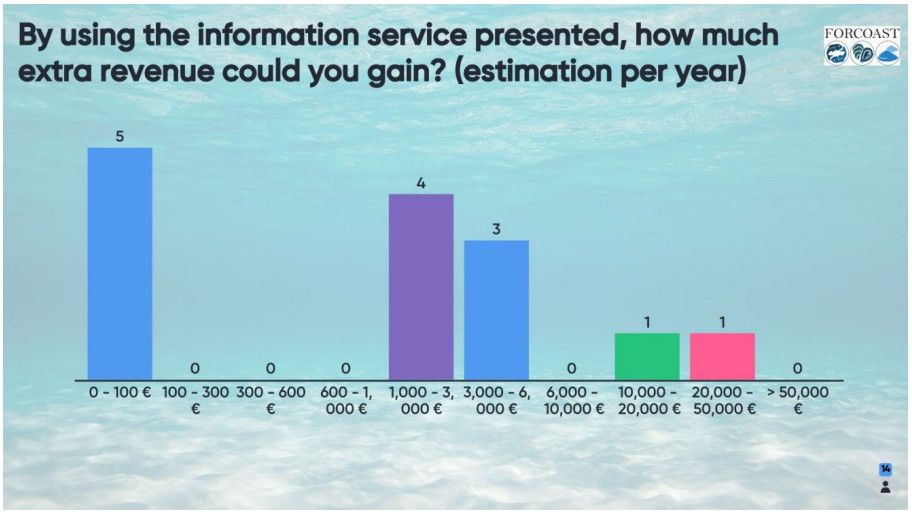

Figure 9. Estimated revenue gain - Spain

When asked for feedback on the service, the following answers were provided:

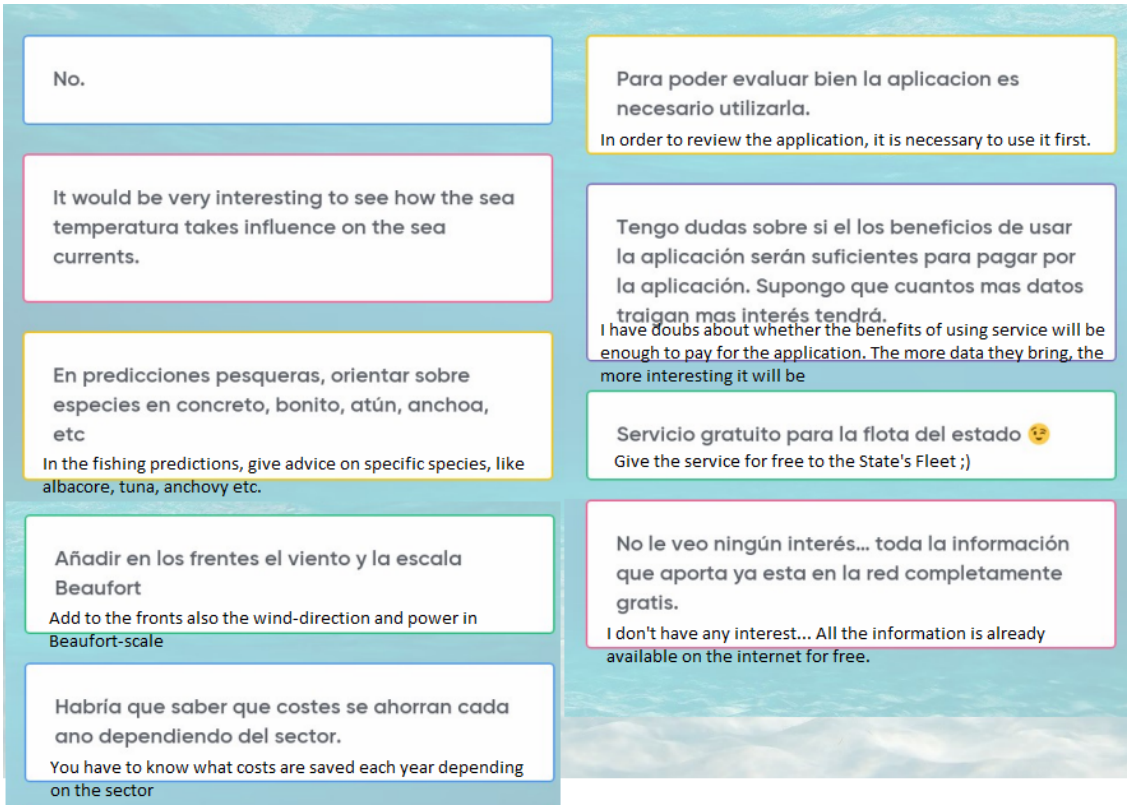

Figure 10. Feedback on the services - Spain

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3.3 Stakeholder workshop(s) Denmark

This workshop was presented by representatives of the University of Aarhus and Deltares and two services were addressed in the workshop. First, the 'Marine conditions' service, and second, the 'Site prospection' service. The workshop was held online and in total there were 8 participants from various companies. The 'Marine conditions' feedback session had 5 participants, whereas 'Site prospection' accounted for 6 participants. This is due to the participants only providing feedback on the services that are relevant to their activities.

The following table includes the workshop participants.

Table 2. Participants to the Dannish Pilot workshop

Company	**Activity**	**Person name**
Oyster Boat	Oyster farmer	Laurits M Bernitt
Venøsund Fisk og Skaldyr ApS	Larviculture Limfjorden	Ole Borbjerggaard
Vilsund Blue	Muslinger farming	MARIA VAN URK
AQUAPRI Denmark A/S	Sea farm	Henning Priess
DTU-MSC	Siting	Daniel Taylor
AquaProcess	Consultation	-
Blå Biomass ApS	Blue mussels	Klaus Astrup Nielsen Lars
Association Muslingeerhvervet	Blue mussels	Henrik Nielsen

3.3.1 A1 – Marine Conditions

Out of the 5 participants in the 'Marine Conditions' service feedback session, 1 participant said he/she worked in the bivalve mariculture sector and 2 participants said they work working in the research sector. The other participants did not answer the question. All of the participants were based in Denmark.

When asked to rate the impression of the service following the demonstration earlier in the workshop, all aspects got a 7.4 out of 10. Although this is overall positive, some participants referred to the ease of finding and retrieving information and the understandability of the service results as less satisfactory.

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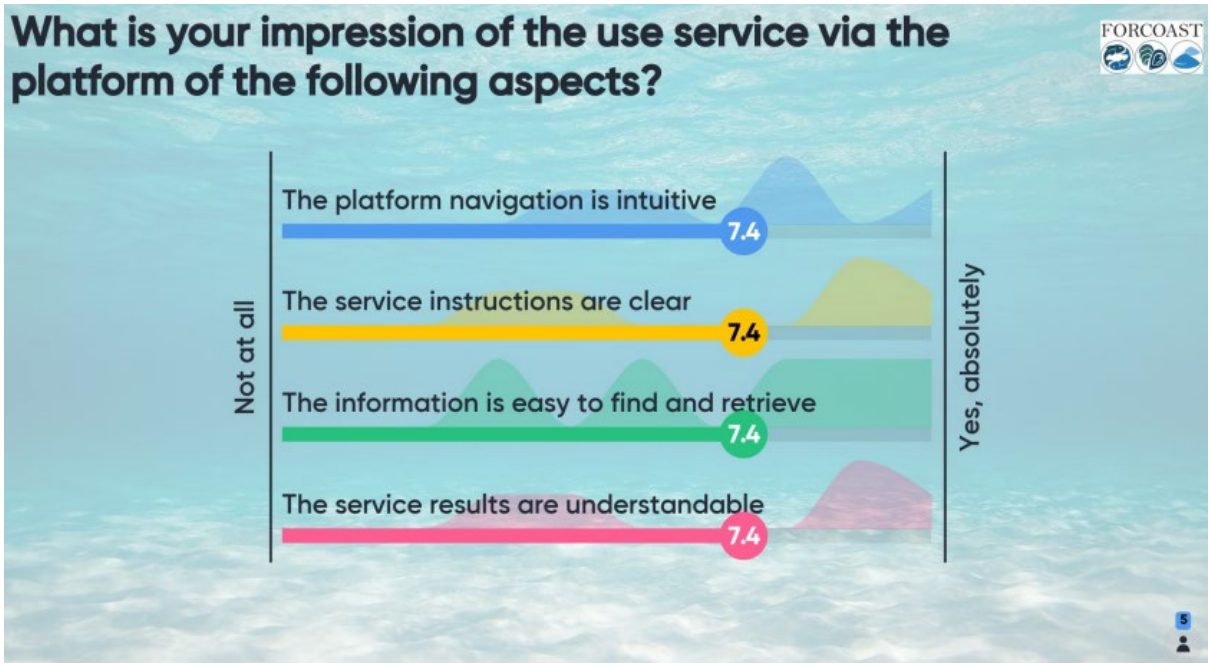

Figure 11. Participants'impression of the service – Denmark, Marine conditions workshop

The participants were also asked to rate the added value to their user experience if they would automatically receive the most recent information bulletins on their smartphones. The participants provided mixed results, where a participant gave it a 10 out of 10, while another participant only gave it a 3 out of 10. Overall, a score of 6.4 was reached. The mixed opinions were also reflected in the next question, where 2 participants would subscribe to the service as it is, 1 participant would use it but would like some changes, and 2 participants would not use the service at all. When asked for the estimated extra revenue the use of the service could provide mixed answers were given between 0 and 6,000 euros.

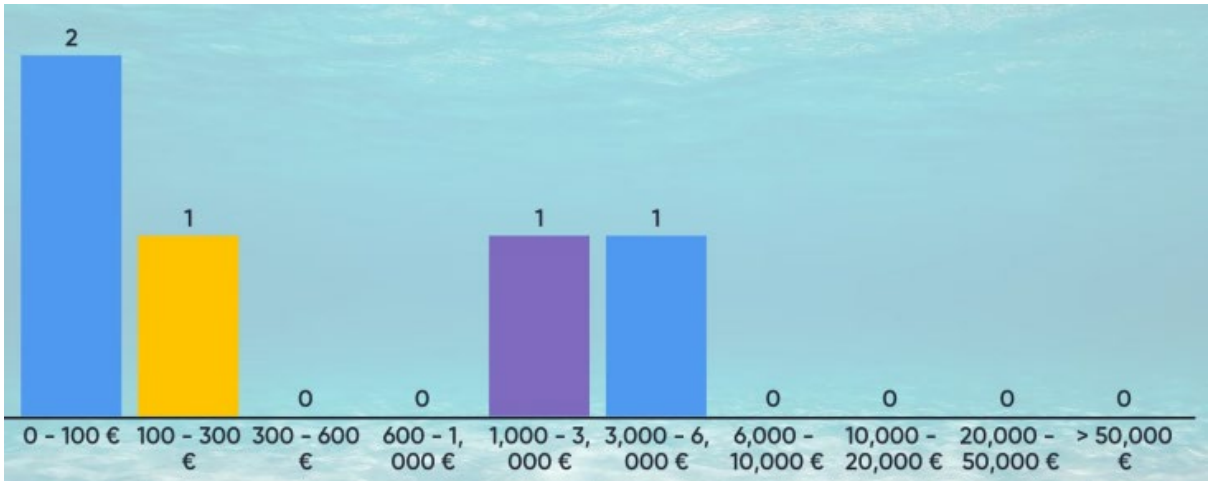

Figure 12. Estimated revenue gain - Denmark, Marine conditions workshop

Finally, when asked for feedback, only two comments were made, emphasizing the importance and uniqueness of the FORCOAST services.

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3.3.2 A3 – Site Prospection

The following workshop for 'Site prospection' had 6 participants. When asking the participants about their impression of the service and platform, the platform navigation and service instructions were both 8 or more out of 10, while the findability of the data and the understandability of the service results scored lower, with 6.6 and 6.8 respectively. Two participants even rated the understandability of the service results to be 4 or 5 out of 10 points.

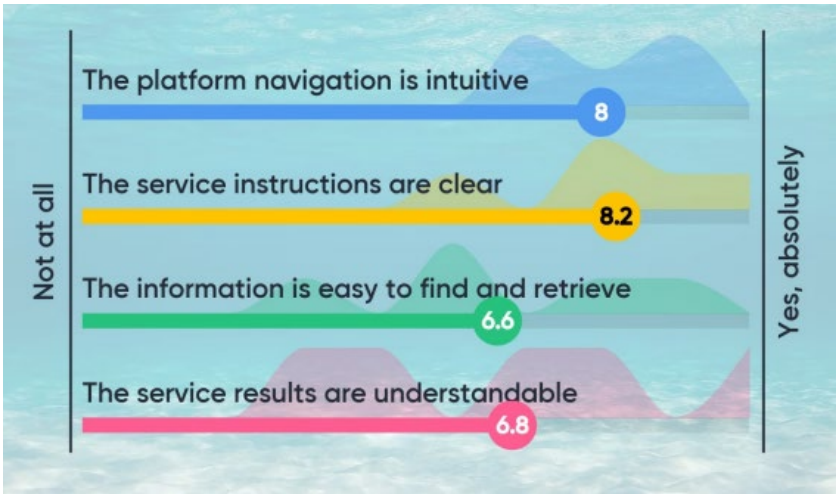

Figure 13. Participants'impression of the service – Denmark, Site prospection workshop

Then the participants were asked to rate the added value of receiving information bulletins through their phones. An average score of 5.7 was reached. This is not really a surprise, as the service is not actually forecasting events, and therefore, receiving scheduled bulletins is less valuable than services that do provide up-to-date forecasts.

When the participants were asked if they would use the service, half of them said they would subscribe to the service as it is (3), while the other half said they would not make use of this service (3).

Finally, some estimates were made on the additional revenue the service could provide. 3 participants said it would be about 0 to 100 euros a year, other participants estimated between 600 and 1,000 euros a year (1) and between 1 thousand and 3 thousand euros a year (1).

In this Mentimeter survey, only one participant provided feedback, saying that: "There is no other source of this information. The information may prove crucial to stabilize production, and is thus very valuable." This feedback reassures that with this service we are providing the information needed to address specific needs crucial to the business of a specific group of end users.

3.4 Stakeholder workshop(s) Bulgaria

On the 27th of June 2022, a user workshop was organized for the 'Suitable Fishing Areas' service for local stakeholders in Bulgaria. The workshop had 14 participants and was done online, hosted in Bulgarian mainly with some parts in English when needed. It was presented by FORCOAST partners from the University of Sofia. 10 participants were active in the research field, 4 in management, 2 in fishery and 1 in aquaculture. All the participants were active in the Black Sea, but not all in Bulgaria. There were also two participants active in the Romanian part of the Black Sea, and one participant in the Turkish part.

The following table shows the workshop participants:

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Table 3. Participants to the Bulgarian Pilot workshop

Name	Organization
Miroslav Tsvetkov	Naval Academy Varna
Dimitrina Kostova	National Fishing Network
Irina Gancheva	Sofia Univeristy St. Kliment Ohridski
Mirna Matov	Muzeiko
Magda Nenciu	NIMRD-Romania
Valery Penchev	Black Sea - Danube Association of Research and Development
Dimitar Dimitrov	Institute of Oceanology
Rumyana Roideva	Black Sea Basin Directorare
Konstantin Petrov	Institute of Oceanology
Ivelina Zlateva	Institute of Oceanology
Irina Makarenko	Black Sea Commission Permanent Secretariat
Veselina Mihneva	Institute of Fishing Resources
Violeta Slabakova	Institute of Oceanology
Mira Robinson	Black Sea Basin Directorare
Violin Raykov	Institute of Oceanology
Nikolay Valchev	Institute of Oceanology
Natalya Andreeva	Institute of Oceanology
Petya Ivanova	Institute of Oceanology
Nina Dzambekova	Institute of Oceanology
Petyq Evtimova	Institute of Oceanology

When asking the participants about their impression of the service and platform, they were positive about the service, giving each category at least an 8.8 out of 10. The understandability of the service results scored the highest with a 9.3 out of 10.

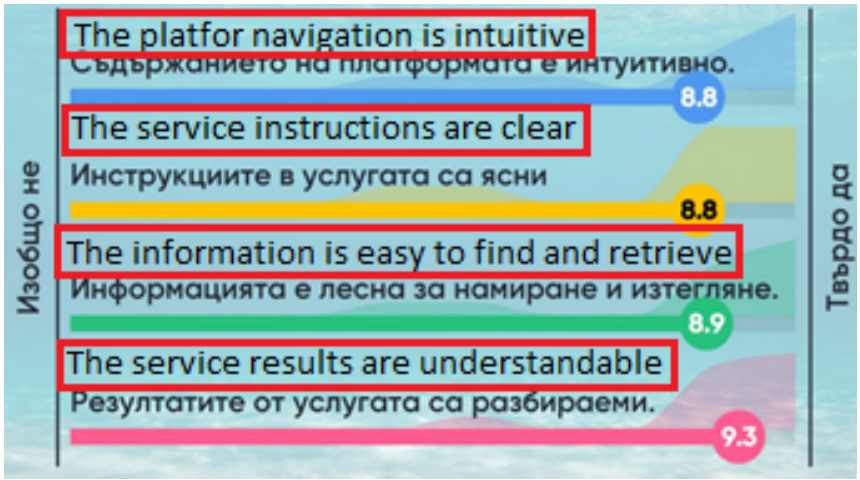

Figure 14. Participants'impression of the service – Bulgaria

They were also positive when asked to give a score from 1 to 10 for the added value of automatic up-to-date forecast information bulletins sent to their phones. An average score of 9.2 was given.

10 out of the 12 participants who answered the question "Would you make use of this service?" said they would subscribe to the service, and the two other participants said they would subscribe but

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would like to see some changes in how the results are presented. Nobody said they would not subscribe to this service.

Finally, when asking for an estimate of the extra yearly revenue the application the service could provide, the category of 100 to 300 euros got the most votes. Other estimates were spread between 0 to 3,000 euros per year.

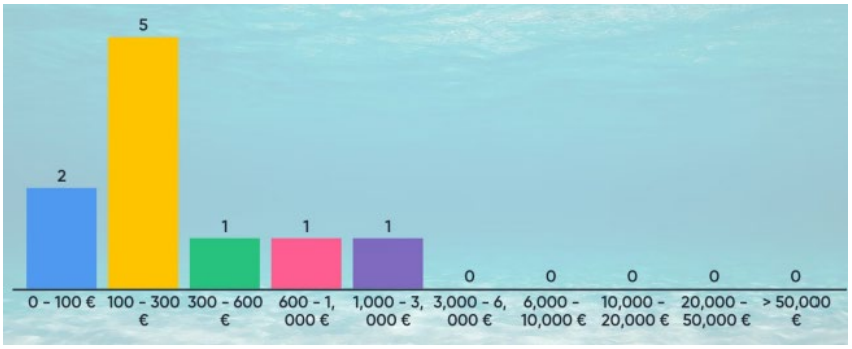

Figure 15. Estimated revenue gain - Bulgaria

Additional comments and feedback from the participants mostly consisted of remarks about the quality and usefulness of the service.

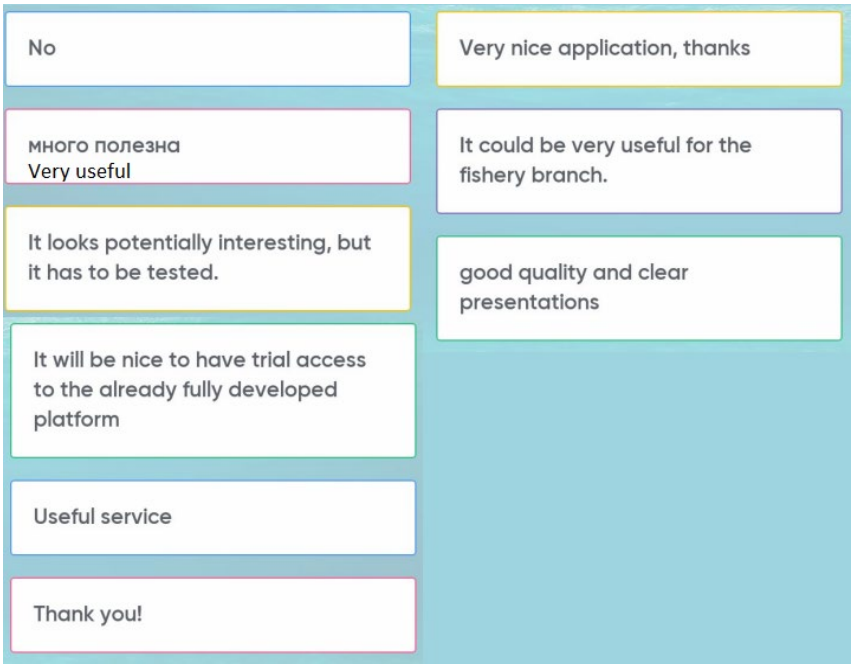

Figure 16. Feedback on the services - Bulgaria

3.5 Stakeholder workshop(s) Italy

This workshop was hosted online and showcased two services. First, the 'Fronts detection' service, and second, the 'Land pollution' service. The workshop had in total 3 participants from various companies. Although this was the lowest attendance compared to the other workshops, the attendees are contacts from aquaculture organisations with a sustancial reach out in the mariculture industry in the Adriatic Sea, and could be seen as intermediate users/contacts. The 'Fronts detection' Mentimeter survey had 3 participants, whereas 'Land pollution' had 2 voters. These three participants indicated in which sector(s) they were performing activities. Bivalve mariculture was indicated twice, while

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oysterground restoration, management and research were all indicated once. All participants were based in Italy.

The following table shows the workshop participants:

Table 4. Assistants to the Italian Pilot workshop

Name	Organization
Lorenzo Gennari	Bivi srl
Giuseppe Prioli	AMA - Associazione Mediterranea Acquacoltori M.A.R.E. Soc. Coop. ar.l.
Andrea Rosina	CORILA

3.5.1 F2 – Fronts Detection

The participants were asked to rate their impression of the service and its use. They were all very positive, with the lowest overall mark being 8.7 for the findability and retrievability of the information. The rest of the statement scored a 9 or higher.

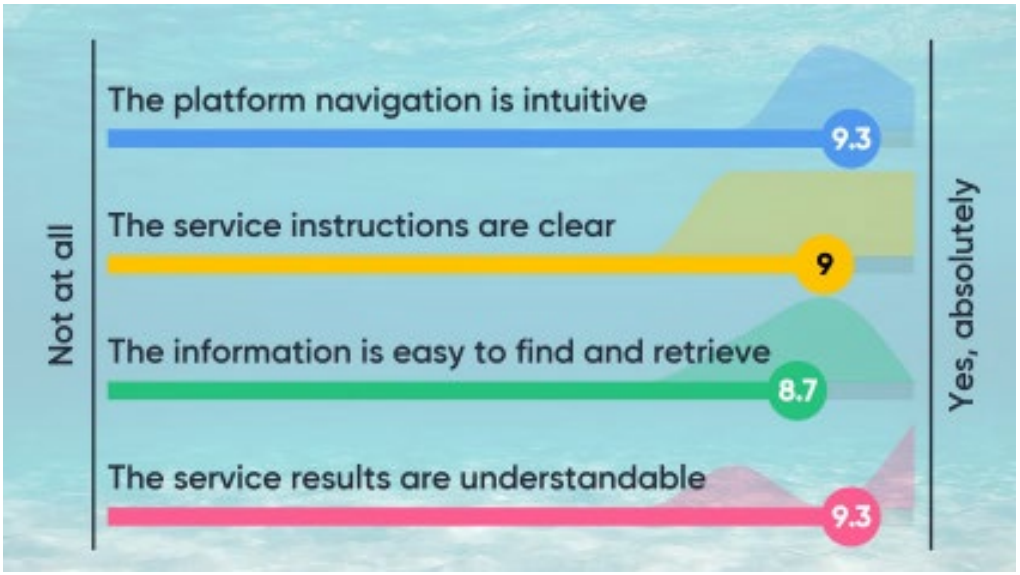

Figure 17. Participants'impression of the service – Italy, Fronts detection workshop

The participants were less positive about the automatic bulletin service for their phones. The average score here was 5.5. The reason, although not easy to explain from their side, was indicated to be the lack of experience in using this kind of technologically advanced services on the go, which would suppose a novelty and higher technological maturity than the data they are used to check (oceanographic, meteorological, etc). When asked if they would make use of the service one of the participants said they would use it as it is, and the other two said they would like to use it but would like to see some changes to the service.

When assessing the estimated yearly extra revenue that could be gained from the service, a minimum estimate of 600 euros was given by all participants, with one participant expecting between 1,000 and 3,000 euros of potential additional revenue.

Finally, when asking for feedback, one participant stressed that the working conditions onboard might make it difficult to operate the service. For example, wet hands, unreliable internet connection and little time aboard the boat could pose some problems.

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3.5.2 A2 – Land Pollution

Lastly, the last Mentimeter survey that was conducted for the user workshops was the survey on the 'Land Pollution service'. This survey had two participants. When they were asked about their impression of the platform, they were both very positive. The statement about the service instructions even got a 10.

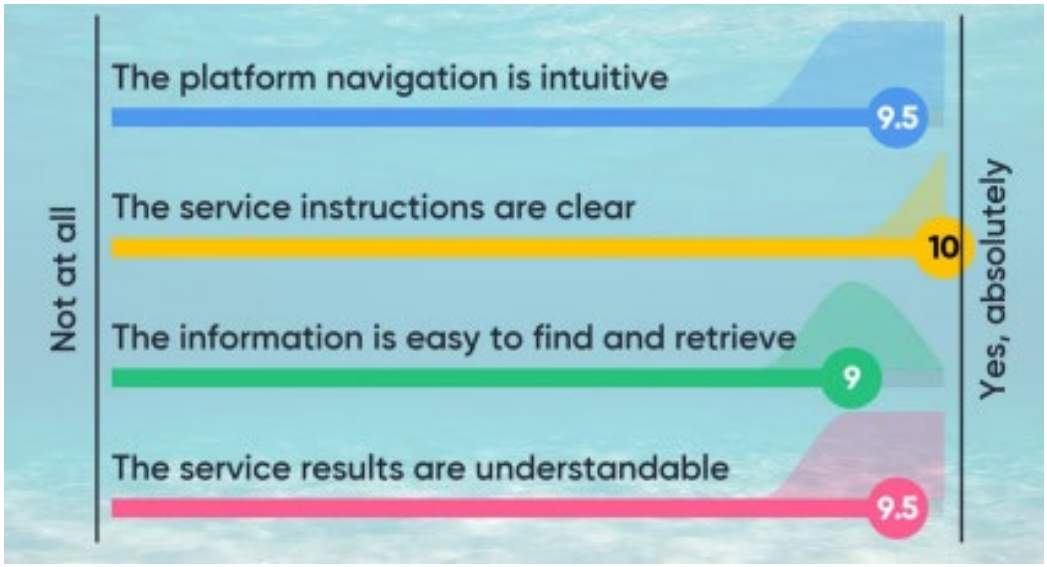

Figure 18. Participants'impression of the service – Italy, Land pollution workshop

When asked about the added value of scheduled information bulletins, one participant rated it with 8 out of 10, while the other participant only rated it 5 out of 10. However, they would both subscribe to the service as it is. They also agreed that the potential yearly additional revenue that this service could provide would be between 1,000 and 3,000 euros.

The interaction with the users led to an email communication from one of the attendees to us which, although being a negative message on the situation of the sector from his perspective, gives us a good insight into how running an aquaculture business is particularly challenging nowadays and that the sector may not be totally ready or mature for such technological implementations as the one implemented at FORCOAST. The email reads as:

"

After Covid and in consideration of the current crisis, we are reducing our activities and we are about to stop.

In these conditions, we can not afford any extra-expense for services and a testimonial has no sense.

I am really sorry for that, but I am afraid that the shellfish industry (at least in Italy) is highly threatened by climate change and bureaucracy and will not be able to take benefit of the current progress.

Clearly, that does not mean that the services you developed and you propose cannot be useful.

The fact is that we do not have sufficient economical resources, time and skills, to deal with the "ecologica transition".

As a result of this situation, the EU shellfish production is stagnant or decreasing.

From a scientific point of view, you made a great work, but social and economical constraints made it very difficult to be transferred to industry.

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In my opinion, these considerations should be part of the conclusions of your project.

We first need funding tools to strengthen our sector, only after that we will be able to express our potential for growth.

Otherwise we will disappear and import from extra UE countries will carry on increasing.

”

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4 Roadmap to TRL 9

4.1 Technology readiness levels

The roadmap for further development of the FORCOAST services used Technology Readiness Levels (TRLs) to quantify the maturity of the services. For reference, these are defined as follows:

Table 5 TRLs (source: https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-13-general-annexes_horizon-2021-2022_en.pdf)

TRL	Description
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in a lab
5	Technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
6	Technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in an operational environment
8	System complete and qualified
9	Actual system proven in an operational environment (competitive manufacturing in the case of key enabling technologies, or in space)

4.2 TRL at the start of the FORCOAST project

In order to describe the TRL of FORCOAST services, a breakdown in the various platform (sub)components, services and pilot areas considered in FORCOAST is required. These are as outlined in the subsections below. At the start of the FORCOAST project, the local models, services and IT components were estimated at different levels of technological readiness (ranging from TRL2 to TRL7).

4.2.1 FORCOAST pilot areas and local hydrodynamics / bio-chemical models

FORCOAST considers 8 different pilot areas. For each of these pilot areas, project partners are running local, high-resolution hydrodynamic and/or bio-chemical models. These pilot areas and models are described in more detail in their state at the beginning of the project in deliverables *D3.7 – Inventory of existing models per pilot* and. The estimated TRLs of the local models in the pilot areas at the beginning of the project, as indicated in the Grant Agreement, are shown in Table 6.

Table 6. Estimated TRL of the local hydrodynamics and/or bio-chemical models per pilot at the beginning of the project

Pilot Area	TRL
1. Atlantic - Portugal	7
2. Atlantic - Spain	6
3. Black Sea - Bulgaria	5
4. North Sea - Belgium	2
5. Atlantic - Ireland	2
6. Baltic – North Sea Denmark	3
7. Black Sea – Bulgaria	3
8. Northern Adriatic Sea - Italy	5

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4.2.2 FORCOAST services

Within the FORCOAST project, a portfolio of services (referred to as Service Modules for development purposes) has been developed. These services are described in more detail in deliverables *D3.9 – Sector-specific decision workflow synthesis* and *D3.10 – Technical Specifications for tailored products*, as well as in the FORCOAST website (services section) and Platform User Manual for service use and interaction purposes.

The services were implemented for selected pilot areas as indicated in Table 7.

Table 7. Overview of FORCOAST Service Modules

Service Module	**Pilot areas (ID)**
F1 (Suitable Fishing Areas)	Bulgaria (3)
F2 (Fronts Detection)	Bay of Biscay (2), Norhern Adriatic Sea (8)
A1 (Marine Conditions)	Sado Estuary (1), Limfjord (6)
A2 (Land pollution)	Galway Bay (5), Eforie (7), Northern Adriatic Sea (8)
A3 (Site Prospection)	Limfjord (6)
A4 (Spat Capture Assistance)	Southern North Sea (4)
R1 (Contaminants Source Retrieval)	Glaway Bay (5), Southern North Sea (4)

An estimation of the initial TRL of these services is added in Table 8. Since the services were designed and developed within the project, their initial state refers to the first working prototypes in testing mode, and using the remote sensing and local model output available at that point in time without the developments that have been taking place subsequently. These early prototypes were achieved between months 4 and 8 of Task 4.2 – Implementation of web and mobile clients, between September 2020 and January 2021 depending on the service.

Table 8. Estimation of TRL per service at start of FORCOAST project

Service Module	**TRL**
F1 (Suitable Fishing Areas)	5
F2 (Fronts Detection)	4
A1 (Marine Conditions)	6
A2 (Land pollution)	4
A3 (Site Prospection)	4
A4 (Spat Capture Assistance)	4
R1 (Contaminants Source Retrieval)	5

4.2.3 FORCOAST platform IT components

The FORCOAST services are provided through the FORCOAST platform. The FORCOAST platform consists of a number of IT components, which are described in more detail in deliverables *D4.1 - Web and Mobile Clients Prototype I*, *D4.3 - Service Tools Prototype I* and *D4.5 - Service Routing and Deployment Prototype I* in their initial implementation status in Prototype I.

The TRL of these IT components at the start of the FORCOAST project are presented in Table 9.

Table 9. Estimated TRL of the FORCOAST platform IT components at the start of Prototype I

IT components	**TRL**
Backend infrastructure	6
Front-end user Interface	7

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Messaging service	6

4.3 TRL at the end of the FORCOAST project

During the FORCOAST project, the pilot area models, the services and the IT components as described in Section 4.2 have been further developed. The following activities have taken place:

1. **Validation of the technology** developed for usability within the wild fisheries, bivalve mariculture, and oysterground restoration sectors. Activities related to this are reported in deliverables *D5.3 – Report describing common methodology for numerical model validation* and *D5.4 – Final coordinated pilot model evaluation report*.
2. **Demonstration of the technology** developed to users within the wild fisheries, bivalve mariculture, and oysterground restoration sectors. Activities related to this are reported in Section 3 and deliverables D5.2 – *Evaluation report of the pre-operational platform by end users*.
3. **Prototype demonstration in an operational environment** at users within the wild fisheries, bivalve mariculture, and oysterground restoration sectors. Activities related to this are reported in deliverable *D2.3 – End user survey results*.

Based on these activities the TRLs of the FORCOAST components at the end of the project are estimated at TRL7.

4.3.1 FORCOAST pilot areas and local hydrodynamics / bio-chemical models

Details on the model's characteristics and specifications are present in *D3.8 – Final version of FORCOAST numerical models for each pilot area.*

Based on the work carried out in FORCOAST and the assessment of the consortium the TRLs of the local Pilot models at the end of the FORCOAST project are estimated in Table 10. These values are in accordance with the ones stated in the Grant Agreement, aiming to reach TRL 7 for all Pilots.

Table 10. TRL of the local pilot Models at the end of the project

Pilot area	**TRL**
1. Atlantic - Portugal	7
2. Atlantic - Spain	7
3. Black Sea - Bulgaria	7
4. North Sea - Belgium	7
5. Atlantic - Ireland	7
6. Baltic – North Sea Denmark	7
7. Black Sea – Bulgaria	7
8. Northern Adriatic Sea - Italy	7

4.3.2 FORCOAST services

Based on the work carried out in FORCOAST regarding the development of the services from their initial state (Table 8), and the assessment of the consortium (see deliverable *D6.6 – Final Exploitation Strategy*) the TRLs at the end of the project for each of the FORCOAST services are presented in Table 13.

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Table 11. Estimation of TRL per service at the end of the FORCOAST project

Service Module	TRL
F1 (Suitable Fishing Areas)	7
F2 (Fronts Detection)	7
A1 (Marine Conditions)	7
A2 (Land pollution)	7
A3 (Site Prospection)	7
A4 (Spat Capture Assistance)	7
R1 (Contaminants Source Retrieval)	7

4.3.3 FORCOAST platform IT components

The FORCOAST platform IT components are described in more detail in deliverables *D4.2 - Web and Mobile Clients Prototype II*, *D4.4 - Service Tools Prototype II* and *D4.6 - Service Routing and Deployment Prototype II* in their final development status in Prototype II.

The TRL of these IT components at the start of the FORCOAST project are presented in Table 9.

Table 12. Estimated TRL of the FORCOAST platform IT components at the end of Prototype II and project

Service Module	TRL
Backend infrastructure	7
Front-end user Interface	7
Messaging service	7

4.4 Components TRL summary

Table 13 presents the summary of the TRL of the different FORCOAST components from Sections 3.2 and 3.3.

Table 13. Overview of TRL of the different FORCOAST technology components, at the start and end of the project

FORCOAST component	TRL at the start	TRL at the end
Pilot Area models		
1. Atlantic - Portugal	7	7
2. Atlantic - Spain	6	7
3. Black Sea - Bulgaria	5	7
4. North Sea - Belgium	2	7
5. Atlantic - Ireland	2	7
6. Baltic – North Sea Denmark	3	7
7. Black Sea – Bulgaria	3	7
8. Northern Adriatic Sea - Italy	5	7
Service Module		
F1 (Suitable Fishing Areas)	5	7
F2 (Fronts Detection)	4	7
A1 (Marine Conditions)	6	7
A2 (Land pollution)	4	7
A3 (Site Prospection)	4	6

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A4 (Spat Capture Assistance)	4	6
R1 (Contaminants Source Retrieval)	5	7
IT components		
Backend infrastructure	6	7
Front-end user Interface	7	7
Messaging service	6	7

4.5 Roadmap towards TRL9

In this section we propose a roadmap to improve the TRL of the different FORCOAST components towards TRL 9. This roadmap should serve as a guideline for the exploitation phase to achieve a proven system in operational environment and in a commercial setting. TRL7 to TRL9 definitions can be found in Table 5. In general, to reach a system that is 'complete and qualified' and 'proven in an operational environment', we have to make sure that in the exploitation phase FORCOAST can fulfil a Service Level Agreement that has key performance indicators on accuracy and downtime, among others.

Section 4.5.1 presents general points suggested to reach TRL9 for the FORCOAST services as a whole, while Sections 4.5.2 to 4.5.4 take into account the different IT components of the previous section, providing suggested recommendations.

4.5.1 Generic recommendations

A roadmap focusing on the exploitation side of the platform and services is presented in *D6.6 – Final Exploitation Strategy* Section 3. Steps suggested to complete the system (i.e. to get to a level sufficient to offer a commercial service) include the following:

- Making **service output data available**, before it is ingested into bulletin services to better serve stakeholders that have more capacity and would want to work with the 'raw' output data instead of consulting the generated bulletins. This would also strengthen the data findability and accessibility side of the FAIR data management. While this was not required for the consulted end-users, enabling this functionality may attract other users.
- Maintain the **FORCOAST demonstration platform** in an operational state by the steering committee (see deliverable D6.6), serving as a promotion tool to attract customers towards the commercial side of the offer (premium services).
- **Setting and adjusting service prices** according to the market, customer type and their service use, as well as covering the required costs. See deliverables D6.2, D6.4 and D6.6 regarding the commercial exploitation via the commercial entity.
  Ensure the long-term sustainability of the services by **regularly monitoring the input data sources and reacting to changes** (local Pilot model output data and/or CMEMS datasets) to avoid service disruptions.

4.5.2 FORCOAST pilot areas and local models

Required steps to improve the TRL of local models:

- **Additional calibration and validation:** the Service Modules use model output from local Pilot models. Increasing validation efforts of those underlying models (over long periods, at several stations, spatially and vertically, using various local validation data sources) means providing more reliable information services that can fulfil a Service Level Agreement. Additionally, the quality of the models could be improved via data assimilation (e.g. surface data from remote

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sensing and/or vertical profiles) to increase accuracy. It must be noted that that modelled biogeochemical variables generally have lower accuracies.

- **Reducing model run interruptions:** improving uptime to reach a nearly 100% consistent input data delivery to the Service Modules to avoid as much downtime as possible.
- **Expanding the modelled variables:** providing additional modelled processes and variables (e.g. plastics, specific contaminants, invasive species, etc) would open up possibilities to enhance and/or expand the FORCOAST services for other fields and/or operational user applications.
- **Extending the forecast lead time:** longer forecast lead time would allow operators to take actions earlier and foresee future situations sooner, potentially further reducing the damages caused by hazards.

4.5.3 FORCOAST services

- **Longer test period to allow service validation**. In order to properly quantify the accuracy of the services in operational mode and the (monetary) benefit they bring to the users, they must be used for a proplonged period (at least a year) in the daily operations of selected beta testers. Quantifying the gains of the users (how much additional fish did they catch, how much money did this save them, etc) is a crucial information to provide evidence for the competitiveness of the FORCOAST services in a commercial environment.
- **Fine-tuning the service features:** according to the outcome of the service validation and the user feedback in order to maximise the value the users get from the FORCOAST services.
- **Further validation and calibration of the Service Module algorithms**. Conditional on the validation outcome, further calibration of the Service Module algorithms may be needed to fulfil the accuracy requirements (quantified by the forecast verification metrics of the Service Level Agreement).
- **Guarantee user friendliness.** The services are user friendly and fit-for-purpose according to the current requirements. These could be proven if there are several clients who use the services and are satisfied (we can fulfil the Service Level Agreement). However, guaranteeing user friendliness for future clients might require further adjustments in the services.

4.5.4 FORCOAST platform IT components

- **Implementing user administration:** adding user management to the platform system would allow the user to have more control over their service use and preferences, as well as automate some mechanisms needed to access the full service. At the same time, user registration will also allow us to gather statistics on the user profiles. Such business analytics are essential for service improvement and service evolution.
- **Implementing platform transactions:** allowing the user to manage their payment methods.
- **Improve the user experience** and navigation in the platform, offering a smooth and intuitive browsing between and within the services.
- **Explore new service delivery channels** (means to share the service output): at the moment the two channels are the web application platform prototype and instant messaging (Telegram). Further options, based on user feedback, could be via email as a pdf report, other instant messaging apps, or SMS notifications for users without internet access.

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5 Conclusions

Since the FORCOAST services and IT components have increased in maturity and reached TRL7, the first users have been able to test them and describe the advantages they offer. The user testimonies allow us to conclude that the FORCOAST service design and implementation is appropriate to provide solutions the sectors of wild fishery, bivalve aquaculture and oysterground restoration.

The Pilot user workshops that took place between May and June 2022 can be seen as the final feedback and validation events with direct contact with external stakeholders in person or online. This refers only to FORCOAST-organised events directed to local Pilots, since engagement with relevant stakeholders and users is a continuous effort (beyond the project lifetime). We can conclude from the mid-2022 workshop outcomes that user satisfaction and interest is high, and that FORCOAST could bring monteray benefits to the targeted sectors, which reassures the applicability of the services beyond the current partner users. It should be noted, however, that some of the targeted sectors (e.g. shellfish industry) currently do not have financial or human resources to integrate such technology into daily operations.

Lastly, regarding the suggested recommendations to increase the TRL of the different FORCOAST components towards TRL9 vary from increasing the robustness of the system, improving the service quality to ensuring long-term data supply sustainability, and quantifying user benefits through a prolonged test period in operational mode.

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