



DELIVERABLE 2.1

TOOLBOX FOR DATA ANALYSIS, VISUALIZATION, AND PLANNING FOR DECISIONS MAKERS

Work Package 2
Technology

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Author(s)	Adélio Silva, Pedro Galvão, Emma Huijben
Editor	Ghada El Serafy
Approved by	Roderik Hoekstra
Abstract	This report describes the conceptual design and project specific services of the data platform developed in the UNITED project.
Keywords	Data platform, visualization, dashboard, planning, decision making
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	platform has been included in the UNITED catalogue of multi-use blueprints (D1.5)
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ACRONYMS

CMEMS	Copernicus Marine Service
DSS	Decision Support System
IT	Information technologies
SLA	Service Level Agreement
WP	Work package

EXECUTIVE SUMMARY

Efficient environmental monitoring is a key aspect of prosperous multi-use scenarios. Process control and an optimization of the operations processes is based on information derived through monitoring, which also enable the tracking of environmental effects and proper operation windows (ex. severe weather, currents, sediment transport or waves). The potential benefits associated with the multiple uses of marine space also requires to be properly evaluated.

To this end, a set of tools to enable spatial planning and to make data and service layers available for operational pilots, providing agile visualization and analysis tools to evaluate data and build a solid base for decision makers were set up.

The derived information is managed and distributed through a multifaceted platform (HISEA Platform) that supports standardized access to geospatial data/information and services and provides generalized analytics and visualization tools for multi-temporal and geospatial data and forecasting system able to utilize domain-specific models and support them.

This Deliverable provides an overview of the general capabilities of the platform and the tools and services already met in place (or in the way to be met in place).

1. INTRODUCTION

The UNITED project has five real-life ocean multi-use pilot sites, where different combinations of activities are already being carried out:

- Offshore wind and tourism – Denmark
- Aquaculture & Tourism – Greece
- Blue mussels, seaweed, and offshore wind energy – Germany
- Offshore wind, flat oyster aquaculture & restoration, & seaweed cultivation – Belgium
- Offshore seaweed and floating solar energy – Netherlands

Each pilot site collects multiple data and indicators that need to be shared with different permission levels between operators, project partners, and the public.

To achieve an effective balance and synergy between multiple uses of marine space, careful considerations need to be placed on the engineering aspects of the structures and elements being co-located within the same space. To inform such activities, a set of tools which enable spatial planning will make data and service layers available for operational pilots, provide agile visualization and analysis tools to evaluate data and build a solid base for decision makers.

To enable easy use of these tools by non-technological experts (the common user) an intuitive web managed by HiSea Platform was set up. HiSea platform supports standardized access to geospatial data/information and services, provides generalized analytics and visualization tools for multi-temporal and geospatial data and may provide (as required) forecasting services to properly inform about suitable operation windows and/or set-up warning/alert services.

The following sections provide an overview of the HiSea platform capabilities, the tools already being managed by it and the potential for a wider use by these type of multi-use projects allowing not only to get benefits in terms of operation, management, and safety of each one of the activities but also to get a better insight about the potential advantages of sharing resources and information between the co-located activities. A more detailed attention to the procedures included in the platform to schedule (automatize) and/or ask for on-demand tasks is provided in Deliverable D2.3.

Note that the services providing platform is subject to ongoing development and requires it to be updated on a regular basis with new functionalities, data sources, forecasting models (etc.). It is therefore noted that the examples and descriptions provided in this document are indicative, with the main purpose of making the reader familiar with some general concepts.

2. HISEA PLATFORM WITHIN UNITED

2.1. General overview

In the context of UNITED, combining local monitoring data with existing public data and analytical and modelling capabilities, creates the proper environment to extract information (and knowledge) capable to better inform about different operation, management, and planning options.

However, although both the data availability, the analysing and modelling capabilities are continuously increasing, the derivation of information usable by the interested stakeholders is not always an easy task. One of the UNITED goals is to identify the information needs of the different users and the benefits that each one of them may draw from the information and, finally, provide ways to distribute the information in a way accessible to anyone.

To achieve these purposes, an IT platform developed in the framework of the previous EU HiSea project, capable to properly manage different types of data, models and algorithms, and publish/distribute information in fitted to use forms, was adopted in the project. HiSea platform is based on a client-server architecture following a microservices philosophy. This capability represents a truly innovative approach and is the guarantee of a safe investment once it assures the easy adding of new capabilities with a minimum effort.

One of the relevant aspects of HiSea is its capability to easily connect to different types of data or models. Commonly periodic sampling and real time sensors are usually considered operational tools, in the sense that the systems owners/operators are expected to manage their systems based on the results obtained from these components. Modelling, however, is rarely used in these scenarios being mostly used in off-line studies for planning purpose. By means of its capability to connect to the data sources and use these data sets to automatically define initial and boundary conditions for the models, the models are transformed from planning tools usually operated by model experts to an operation tool capable to be operated by non-model experts. As a result, it is possible to deliver not only the traditional advanced data analysis but also to integrate the models in day-to-day operations, providing operational forecasts of the system state, defining alerts, producing automating reports, etc.

To make these operations simple enough to be managed by non-specialists in the different areas, HISEA allows to build specific dashboards and reports properly fitted to the different users' needs that contain a minimum set of options needed to operate the system. This represents an added value when it is necessary to anticipate problems or plan operations in an efficient way.

A first version of the platform, including opensource available data sources was made available in March 2022. In the subsequent months, the data platform was further developed by including the data collected by the pilots and adding functionality that allows the partners and pilots to analyse and cross-compare the performance of their activities against environmental conditions.

This is an iterative process that is being coordinated by UNITED partners Hidromod, Deltares and 4H-Jena, with close participation of pilot representatives to make sure that it responds to their needs. The aim is to have a digital platform that integrates all the field data that has been collected by the pilots and make them accessible to the project partners and the wider multi-use community as a source of inspiration for follow-up MUCL activities. Also, it is aimed to present a state-of-the-art technical concept how data could be stored and visualized for the purpose of and to support multi-use activities in the future.

2.2. General structure of the platform

The HISEA platform enables hosting a set of services that supply data to the frontend applications. Data may be gathered from external sources (such as CMEMS) and products provided by consortium partners

(local monitoring), processed into standard formats and shared via a common set of services. The objective of the adopted platform architecture is to offer a service that:

- Integrates the contributions of all the members of the consortium.
- Is easily maintainable.
- Is easily scalable.
- Assures a reasonable and convenient Service Level Agreement (SLA).

With this set of requirements, the adoption of an architecture based on what is commonly known as ‘microservices’ seems appropriate, since applications built using microservices possess certain characteristics. They:

- Are fragmented into multiple modular, loosely coupled components, each of which performs a discrete function.
- Have those individual functions built to align with business capabilities.
- Can be distributed across clouds and data centres.
- Treat each function as an independent service that can be changed, updated, or deleted without disrupting the rest of the application.

A microservice based architecture allows the platform managers to split applications into distinct independent services, each managed by individual groups within the consortium. They support the separation of responsibilities critical for building highly scaled applications, allowing work to be done independently on individual services without impacting the work of other developers in other groups working on the same overall application. In short, the HISEA platform can grow as its requirements grow.

In the framework of UNITED, HISEA platform is required to perform (at least) the following tasks:

1. Acquire data from CMEMS (or other external sources) and from partners monitoring services.
2. Convert the acquired data to standard formats (to assure interoperability).
3. Work out the data to produce user required information.
4. Provide forecasts as required.
5. Enable to define warnings and alerts according to sets of constraints defined by the users.
6. Serve the information via easy-to-use web and mobile services and/or reports.

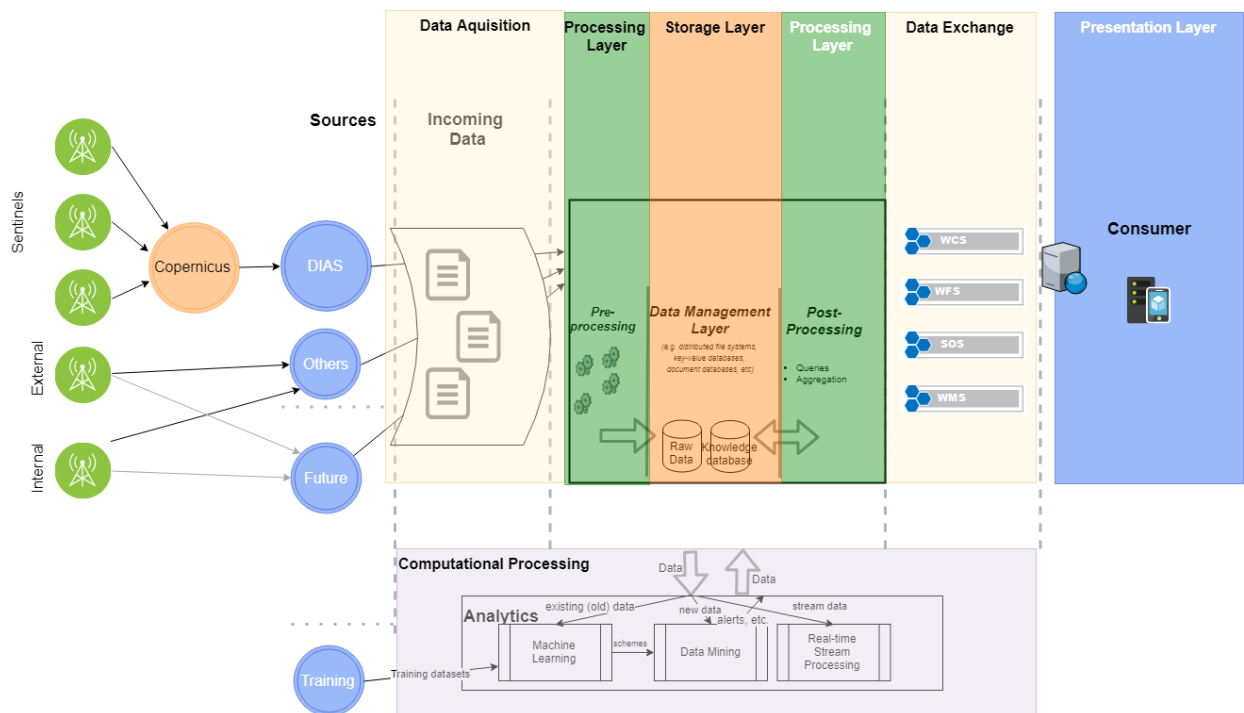


Figure 1: Platform architecture overview

The platform architecture was designed to guarantee versatility, minimum maintenance and upgrading effort possible and the capability to be deployed in different computational environments (Windows, Linux, local servers, cloud). The following backend services/tools have been implemented:

- Data Acquisition
- Data Storage and indexing
- Model and algorithm execution
- Warnings and alerts
- Reporting
- Publishing

2.2.1. Data Acquisition

Data is available in multiple formats (ex. ascii or xls for time Series, HDF5, NETCDF, GRIB for grid data) and the data can be accessed through different protocols (FTP, http, OPENDAP, Threadds, ...). Some types of data are downloaded by the platform while others are only indexed. The data acquisition module is responsible for:

- Downloading or rebuilding indexes to known data sources
- Transforming from the imported formats to the standard formats the platform uses for storage (if required)
- Indexing the new information in the platform data lake.

All these processes may be set up to occur at pre-defined intervals or on-demand.

The data acquisition includes the set-up of some quality-check procedures to assure a first quick validation of the imported data. These procedures, that may go from the simple detection of outliers or

abnormal values to trend analysis algorithms, represent a general automatic data check and so, it may be advisable to perform some more detailed data checks depending on the data type and/or data provider.

The data management may also include additional procedures (to be set-up to run automatically or on-demand) to perform (for instance):

- Data filtering and aggregation (averages, min, max, etc.).
- Indicators.
- Simple calculations and time aggregation.
- Machine Learning algorithms.

2.2.2. Data Storage

Data storage represents one of the big challenges of our days, with a continuous increase in the data produced daily. Although this increase in the data volume has been accompanied by an increase in storage capacity (that also observed a continuous reduction in the cost per megabyte), to keep the services responsive, (if this represents an issue) it is required to decide how much of the available data must be kept promptly available (moving the data excess to more adequate supports).

To deal with this issue, HiSea can store data both in “hot” and a “cold” storage location. The two types of storage differ in their accessibility and their optimization of resources. Data in the “hot storage” is easy and fast to access, whereas data in the “cold storage” takes more time to access but it represents a cheaper storage mode.

2.2.3. Models and algorithms execution

The execution of models and algorithms usually requires the use of some companion tools (procedures) to prepare the data and afterwards export the results to standard formats. A data preparation step allows to prepare data compatible with the model requirements (spatial interpolation of data, format transformation, etc.) and a models/algorithms results processing allows to return the produced data in the adopted standard formats.

2.2.4. Warnings and alerts

Warnings and alerts services may represent relevant aids to operation as they may help to adopt in time proper actions in case of the possibility of occurrence of some adverse conditions. A warning or an alert is issued if a pre-defined, or a combination of predefined, conditions is likely to be met.

2.2.5. Reporting

Reports created by the platform can contain Time Series and images. Images can be created from grid files or Time Series indexed in the database, creating charts or maps. Reports can also contain raw Time Series values in the form of tables. An example is shown in the figure below.

Reports can be created in office compatible formats (Open XML), pdf, xml or simple ASCII. Other formats can be incorporated in the future since the design general base structure is flexibly based on interfaces.



METEOCEANOGRAPHIC FORECAST REPORT | VALENCIA

11-05-2020 18:25

Meteorological and oceanographic forecasts for the port of Valencia, between 11-05-2020 and 13-05-2020, local hour.

Alarms

Parameter	Warning	Alert
Wind speed (m/s)	≥8 to 10	≥ 10
Waves power (kW/m)	≥10 to 20	≥ 20



1. WAVES

Date/hour	Monday, 11-05-2020												Tuesday, 12-05-2020												Wednesday, 13-05-2020											
local	00	02	04	06	08	10	12	14	16	18	20	22	00	02	04	06	08	10	12	14	16	18	20	22	00	02	04	06	08	10	12	14	16			
Direction (°)	↙	↙	↑	↑	↗	↗	↗	↗	↗	↗	↗	↗	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙			
Hs (m)	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.5	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6			
Tp (s)	7	7	7	3	3	3	3	3	3	4	6	6	6	6	6	3	2	3	4	5	5	5	5	5	6	6	6	6	6	6	6	6	6			
Pw (kW/m)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			

Forecast from the CMEMS model with a horizontal resolution of 8 km for the port of Valencia.

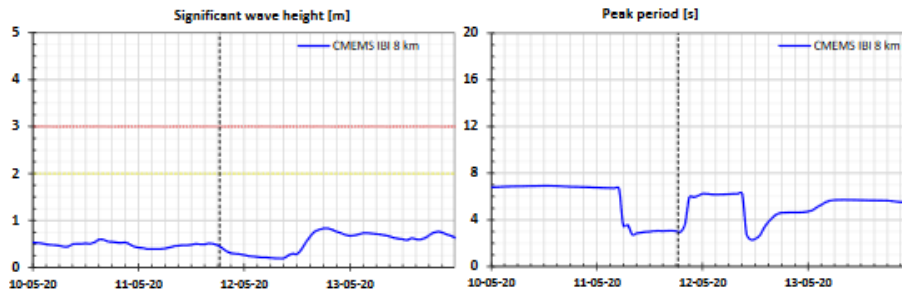


Figure 2: An example of the automatically generated report

2.2.6. Publishing

Publishing is used to disseminate reports, warnings or alerts to a list of users. Publishing can occur by:

- E-mail
- SMS
- Https
- FTP local file share

2.3. User interface

The platform user interface (service frontend) is a crucial component since it is through the frontend that users have access to the service. For this reason, the level of acceptance of the service is closely related to its capability to adequately answer the user's questions and to provide what the user needs in terms of interface design and effectiveness.

In this perspective, the frontend is a critical component that must be implemented in close cooperation with potential users to ensure that it integrates the required functionalities and delivers information in a comprehensive way (e.g., content, formats, design, etc.).

The frontend is the gateway to access the data, and so it is important that it includes procedures to assure that the access to the data is done according the "conditions for use" defined by the data owner. This is guaranteed by a user authentication service that entitles each user with proper data access privileges.

2.3.1. Authentication service

As mentioned, data security is a general concern in the sense that the systems may contain sensitive data that must be properly protected against non-allowed accesses. In line with these concerns, the HiSea platform services are protected with a common authentication component following state of the art practices. The user's authentication service makes use of a custom middleware IdentityServer4 that implements OpenID Connect and OAuth 2.0 endpoints. The main features of this implementation are:

- Centralized login logic and workflow for all applications (web, native, mobile, services)
- Single sign-in over multiple application types
- Issue access tokens for APIs for various types of clients, (e.g. server to server, web applications, SPAs and native/mobile apps)
- Social logins are also allowed

The following figure gives more technical information about the workflow. The user uses the client (browser, mobile, etc) and identity through username and password via OAuth to the IdentityServer. If the ID is recognized as valid the user receives a token that can be used to request data to the API. Once the API receives the token it validates it with the IdentityServer and, if the ID is considered valid the user receives the information request. All communications are encrypted using certificates and all parts are separate by duties.

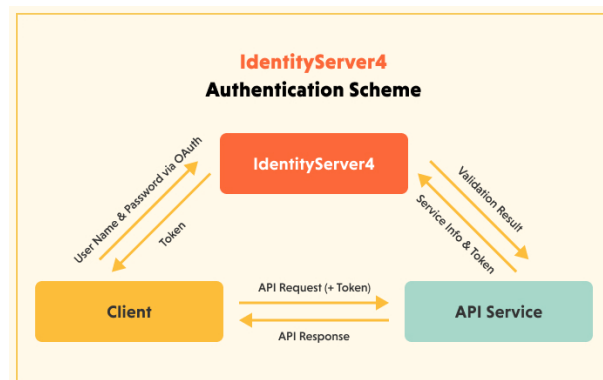


Figure 3: IdentityServer authentication scheme

To provide a good user experience and follow the European data protection guidelines, the following services were implemented:

- User Registration and Login
- Password reset
- Social logins
- Delete account
- User profile settings (image, name, mail, ...)

The platform recognizes four main types of users (other access levels can be implemented as required): User, Power user, Administrator, and Super administrator. Each type of user is allowed to execute some actions, as listed below:

User:

- View projects

Power-user:

- View projects
- Edit account information
- Create private dashboards
- Export information from dashboards

Administrator:

- All the Power user actions
- Create and edit dashboards
- Add general users to the projects

Super Administrator:

- All the administrator actions
- Create and edit projects
- Manage data in back-office

2.3.2. Cyber security

Regarding cyber security, the HiSea platform assures secure communications using HTTPS encryption on all services. User authentication and authorization is implemented with OpenID Connect and OAuth 2.0. The application includes Access and event logging. The platform is also compatible with hardened system security such as:

- NIDS (network intrusion detection system, ex SNORT)
- Antivirus
- Application/process Whitelisting
- HIDS (host-based intrusion detection system)
- Removable Media Management

2.3.3. Dashboards as a web application

The web client is designed in a way that may serve different types of users with different needs, offering different ways of accessing the information without the need for significant platform changes.

These capabilities were translated into dynamic (customizable) web dashboards that allow any user to select what to see and how to see it easily and intuitively. Moreover, these web client functionalities (GIS, graphics, reports, etc.) have been encapsulated in controls that can be grouped by the administrator in workspaces (sites) that can be published (as private or public) and made available for anyone or just for a limited number of selected users.

The control of whom and with which privileges have access to the different services is assured by the above-described authentication service.

Once logged in, a user may access the data (visualize, download, etc.) using one or multiple fully customizable dashboards. Each dashboard set can include multiple widgets, maps, charts, reports, and others (see examples in Figure 4 and Figure 5).

Populating a dashboard mainly means selecting different widgets to display the content of the different available data sources and model outputs that can be selected from a platform catalogue. A “widget” is a

way (a graph, a map, etc.) to represent data. Widget sizes and locations on the dashboard can be easily adjusted by stretching and dragging.

The representation of a data set (or a group of data sets) through a widget follows the process described below:

1. Select widget type
 - Data view: Line Chart, Column Chart, Mixed Chart, Pie Chart, Pyramid Chart, Bar Chart, Candlestick Chart, Map, Gauge, Scatter Chart, Process Flow, Homologous Periods Chart.
 - Custom view: PDF Viewer, Notes, Table, Reports, Image Slider, Time Series Exporter, and Chat.
2. Select data to display.
3. Adjust widget settings depending on the selected chart type:
 - date selection
 - time-series settings
 - time-series aggregation
 - chart/map/gauge/PDF etc. settings

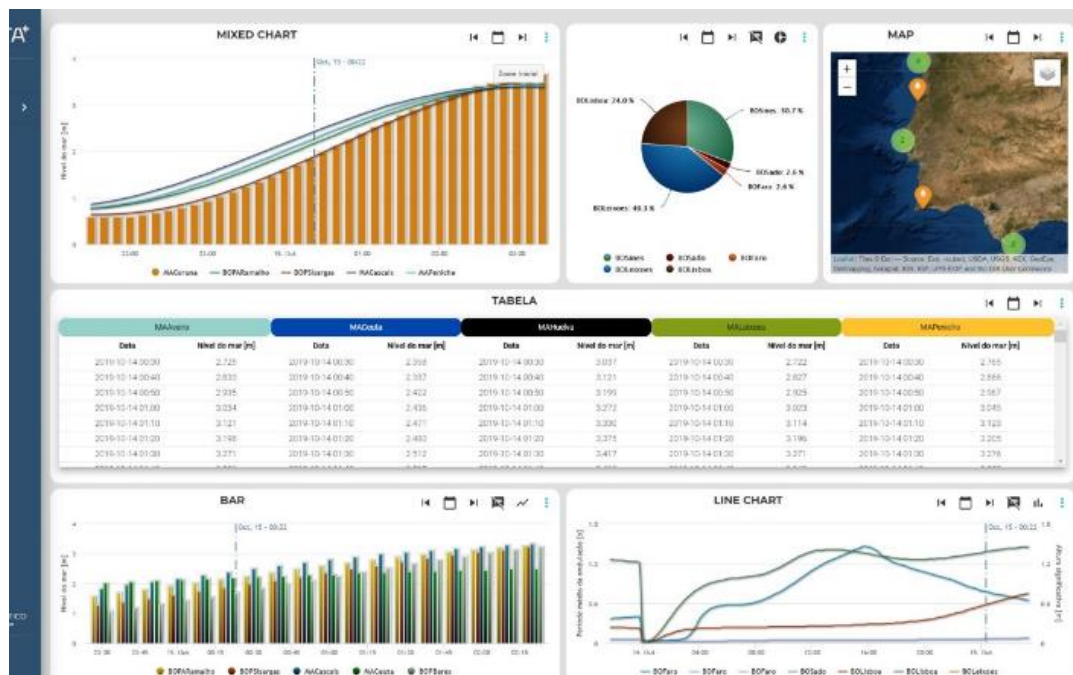


Figure 4: Dashboard example

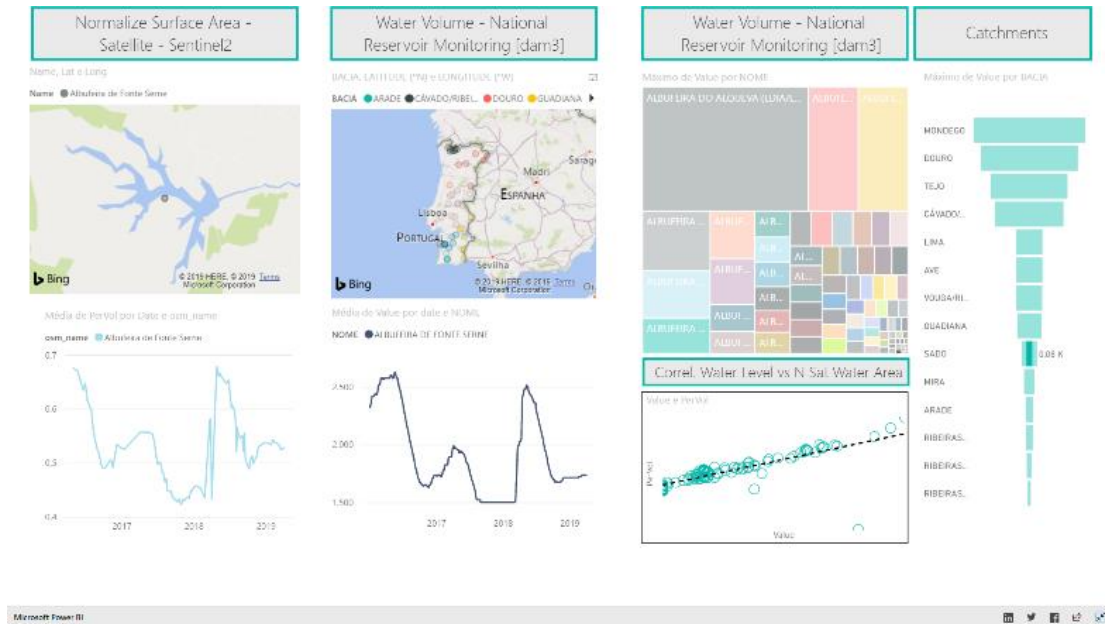


Figure 5: Dashboard example

The users may create Dashboard groups under the scope of a project. The platform uses projects to bring together users, data, and visualization (Figure 6). When the administrator creates a project, he assigns users and data. This process ensures that only the users associated with that project can see the data. The same data set can be associated with multiple projects, as can users. Finally, Dashboards can be grouped into side menus (see Figure 7). An administrator can decide whether the dashboard collection should be public or private.

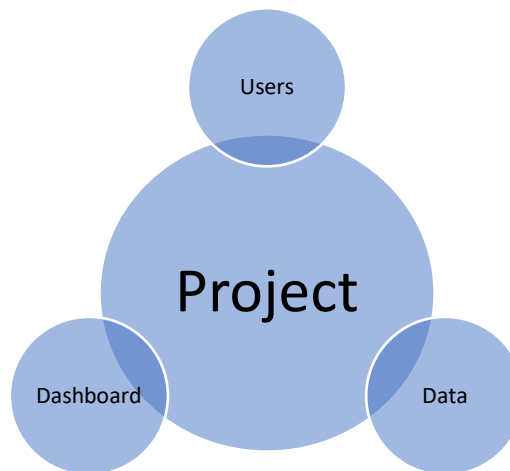


Figure 6: A project gathers together users, data and dashboards

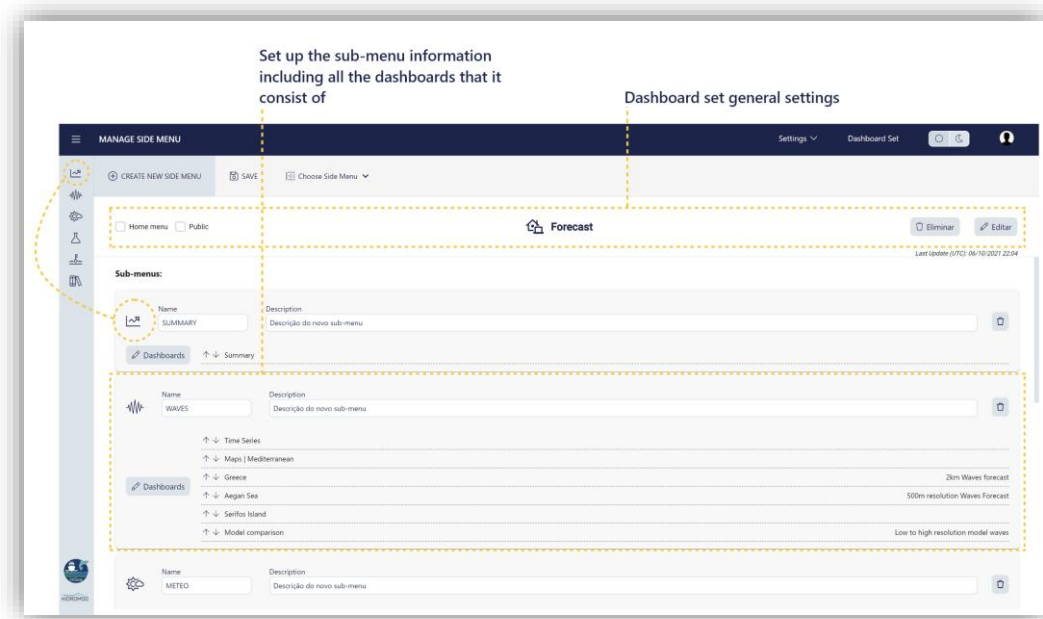


Figure 7: Grouping a dashboard in the side menu

3. SPECIFIC UNITED FEATURES AND SERVICES

Beyond the more generic meteo-oceanographic and water quality services the platform produces automatically, some additional services are available to run on demand.

3.1. Current data layers and data sources

The preceding description of the data platform, a tool that can be used to visualise and analyse datasets, exemplifies that it is not a static product, but a dynamic one. It has been developed in such a way that it can easily handle different types of data formats and data sources. This means that the data layers and data sources that are included in the platform can readily change depending on the user's activities, needs and preferences. Within UNITED the data platform is centred around the five demonstration pilots. The specific data layers and data sources that are included in the platform for UNITED do not only depend on the needs, preferences, and activities of the pilots; they also change along with the pilots' progression through the three implementation phases from pre-operational to post-operational. More specifically, the implementation phase determines the availability of data that has been collected at the offshore pilot locations. At the moment of writing this deliverable, the UNITED pilots have not yet finished decommissioning, which means that they have not yet reacquired all measurement devices and the data that is stored on them. Consequently, the data platform currently contains predominantly data layers from external open-source data providers. However, if the measurement devices can be retrieved successfully and if the data collection itself was successful, the site-specific datasets can easily be included into the data platform as well. Afterwards, the numerous widgets that are available in the platform provide an easy way to visualize and analyse the collected data.

Currently, the data platform contains data layers for the following variables:

- air temperature
- atmospheric pressure at sea level
- attenuation
- chlorophyll
- current speed
- dissolved oxygen
- mean wave direction
- net primary production
- peak wave period
- precipitation
- relative humidity
- Salinity
- Sea level
- sea surface temperature
- seabed substrates
- significant wave height
- SPIM
- SPML

- Suspended matter
- turbidity
- wind gust
- wind modulus

These datasets are either based on numerical models or (satellite) observations and are obtained from the following data sources:

- ACRI
- CMEMS
- DWD
- EMODNET
- GLOSS
- HIDROMOD

More details on the open-source datasets, such as the spatial and temporal resolution, are presented in UNITED Deliverable 2.3. The selection of these data layers and data sources was made in consultation with the pilots. The selected datasets are included in the platform through the data acquisition module that was described in section 2.2.1. Moreover, a service, i.e. a chain of procedures, has been set up in the platform to make sure that the platform contains the most up-to-date versions of the datasets, as described in D2.3 on automation and scheduling.

As mentioned before, the overview presented above describes the state of affairs at the moment of writing this deliverable. However, it serves as an example of the kind of data layers and sources can be included to illustrate the features and capabilities of the platform, the visualization and analysis toolbox that is the official output of task 2.1 and described in this report.

3.2. Dashboard configuration

The platform allows to create different sites that may represent the different pilots (Figure 8). Each pilot site may contain public and private pages. The public pages are freely accessible to anyone that registers on the platform. The private pages are password protected only accessible to properly identified users.

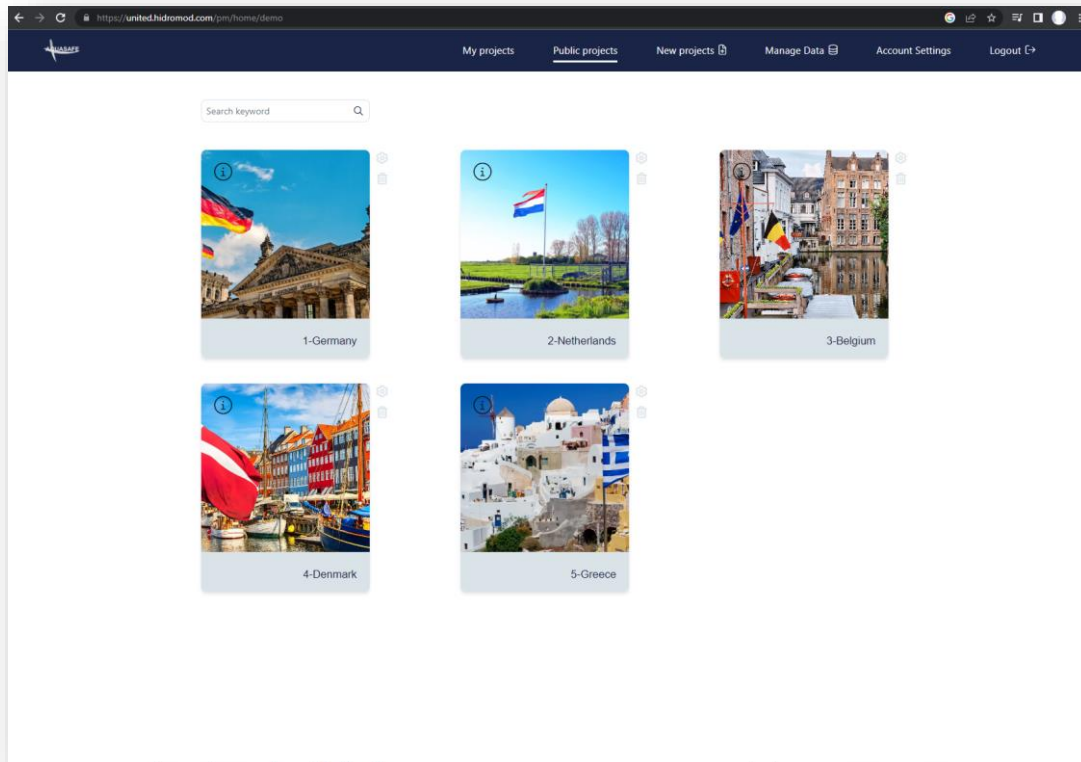


Figure 8: Organization of the platform by sites

The sites may be organized following a thematic structure as exemplified on Figure 9, Table 1 and Table 2. Figure 9 shows an example of the summary page of the public dashboard for the German Pilot. The different kind of widgets provide different ways to visualize the data. The sidebar on the left of the dashboard can be used to navigate to additional pages for different groups of variables, e.g. various atmospheric variables or various oceanic variables.

An example of the menu options, variables, and widget of the public dashboard for the German Pilot are presented in Table 1, while those for the private dashboard are presented in Table 2. As mentioned before, it should be noted that the data platform is a dynamic product. This means that the current version of the dashboards can look different compared to the examples provided in this report. The example of the menu options in Table 2, is based on the original data collection plan of the German Pilot and their idea about the dashboard structure that can be used to group and visualize the data. However, this structure might be changed during the course of the project, based on the availability of the data (whether the data collection was successful or not) and on the preferences of the German pilot. The difference between Table 1 and Table 2 highlights the possibility to provide different menu options depending on the user, for example, to keep certain datasets private until they can be shared with the public users.

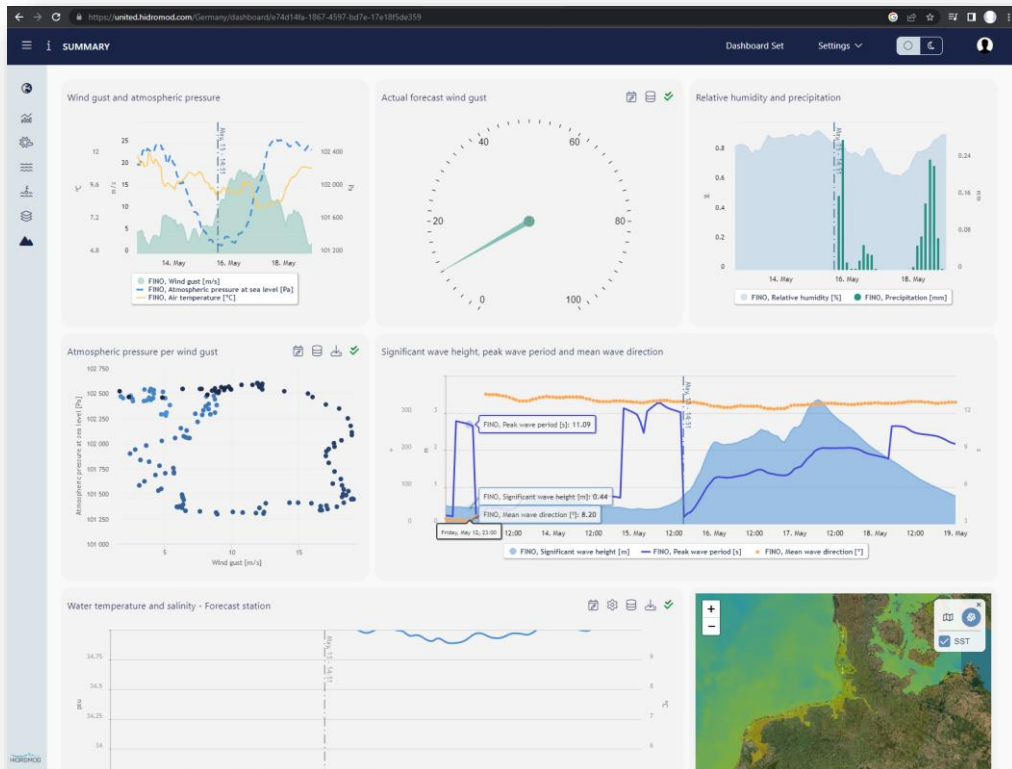


Figure 9: Sample dashboard for the German public site

Table 1: FINO3 public dashboards

Side-Bar Headline	Dropdown Menu 1	Widget	Widget type
Forecast Overview FINO3	Main	Location	Map
		wind direction & speed	graph + bars over time
		current direction & speed	
		wave height (significant) & direction	
		sea level (CUX, Esbjerg & FINO3)	graphs over time
FINO3 Data Overview	Water	Location	Map
		significant wave height	graph over time
		wave period	
		wave direction	bars over time
		water temperature 0,5m/6m/12m/18m	graphs over time
		Location	Map

	Atmosphere	wind speed	graph over time
		wind direction	graph over time
		air temperature	graph over time

Table 2: Example of the options for the private dashboard of the German Pilot (FINO3)

Side-Bar Headline	Dropdown Menu 1	Dropdown Menu 2	Widget	Widget type		
Forecast Overview FINO3	Main		Location	Map		
			wind direction & speed	graph + bars over time		
			current direction & speed			
			wave height (significant) & direction			
			sea level (CUX, Esbjerg & FINO3)			
FINO3 Data Overview	Water		Location	Map		
			significant wave height	graph over time		
			wave period			
			wave direction			
	water temperature 0,5m/6m/12m/18m					
	Atmosphere			Location	Map	
				wind speed	graph over time	
				wind direction		
air temperature						
UNITED offshore site	Mussel System (Water)	AquaTroll	Location	Map		
			turbidity	graph over time		
			pH			
			redox			
			chlorophyl a			
		O2				
		NO3 Sensor			Location	Map
					NO3	graph over time
		Hobo Sensors			Location	Map
					light level 3m, 6m, 9m	graphs over time
					water temperature 3m, 6m, 9m	

		Load Cells	Location	Map	
			east	graphs over time	
			west		
	Lander (Water)	measured on the seabed (20m)	Location	Map	
			echograms	pictures	
			wave height	graphs over time	
			wave period		
			wave direction		
			current speed		
		current direction			
		current profile			
		pressure			
		tilting			
		Winder		Location	Map
				pCO2	graph over time related to depth
chlorophyll a					
algae classification					
conductivity					
temperature					
pressure/depth					
turbidity					
dissolved oxygen					
PAR light intensity					
United nearshore site	AquaTroll		Location	Map	
			turbidity	graph over time	
			pH		
			redox		
			chlorophyll a		
			O2		
	Hobo Sensors		Location	Map	
			light level (3m, 6m, 9m)	graphs over time	
			water temperature (3m, 6m, 9m)	graphs over time	
	WBAT		Location	Map	
			echograms	pictures	
	Horiba		Location	Map	
			pH	graph over time	
			temperature		
			conductivity		
	turbidity				

			dissolved oxygen	
			total dissolved solids	
			depth	

3.3. On demand simulations

The HiSea platform also provides the capability to run on-demand models and algorithms. Two examples are the Decision Support System (DSS) and the oyster growth model. DSS is based on several constraints defined by the user, returns information about periods when these conditions are met or not. The DSS system uses updated met ocean forecasts automatically downloaded and updated by the platform. The user can finetune the desired intervals for each parameter and obtain an estimation of the next available days that fulfil the necessary options. More information about the DSS is presented in UNITED Deliverable 2.5.

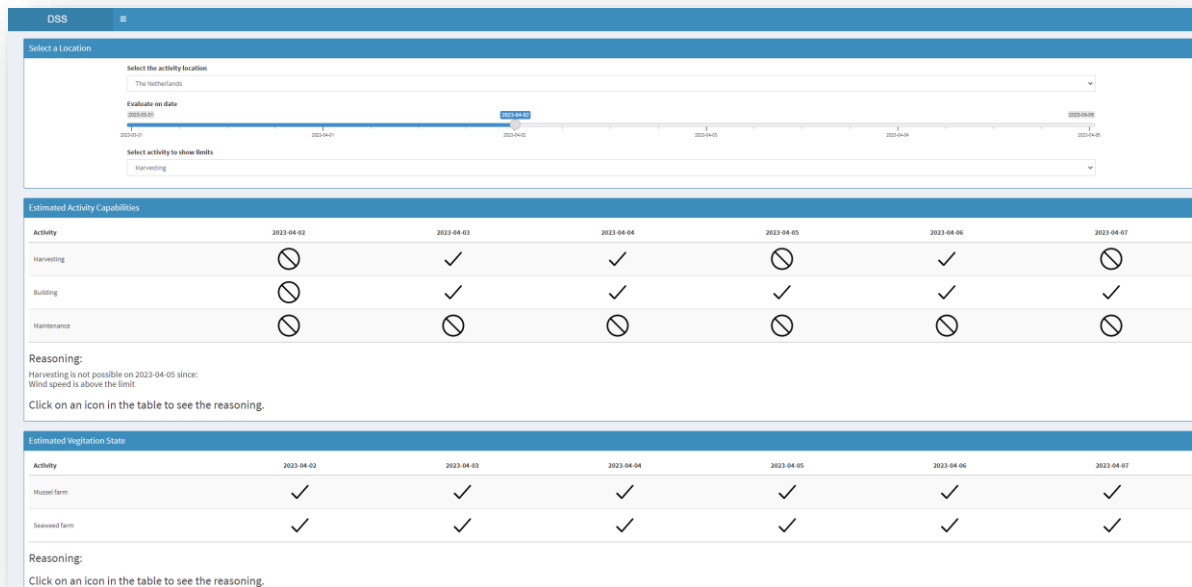


Figure 10: DSS dashboard

After centuries of overexploitation, European flat oyster (*Ostrea edulis*) habitats are increasingly being protected and large-scale oyster habitat restoration projects have been initiated in the North Sea, the English Channel, the Irish Sea and the north-eastern Atlantic. Understanding the habitat requirements of flat oysters is key in the selection process of restoration sites.

Stechele (2022, 2023) determined a theoretical niche for all life stages of the flat oyster using a dynamic energy budget (DEB) model forced with temperature, chlorophyll a and salinity in combination with sediment composition. The suitability of Northern Europe's marine environment for flat oysters is evaluated by applying the proposed niche model on a spatial scale and evaluating spatio-temporal variability in life history traits and metabolic characteristics, such as fitness, reproductive output, settlement success and growth. Results show that habitat suitability is limited by low maximum summer temperature and low food availability at higher latitudes and in areas under strong influence of the Atlantic Ocean. Restoration

efforts in Ireland and Scotland should be confined to protected and shallow coastal environments. Suitability in the southern North Sea is patchy and mainly depends on seabed substrate. The nearshore areas of the English Channel are highly suitable.

The developed model is also available in concept on the HiSea platform. An example screenshot is presented in Figure 11.

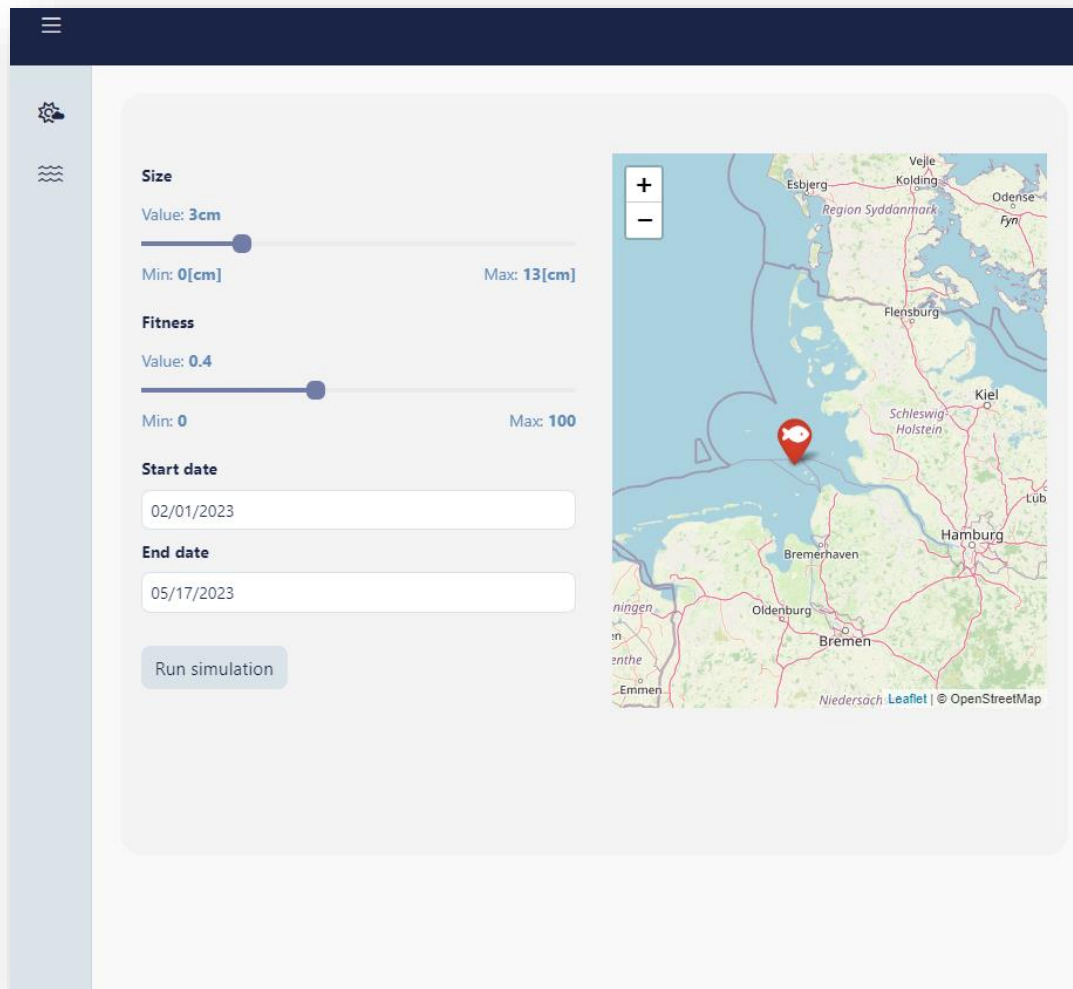


Figure 11: Oyster growth simulator

4. CONCLUSIONS AND RECOMMENDATIONS

UNITED projects propose to provide tools and assessments that may provide evidence of the viability of multi-use of marine space. The concept of UNITED is to provide practical, promising designs, technological proposals, and models for combining activities in terms of economic potential, legal and societal acceptability, and environmental impact along with the practical application thereof in key pilots.

To achieve these objectives UNITED takes into consideration 5 relevant aspects (pillars): technical, regulatory, economic, social, and environmental viability.

The present Deliverable addresses some of the technological capacities implemented in UNITED to support the operation, management, and planning activities, based on available data, models and algorithms. These capacities also include the provision of agile visualization and analysis tools to evaluate data and build a solid base for decision makers.

To properly manage the complex service chain that is required to transform data into information (and knowledge) effectively usable by non-technological experts (the common user), it was set up an intuitive web frontend, managed by HISEA Platform. HISEA platform supports standardized access to geospatial data/information and services, provides generalized analytics and visualization tools for multi-temporal and geospatial data and may provide (as required) forecasting services to properly inform about suitable operation windows and/or set-up warning/alert services.

As a result, the UNITED pilots now have access to an easy-to-use service that allows:

- To easily manage and analyze the data with relevance for the local operations.
- To have access to short to medium term forecasts that may optimize the operations and reduce risks.
- To make available decision support systems capable of taking into consideration multiple operations restrictions.

To be indeed effective, these services must be built in close cooperation with the users. The goal is that the provided information is in line with the specific needs and be easily consumed. To achieve such a goal, it is usually required to maintain a close dialog between the service providers and the final users that makes the services evolve step by step. In the first stage probably the service providers do not have yet a clear insight into the users' needs, and the users do not have a clear view of how the services may help them. As the services start to be implemented both parties get a better knowledge of the needs and the capabilities that may be offered to fulfill these needs and, in this process, the services become more focused and more useful. This first stage is a barrier that requires the commitment of both parties.

In UNITED this path is being followed by the different pilots, in some cases (as expected) going faster than in others but moving on in all cases. Beyond the more generic meteo-oceanographic services that provide alerts and warnings that may help to take in time corrective and/or preventive measurements, a DSS was implemented (see D2.5 for details) and some specific models were set up (ex. mussels growing simulator).

These services have potential to grow (as the users take more notice of the capabilities and associated benefits) and also have a high potential to be applied to other sites, as the used technology architecture, based on microservices, allows a low effort implementation process.

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Stechele, B., Hughes, A., Degraer, S., Bossier, P. & Nevejan, N. (2023). Northern Europe's suitability for off-shore European flat oyster (*Ostrea edulis*) habitat restoration: A mechanistic niche modelling approach. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 33(7), 696–707. <https://doi.org/10.1002/aqc.3947> STECHELE ET AL. 707