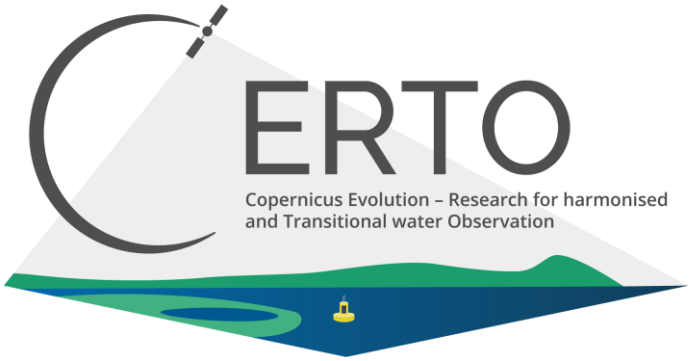

Horizon 2020

H2020 LC-SPACE-04-EO-2019-2020

Copernicus Evolution – Research for harmonised and Transitional-water Observation (CERTO)

Project Number: 870349

Deliverable No: D2.1		Work Package: Community requirements	
Date:	06-OCT-2020	Contract delivery due date	30-SEP-2020
Title:	Content and user requirements for the CERTO prototype		
Lead Partner for Deliverable	CNR		
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Dissemination level (PU=public, RE=restricted, CO=confidential)			PU
Report Status (DR = Draft, FI = FINAL)			DR

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme grant agreement N° 870349

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1. Executive Summary

- This is the first deliverable of CERTO WP2. The general objective of WP2 is to identify user needs, content and quality requirements, and concerns in terms of specific information that is required on any aspect of the state of transitional waters.
- This deliverable aims at defining the details of the products and service to be developed in close cooperation with large user groups, including the DANUBIUS European Research Infrastructure, GEO AquaWatch/Blue Planet, Lagoons for Life and end-users in regional case studies. The deliverable also includes a detailed description of the case studies that will be considered as exemplars in the project, i.e., Danube Delta (Black Sea), Venice Lagoon and North Adriatic Sea (Mediterranean Sea), Tagus Estuary (Atlantic Ocean), Plymouth Sound (English Channel), Elbe Estuary and German Bight (North Sea), Curonian Lagoon (Baltic Sea).
- Users were selected from a variety of aspects: different requirements in terms of targeted sectors; different interaction with the Copernicus services (e.g. direct users or through downstream providers) and also different types of users (e.g. companies, agencies and "brokers" of groups of services). This enabled the wide diversity of Copernicus users to be sampled.
- During meetings with the users, requirements with regard to information, quality and technical aspects were listed, reviewing existing products implemented in the Copernicus core services as well as indicators that could be obtained from EO.
- This deliverable documents the results of the user requirements analysis for each case study, to design targeted products for coastal applications. Community requirements were assessed by means of a questionnaire, which represented the basis of one-to-one discussions with users and main stakeholders, and enabled the collection of requirements grouped into specific targeted sectors (Maritime safety, Water pollution, Offshore Energy, Tourism & Recreational Activities, Coastal protection, Ports &Shipping, Sustainable Marine living resources, Weather & Climate, Basic and applied research in coastal oceanography).
- It is also noted that user requirements outside the scope of the CERTO were reported and recorded: this valuable information provides the consortium as well as the Copernicus upstream or downstream services with potential future direction to increase user uptake.
- D2.1 is a formal deliverable due M9 but it will be updated as a living document throughout the project.
- Finally, WP2 user interactions were all undertaken during the COVID-19 pandemic in Europe: this meant all contact was virtual. It is recognised, that this had limitations due to lack of face to face contact, and the modes of interaction (e.g. consulting documents, images, web sites, simultaneously) was difficult whilst using zoom, skype or telephone media.

2. Introduction

Water quality is a worldwide issue relevant to food production, industry, nature and recreation. Recognising its importance, Copernicus provides satellite data and services for water quality data and information to end-users in industry, policy, monitoring agencies and science. However, water quality data production for oceans, regional seas and lakes is split across three services, Copernicus Marine, Climate Change, and Land, with different methods used, while transitional waters are not supported by any service.

Provision of optical water quality indicators between the three services has largely evolved independently. Transitional waters "fall between" the remits of the three relevant services producing water quality information. As a consequence, different user requirements and also the technical and satellite capabilities have led to methodological differences as well as gaps in data provision, most notably in complex near-shore and inshore environments that include estuaries, lagoons, bays and large rivers. Presently, the lack of a harmonised approach between the services means that data consumers such as industrial actors or monitoring agencies whose remit covers coastal, estuarine or lake environments, or scientists interested in connected lake-river-sea systems (notably in the developing European DANUBIUS Research Infrastructure (DANUBIUS-RI), or downstream service providers, would need to visit two or even three services and obtain products that are in different formats, processed with different methods and with different characteristics. Users would also need considerable expertise in remote sensing to judge which sources are most relevant to their needs in situations where there is overlap. In other cases, potential users have no data available from Copernicus (e.g. in estuaries).

CERTO aims to address these issues by undertaking R&D necessary to produce harmonised water quality data, extending support to the large communities operating in transitional waters and evaluating cross-cutting optical water quality Indicators that may be used across coasts, transitional and inland waters (monitored through WFD and MSFD). CERTO is producing the evidence that will be needed by the "entrusted entities" that run Copernicus services as to the improvements, potential to increase the user community, possible downstream services and wider impact of the prototype.

In such a context, CERTO aims at a prototype system that will incorporate research on harmonised water optical classification approaches, improved atmospheric correction in optically complex waters and environmental indicators that can be applied to all these waters. The project and, in particular, the WP2 "Community requirements", therefore, interacts closely with key end-user communities, including the developing DANUBIUS-RI, GEO AquaWatch and Blue Planet and the nascent Lagoons for Life community and efforts addressing the UN Sustainable Development Goals, in order to extend Copernicus services to meet the requirements of user communities that have thus far not been met (or only partly met) through the existing services. The objective, therefore, is to engage with broad groups of users and to ascertain their requirements detailing the products and service to be developed, in terms of information, quality and technical aspects; then based on these requirements, to set up a validation plan and a technical implementation plan. Community engagement is undertaken largely through six user case areas, focussing on transitional waters around Europe (Figure 1, Table 1): these provide the contact with local / regional stakeholders as well as forming the "laboratories" in which to test the methods and innovations arising from CERTO and providing the evidence to its value to end-users and the Copernicus upstream service providers. CERTO brought together these user-case studies with a wide variety of stakeholders to focus attention on industrial, policy,

environmental issues in poorly characterised transitional waters (three lagoons and three estuaries) each with associated coastal zones.

To produce harmonised water quality data, extending Copernicus to a large number of relevant stakeholders, CERTO set a tight collaboration and a direct exchange of information with relevant stakeholders, such as Copernicus service entrusted entities, downstream service providers, end-users, research and local communities. Some of these actors are key final users while others are intermediate users that will get advantage of CERTO targeted products in designing downstream services for coastal areas and transitional waters.

WP2 started the process of continuous engagement with local stakeholders in these specific European transitional waters, invited to represent varied interests (e.g. eutrophication, sediment loads, river-estuary interactions, including dredging). The dialogue focuses on current gaps in data availability from the Copernicus services (jointly exploring what is available and how it could or could not be used), followed by formulation of a minimum and ideal set of requirements for the CERTO Prototype (e.g. water quality variables, spatial resolution, and product uncertainty). The six case studies have been carefully selected to be complementary, but also overlap in terms of service or user characteristics in order avoid basing conclusions only on a single instance. Each of the six case studies is connected with one project partner, and each case study has one or more users.

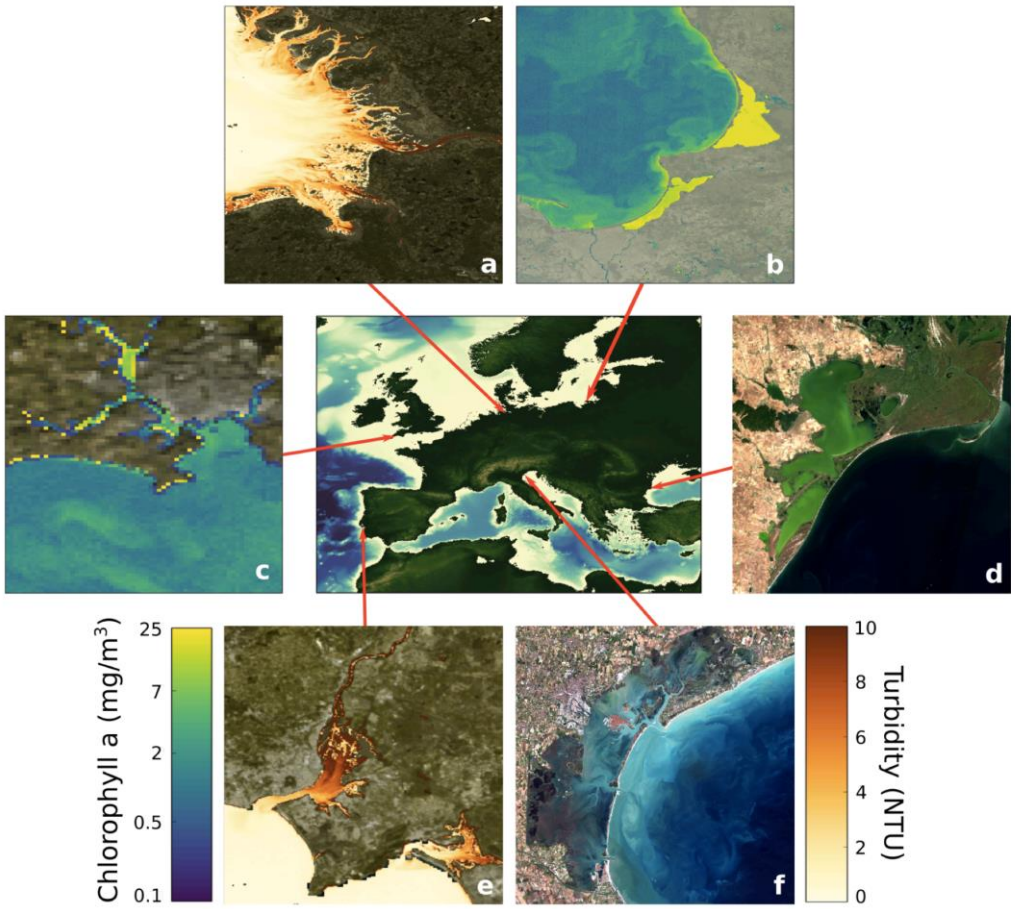

Figure 1. *Six case study areas a) Elbe estuary/German Bight: turbidity from OLCI; b) Curonian Lagoon, OLCI Chl-a concentration; c) Tamar estuary: OLCI chl-a concentration; d) Razelm Lagoon. MSI true colour; e) Tagus estuary: OLCI turbidity; f) Venice Lagoon: true colour MSI. All derived variables are a blend of algorithms based on a first attempt at optical water type classification; land is filled with true colour TOA radiance from the same image. True colour images are Rayleigh corrected. Central map is bathymetry/topography from GEBCO.*

Community requirements were assessed by means of a questionnaire, approved by the University of Stirling Ethics committee, submitted to the users and stakeholders including both international (DANUBIUS-RI, GEO AquaWatch/Blue Planet, Lagoons 4 Life) and end-users in regional case studies. The questionnaire formed the basis of one-to-one discussions with the users and main stakeholders and enabled collection of user requirements regarding, in particular, content requirements, quality requirements, and technical requirements. Discussions with users encompassed review of existing products, methodologies and approaches implemented in the Copernicus services as well as policy (e.g. EU Directives Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD)) and industry (e.g. aquaculture, port authorities, etc). The discussions were also aimed at identifying targeted products and a list of indicators for users and stakeholders, spanning industry (e.g. shipping and aquaculture), local authorities (e.g. Port authorities) and regulators (e.g. environmental agencies in charge of reporting on MSFD and WFD.

Table 2.1. *Updated table of CERTO case studies: Danube Delta (Black Sea), Venice Lagoon and North Adriatic Sea (Mediterranean Sea), Tagus Estuary (Atlantic Ocean), Plymouth Sound (English Channel), Elbe Estuary and German Bight (North Sea), Curonian Lagoon (Baltic Sea)*

User-case areas	Institutional lead partner
1. Danube Delta	GeoEcoMar
2. Venice Lagoon and North Adriatic Sea	CNR
3. Tagus Estuary	FC.ID
4. Plymouth Sound	PML
5. Elbe Estuary and German Bight	BC
6. Curonian Lagoon	CNR

3. Stakeholders

CERTO stakeholders include Copernicus service entrusted entities, downstream service providers, end-users, research and local communities, directly exploiting/benefiting from ecosystem services in the case study areas. Some actors from these communities are already partners in the CERTO consortium. Key external users, which are not partners in the consortium, were identified in order to establish a tight collaboration for the improvement of the services.

Stakeholders involvement is focused on

i) user-led product definition and development;
ii) tailored end-products; increased project visibility and awareness;
iii) information sharing.

In particular, stakeholders are involved in the analysis of the requirements and existing gaps for those sectors that will benefit from the project outcomes (Figures 2 and 3). Here we aim to identify and categorise users for these sectors, for each of the six user-case areas. This is considered as a first step in the co-design and implementation of services and products, and sets the basis for an on-going relationship with stakeholders, encouraging multidirectional communication and develop contact networks

Consultation with the user communities for general requirements focused on current gaps in data availability from the Copernicus services (jointly exploring what is available and how it could or could not be used), followed by formulation of a minimum and ideal set of requirements for the CERTO Prototype (e.g. spatial resolution, water quality variables and product uncertainty).

The six user-case studies encompass a wide variety of stakeholders to focus attention on industrial, policy, environmental issues in poorly characterised transitional waters (three lagoons and three estuaries) each with associated coastal zones.

The stakeholders/contacts database enables interested parties to receive further project information on a regular basis and is GDPR compliant.

3.1. Interaction with the Advisory Board (AB)

The AB in CERTO has two roles: firstly, they comprise leading representatives from user groups (notably GEO, the Group on Earth Observations), science, environment agencies, an umbrella organisation for European remote sensing companies (EARSC) and environmental management. They provide independent advice and feedback on the application of the CERTO research to achieve the project objectives, the integration of interdisciplinary research, communication with all their stakeholder groups and the dissemination of research findings and exploitable results.

Second, they provide guidance and input to the optimization and monitoring of the project activities and goals, taking into account innovation and application of EO products in different fields, sites and sectors. They provide a global perspective (GEO and Future Earth Coasts, the “home” of Lagoons for Life), pan-European commercial (EARSC), policy and conservation (JNCC) and science (HZG).

The composition of the AB is given below (Table 3.1).

Table 3.1.: *Advisory board members*

Organisation name	Representative	Role
GEO AquaWatch	Dr S. Greb, Director GEO AquaWatch	Links with GEO AquaWatch; global user community focus
GEO Blue Planet	Dr P DiGiacomo GEO Blue Planet	Links with GEO Blue Planet; global user community focus
Future Earth Coasts	Dr S Ferse, Executive Director	Links with Future Earth Coasts; global user community focus
Joint Nature Conservation Committee, UK	Dr G Jones	Links with JNCC; policy / government focus
European Association of Remote Sensing Companies	Dr R Donnelly, Business manager, EARSC	Links with EARSC; focus European companies in remote sensing
Helmholtz-Zentrum Geesthacht	Dr H Krasemann	Scientific expert on water quality and EO methods and intercomparison

GEO AquaWatch is an initiative within GEO that aims to develop and build the global capacity and utility of Earth Observation-derived water quality data, products and information to support water resources management and decision making. Its goal is to develop and build the global capacity and utility of EO-derived water quality data, products and information to support effective monitoring, management and decision making.

GEO Blue Planet is a network of ocean and coastal-observers, social scientists and end-user representatives from a variety of stakeholder groups, including international and regional organizations, NGOs, national institutes, universities and government agencies. GEO Blue Planet has a demonstrated capacity to bridge the gap between data and services to deliver usable information that supports informed decision-making toward reaching sustainable development.

Future Earth Coasts is a 'community' of organisations, scientists and practitioners from all disciplines of science, engineering, the humanities and law whose work addresses Global Environmental Change. It seeks to develop links with those involved in policy-setting and governance of coastal regions across the World, aiming to be a platform for international engagement and to support adaptation to global change by linking natural and social sciences with knowledge of coastal communities at global, regional and local scales, also providing a knowledge base to address the risks and opportunities arising from global coastal change.

The Joint Nature Conservation Committee (JNCC) is the statutory adviser to the government and devolved administrations on UK and international nature conservation. Its work contributes to maintaining and enriching biological diversity, conserving geological features and sustaining natural systems.

The European Association of Remote Sensing Companies (EARSC), is a membership-based, not for profit organisation which coordinates and promotes the activities of European companies engaged in delivering EO-derived geo-information services. EARSC represents this sector in its broadest sense, creating a network between industry, decision makers and users and covering the full EO value chain from data acquisition through processing, fusion, analysis to final geo-information products & services.

Dr. Krasemann is a science contact, based at the German research institute Helmholtz-Zentrum Geesthacht (HZG) who are a partner in the DANUBIUS-RI project and operate a DANUBIUS-RI super-site. His expertise is in optical remote sensing.

3.2. Users in the CERTO target sectors

Figures 2 and 3 provide a general overview of the number of users within CERTO, organized by the sectors that will benefit from the project outcomes. The main sectors identified were:

- Maritime safety
- Water pollution
- Offshore energy
- Tourism and recreation
- Coastal protection
- Ports and shipping
- Sustainable marine living resources
- Weather and climate
- Basic and applied research

Beside these general, common sectors, we also recognized some specific fields of interest such as dredging and supply monitoring, data feeding for modelling activity, eco-geomorphology, gap analysis and harmonization of data and info, and sustainable exploitation of reed beds.

Users in CERTO were also characterized as “intermediate” and “final” users.

- Intermediate users are those who will take advantage of CERTO outcomes by subsequently providing downstream services that will use CERTO novel products as data for end users.
- Final users are those end-users that will directly benefit from CERTO’s products since they obtain data directly from the Copernicus services.

Both final and intermediate users were identified for the nine sectors.

Note that a specific user can play a different role in being an intermediate or a final user, depending on the different sector.

Additional details on the users by sector are provided in the following subsections. Special care will be taken to maintain continuous communication with the users through the product and services co-design process to ensure their engagement and the uptake of the outcomes.

Figure 2. *Number of stakeholders engaged in CERTO for each sector that will benefit from CERTO's products and outcomes: users may be in more than one sector*

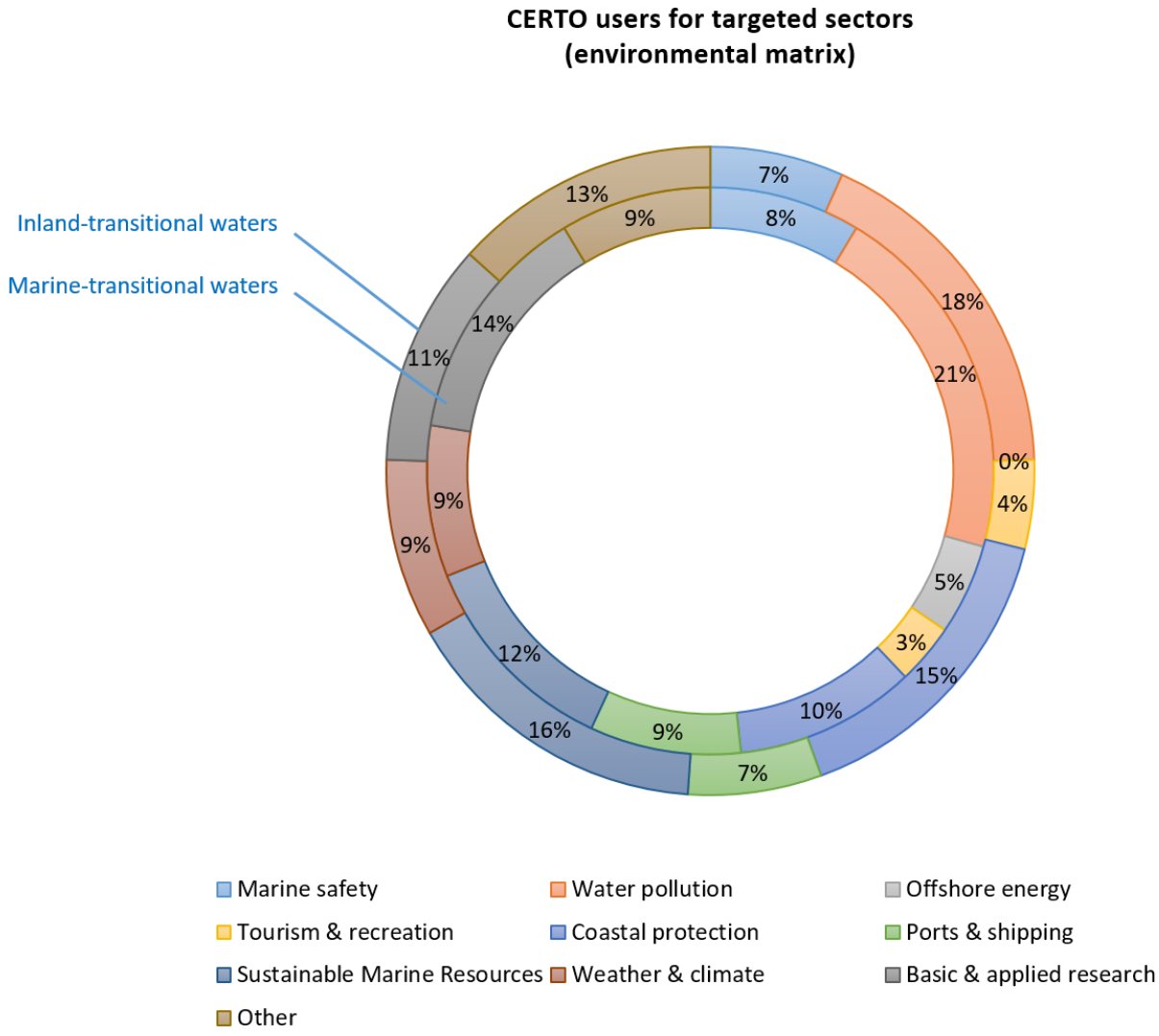

Figure 3. *Percentage of identified users by the different sectors, represented by the two main geographical regions that are explored in CERTO*

3.2.1. Maritime safety

The sector of Maritime safety includes, supervision of ship navigation, SAR operators, coastguard, oil spill response managers, maritime emergency managers, Navy, national and local security agencies. This sector is of interest in all test case areas, except for the Curonian Lagoon. For this sector five intermediate users and one final user are active (Table 3.2.1). In particular, intermediate users are mostly research/technological centres working in applied research (i.e., THETIS for the Venice Lagoon, LNEC for the Tagus Estuary, MBTC and Thales for the Plymouth Sound, BSH for the Elbe estuary) and one local authority (Jurilovca City Hall for the Danube Delta). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.1. *Detail on users for Maritime safety sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
2. Venice Lagoon and North Adriatic Sea	THETIS	Intermediate
3. Tagus Estuary	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate
5. Elbe Estuary and German Bight	Federal Maritime and Hydrographic Agency of Germany (BSH)	Intermediate

3.2.2. Water pollution

The sector of Water pollution includes local authorities and relevant actors that are directly or indirectly involved in the European Water and Marine Strategy Framework Directives - WFD & MSFD. This sector is of interest in all test case areas with seven intermediate and seven final users (Table 3.2.2). In particular, users are research/technological centres working in applied research (i.e., THETIS, ISMAR-CNR, and CORILA for the Venice Lagoon; LNEC and IPMA for the Tagus Estuary, MBTC and Thales for the Plymouth Sound, BSH for the Elbe estuary; KU for the Curonian Lagoon) as well as local authorities and regional/national agencies (Jurilovca City Hall and DDBRA for the Danube Delta; APA, ARH, and ICNF for the Tagus Estuary). All users have previous interactions with the related partner of CERTO Consortium thus building on existing relationships.

Table 3.2.2. *Detail on users for Water pollution sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
	Danube Delta Biosphere Reserve Authority (DDBRA)	Final
2. Venice Lagoon and North Adriatic Sea	THETIS	Intermediate
	ISMAR-CNR	Final
	CORILA	Intermediate
3. Tagus Estuary	Agência Portuguesa do Ambiente (APA)	Final
	Administração da Região Hidrográfica do Tejo (ARH)	Final
	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
	Instituto da Conservação da Natureza e das Florestas - Reserva do Estuário do Tejo (ICNF)	Final
	Instituto Português do Mar e Atmosfera (IPMA)	Intermediate
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate
5. Elbe Estuary and German Bight	Federal Maritime and Hydrographic Agency of Germany (BSH)	Intermediate
6. Curonian Lagoon	Marine Research Institute, Klaipeda	Final

	University (KU)	

3.2.3. Offshore Energy

The sector of Offshore Energy includes energy company managers as well as agencies that are involved in environmental impact assessments. This sector is of interest in two test case areas, with three intermediate users (Table 3.2.3). In particular, these users are research/technological supporting centres (i.e., MBTC and Thales for the Plymouth Sound, BSH for the Elbe estuary). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.3. *Detail on users for Offshore Energy sector*

Case study	USER	Type of user
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate
5. Elbe Estuary and German Bight	Federal Maritime and Hydrographic Agency of Germany (BSH)	Intermediate

3.2.4. Tourism and recreational activities

The sector of Tourism & Recreational Activities includes those final and intermediate users that seek to assess mass tourism issues. This sector is of interest in two test case areas with one intermediate and two final users (Table 3.2.4). In particular, users are research/technological centres working in applied research (i.e., CORILA for the Venice Lagoon) as well as local authorities (i.e., Jurilovca City Hall and DDBRA for the Danube Delta). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.4. *Details on users for Tourism and recreational activities sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
	Danube Delta Biosphere Reserve Authority (DDBRA)	Final

2. Venice Lagoon and North Adriatic Sea	CORILA	Intermediate

3.2.5. Coastal protection

The sector of Coastal protection includes institutional and research-based environmental managers, as well as other organization that work, directly or indirectly on beach and coastal planners. This sector is of interest in four test case areas with four intermediate and five final users (Table 3.2.5). Users are research/technological centres working in applied research (i.e., THETIS, DANUBIUS, and CORILA for the Venice Lagoon; LNEC for the Tagus Estuary; BAW for the Elbe Estuary; KU for the Curonian lagoon) as well as local authorities and regional/national agencies (Jurilovca City Hall and DDBRA for the Danube Delta; ICNF for the Tagus Estuary). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.5.*: Detail on users for Coastal protection sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
	Danube Delta Biosphere Reserve Authority (DDBRA)	Final
2. Venice Lagoon and North Adriatic Sea	THETIS	Intermediate
	DANUBIUS	Final
	CORILA	Intermediate
3. Tagus Estuary	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
	Instituto da Conservação da Natureza e das Florestas - Reserva do Estuário do Tejo (ICNF)	Final
5. Elbe Estuary and German Bight	Federal Waterways Engineering and Research Institute (BAW)	Intermediate
6. Curonian Lagoon	Marine Research Institute, Klaipeda	Final

	University (KU)	

3.2.6. Ports & Shipping

The sector of 'Ports and shipping includes those activities that support port managers, port pilots, ferry companies/captains, shipping companies/captains, cruise companies/captains. This sector is of interest in all test case areas, except for the Curonian Lagoon with five intermediate users and one final user (Table 3.2.6). All intermediate users are research/technological centres working in applied research (i.e., CORILA for the Venice Lagoon; LNEC for the Tagus Estuary; BSH for the Elbe Estuary) while MBTC and Thales (for the Plymouth Sound) are supporting centres; the final user is a local authority (i.e., Jurilovca City Hall for the Danube Delta). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.6. *Detail on users for Ports and shipping sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
2. Venice Lagoon and North Adriatic Sea	CORILA	Intermediate
3. Tagus Estuary	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate
5. Elbe Estuary and German Bight	Federal Maritime and Hydrographic Agency of Germany (BSH)	Intermediate

3.2.7. Sustainable Marine living Resources

The sector of 'Sustainable Marine living Resources' includes fisheries and aquaculture managers and scientists, commercial fishermen, sustainability managers. This sector is of interest in four test case areas, with five intermediate and five final users (Table 3.2.7). The intermediate users are four research/technological centres working in applied research (i.e.,

THETIS, ISMAR-CNR, and CORILA for the Venice Lagoon; LNEC for the Tagus Estuary) and one institutional agency (i.e., IPMA, for the Tagus Estuary); final users are local authorities (i.e., Jurilovca City Hall and DDBRA for the Danube Delta) and research centres (KU for the Curonian Lagoon) and direct players on this field (AMA for the North Adriatic Sea and FU for the Tagus Estuary). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.7. *Detail on users for Sustainable Marine living Resources sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
	Danube Delta Biosphere Reserve Authority (DDBRA)	Final
2. Venice Lagoon and North Adriatic Sea	AMA	Final
	THETIS	Intermediate
	ISMAR-CNR	Intermediate
	CORILA	Intermediate
3. Tagus Estuary	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
	Fishermen's Union (FU)	Final
	Instituto Português do Mar e Atmosfera (IPMA)	Intermediate
6. Curonian Lagoon	Marine Research Institute, Klaipeda University (KU)	Final

3.2.8. Weather & Climate

The sector of 'Weather and Climate' includes users and activities that are directly connected to weather forecast centres and deal with data for model validation and assimilation. This sector is of interest in three test case areas, with three intermediate and three final users

(Table 3.2.8). The intermediate users are research/technological centres working in applied research (i.e., THETIS, and ISMAR-CNR for the Venice Lagoon) while MBTC (for the Plymouth Sound) are supporting centres; final users are local authorities (i.e., Jurilovca City Hall and DDBRA for the Danube Delta) and one research centre (DANUBIUS for the North Adriatic Sea). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.8. *Detail on users for Weather & Climate sector*

Case study	USER	Type of user
1. Danube Delta	Jurilovca City Hall	Final
	Danube Delta Biosphere Reserve Authority (DDBRA)	Final
2. Venice Lagoon and North Adriatic Sea	THETIS	Intermediate
	ISMAR-CNR	Intermediate
	DANUBIUS	Final
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate

3.2.9. Basic and applied research in coastal oceanography

The sector of 'Basic and applied research in coastal oceanography' includes academia, as well as public and private research organizations. This sector is of interest in all test case areas, with six intermediate and four final users (Table 3.2.9). In particular, the intermediate users are research/technological centres working in applied research (i.e., THETIS, for the Venice Lagoon; LNEC and IPMA for the Tagus Estuary; BSH for the Elbe Estuary) while MBTC and Thales (for the Plymouth Sound) are supporting centres; final users are also research centres (ISMAR-CNR and DANUBIUS for the North Adriatic Sea; KU for the Curonian Lagoon) and one local authority (i.e., DDBRA for the Danube Delta). All users have previous interaction with the related partner of CERTO Consortium.

Table 3.2.9. *Detail on users for Basic and applied research in coastal oceanography sector*

Case study	USER	Type of user
1. Danube Delta	Danube Delta Biosphere Reserve Authority (DDBRA)	Final
2. Venice Lagoon and North Adriatic Sea	THETIS	Intermediate
	ISMAR-CNR	Final
	DANUBIUS	Final
3. Tagus Estuary	Laboratório Nacional de Engenharia Civil (LNEC)	Intermediate
	Instituto Português do Mar e Atmosfera (IPMA)	Intermediate
4. Plymouth Sound	Marine Business Technology Centre (MBTC)	Intermediate
	Maritime Autonomy Systems Business Lead (Thales)	Intermediate
5. Elbe Estuary and German Bight	Federal Maritime and Hydrographic Agency of Germany (BSH)	Intermediate
6. Curonian Lagoon	Marine Research Institute, Klaipeda University (KU)	Final

3.3. Copernicus Marine regional products and use cases

Within the Copernicus Marine Environment Monitoring Service, the Ocean Colour Thematic Centre (OC TAC) provides worldwide and regional (Atlantic, Arctic, Baltic, Mediterranean and Black Sea; Fig. 4) high-quality satellite ocean colour products, based on satellite Ocean Colour missions. Regional satellite products are higher-level observational combined products and provide accuracy higher than standard Ocean Colour data available from standard ground segments thanks to the regionalization of processing chains that takes into account the bio-optical characteristics of each regional seas for production and data validation.

The challenging requirement for CERTO is to produce outputs for the CMEMS regional areas at least good as those currently provided through the regionalised approach.

For each ocean region, OC TAC delivers two sets of products, i.e., CHL and OPTICS (Table 3.3).

CHL is the phytoplankton chlorophyll concentration (mg m^{-3}). For the regional seas, OC TAC selected the state-of-the-art product algorithm on the basis of optical characteristics of the basin. The data are merged into a single chlorophyll field providing a regional product with an improved accuracy of estimates in coastal waters.

The OPTICS product includes all other variables retrieved from ocean colour sensors, i.e., Inherent Optical Properties (IOPs), such as absorption and backscattering, the diffuse attenuation coefficient of light at 490 nm (Kd490), Secchi depth (transparency of water), spectral Remote Sensing Reflectance (Rrs), absorption coefficient of radiative flux in sea water due to dissolved organic matter and non-algal particles (adg), absorption coefficient of radiative flux in sea water due to phytoplankton (aph), absorption coefficient of radiative flux in sea water (atot), Suspended Particulate Matter (SPM), and the particulate back-scattering coefficient (bbp). In particular, Kd490 is defined as the diffuse attenuation coefficient of light at 490 nm, and is a measure of the turbidity of the water column, i.e., how visible light in the blue-green region of the spectrum penetrates within the water column; SPM is defined as all inorganic matter that stays on a glass fibre filter with an approximate pore size of 0.7 micrometres. Heavy metals and various organic micropollutants adsorb to SPM, the transport of which can affect the ecosystem. High concentrations of SPM cause turbidity which in turn affects the underwater light conditions, thus influencing primary production by phytoplankton and other algae in coastal waters

Both CHL and OPTICS products are available as Near Real time Products (Observations) and Multi Year Products (Reprocessing of Observations) (Table 3.3). Below we provide a brief description of these regional products, in terms of uses and in the nature of their regional algorithms.

Figure 4. *The six geographical areas (2 to 7) of the Copernicus Marine Environment Monitoring Service*

Table 3.3. *CHL and OPTICS regional products, available for the CMEMS geographic areas. All products are remapped at 1 km spatial resolution using cylindrical equirectangular projection.*

	CHL				OPTICS			
	NRT		REP		NRT		REP	
	L3	L4	L3	L4	L3	L4	L3	L4
North Atlantic	Chl-a *daily*	Chl-a *daily monthly*	Chl-a PFT *daily*	Chl-a dai *monthly*	Rrs SPM adg atot aph Kd490 *daily*	Kd490 *monthly*	Rrs *daily*	
Mediterranean Sea	Chl-a *daily*	Chl-a *daily monthly*	Chl-a PFT *daily*	Chl-a *monthly*	Rrs adg aph Bbp Kd490 *daily*	Kd490 *monthly*	Rrs Kd490 *daily*	
Baltic Sea	Chl-a *daily*		Chl-a *daily*		Rrs adg aph Bbp Kd490 *daily*		Rrs Kd490 *daily*	
Black Sea	Chl-a *daily*	Chl-a *daily, monthly*	Chl-a *daily*	Chl-a *monthly*	Rrs Kd490 Bbp Adg Aph *daily*	Kd490 *monthly*		

3.3.1. North Atlantic

For the North Atlantic area, the ESA Ocean Colour CCI Remote Sensing Reflectance (merged, bias-corrected Rrs) data are used to compute surface Chlorophyll concentration (Table 3.3), by using the regional OC5CI chlorophyll algorithm, i.e., a variation of OC5 (Gohin et al., 2002) combined with the CI algorithm. Rrs are generated by merging the data

from SeaWiFS, MODIS-Aqua, MERIS, VIIRS, and OLCI sensors and realigning the spectra to that of the MERIS sensor (i.e., the OC CCI v5, released in October 2020). The resulting OC5CI algorithm was tested and selected through an extensive calibration exercise that analysed the quantitative performance against in situ data for several algorithms in these specific regions. For the regional products, a variant of the OC-CCI chain is run to produce high resolution data at the 1km resolution necessary (Sathyendranath et al., 2012).

For this area, adg, aph, and atot are obtained from a semi-analytic model for the derivation of ocean colour inherent optical properties (Smyth et al., 2006). Products derived from MODIS-Aqua are: Inherent Optical Properties, IOPs (adg, aph, and atot). From VIIRS is derived SPM. Products derived from OLCI are Rrs at different wavelengths and Kd490. Rrs are derived from the CCI multi-sensor product.

3.3.2. Baltic Sea

The Baltic Sea CHL product (1km spatial resolution; Table 3.3) is based on the BAL_HZG_OLCI_v2 processing chain, incorporating two complementary neural network approaches: the C2RCC (Case 2 Regional CoastColour) Atmospheric Correction with revised neural nets from May 2019 is applied to the Sentinel-3 OLCI L1B data to retrieve the remote sensing reflectances; then the OLCI Neural Network Swarm (ONNS) version 0.9 (2019) is applied as bio-geo-optical in-water algorithm to retrieve CHL as well as additional "Optics" products (vertical attenuation coefficient and IOPs). Near-real time L3 OPTICS products available over Baltic Sea (i.e., Rrs, APH440, ADG, and Kd490) are also provided at 1km resolution.

Reprocessed CHL products are estimated via the regional algorithm BalAlg, applied over the Rrs spectra from an ad-hoc configuration of the ESA-CCI processor for CMEMS. This version has the qualification of the fully reprocessed time series (1997-2018) based on CCIv4, which incorporates NASA R2018.0 reprocessing for MODIS-AQUA, SeaWiFS and VIIRS, and POLYMER atmospheric correction for MERIS R2012.0. BalAlg is an updated version of D'Alimonte et al. (2012), with the surface chlorophyll concentration obtained via a Multilayer Perceptron (MLP) neural network. This product is remapped at 1 km spatial resolution using cylindrical equirectangular projection. OPTICS products for Baltic area (i.e., Rrs, and kd490 data) are also based on the CCIv4 data set.

3.3.3. Mediterranean Sea

For this basin, chlorophyll concentration (at 1 km resolution; Table 3.3) is derived from multi-sensor (MODIS-AQUA, NPP-VIIRS, and MERIS) and Sentinel3-OLCI Rrs spectra, by applying the Mediterranean Ocean Colour regional algorithms: an updated version of the MedOC4 (Case 1 water, Volpe et al., 2019) and AD4 (Case 2 water, D'Alimonte and Zibordi, 2003). Discrimination between the two water types is performed by comparing the satellite spectrum at pixel-by-pixel level with the average water type spectral signature from in situ measurements for both water types. These are computed from the MedOC4 in situ dataset (Volpe et al., 2007) for Case 1 waters and from the CoASTS in situ dataset (Berthon et al., 2002) for Case 2. Merging of Case 1 and Case 2 information is performed following D'Alimonte et al. (2003). This product identifies the average chlorophyll content of the surface layer as defined by the first optical depth (roughly one fifth of the euphotic depth). For consistency with the MODIS and VIIRS NASA L2 dataset a BRDF correction is applied to OLCI prior to band shifting and multi sensor merging.

The interpolated, gap-free Level-4 CHL products (1 km spatial resolution) are estimated by means of a modified version of the DINEOF algorithm by GOS (Volpe et al., 2018). DINEOF

is an iterative procedure in which EOF are used to reconstruct the entire field domain. As a first guess, it uses the SeaWiFS-derived daily climatological values at missing pixels and satellite observations at valid pixels. The other Level-4 datasets are the time averages of the L3 fields and include the standard deviation and the number of observations in the monthly period of integration.

The Mediterranean Level-3 reprocessed CHL products also include the phytoplankton functional types (PFT), which provide estimates of Chl concentration of 9 phytoplankton groups: Micro, Nano, Pico, Diato, Dino, Crypto, Hapto, Green and Prokar. Micro consists of Diato and Dino, Nano includes Crypto and Hapto and Pico is referred to Green and Prokar with the adjustment of Brewin et al. (2010) in the ultra-oligotrophic water for Pico and Nano. These classes are estimated via empirical regional functions, correlating chlorophyll concentration with each in-situ PFT fraction computed by a regional diagnostic pigment analysis (Di Cicco et al. 2017). These products have the qualification of the fully reprocessed time series (1997-2018), based on CCIv4.

Finally, OPTICS products (1 km spatial resolution; Table 3.3) include Rrs and Kd490 from multi-sensor (MODIS-AQUA, NPP-VIIRS, MERIS) and Sentinel3-OLCI observations. Exclusively for multi-sensor also the absorption of phytoplankton (aph443), Gelbstoff material (adg443), and the particulate backscattering (bbp443) coefficients at 443 nm are provided. For multi-sensor observations Kd490 is achieved via Mediterranean regional algorithm, developed on the basis of MedBiOp in situ dataset (Volpe et al., 2019). Inherent Optical Properties (aph443, adg443 and bbp443 at 443nm) are derived via QAAv6 model. For consistency with the MODIS and VIIRS NASA L2 dataset, BRDF correction is applied to OLCI prior to band shifting and multi sensor merging. The Level-3 reprocessed products (i.e., Rrs and Kd490) are based on the 1997-2018 CCIv4 time series.

3.3.4. Black Sea

For the Black Sea, OPTICS products (Table 3.3) are obtained from multi-sensor (MODIS-AQUA, NPP-VIIRS, MERIS) and Sentinel3-OLCI observations. As with the Mediterranean area, absorption of phytoplankton (aph443), Gelbstoff material (adg443), and the particulate backscattering (bbp443) coefficients at 443 nm are provided exclusively for multi-sensor also the Inherent Optical Properties (aph443, adg443 and bbp443 at 443nm) are derived via QAAv6 model (Lee et al., 2002). Then, geophysical fields (i.e. chlorophyll, kd490, bbp, aph and adg) are estimated via state-of-the-art algorithms for better product quality. The Level-4 product includes monthly averages at 1 km spatial resolution along with the respective standard deviation and the number of observations in the period of integration.

Reprocessed OPTICS products are based on the fully reprocessed CCIv4 time series (1997-2018) that incorporates NASA R2018.0 reprocessing for MODIS-AQUA, SeaWiFS and VIIRS, and POLYMER atmospheric correction for MERIS. Rrs spectra are obtained from an ad-hoc configuration of the ESA-CCI processor for CMEMS at high resolution, and result from the merging of SeaWiFS, MODIS-Aqua, MERIS and VIIRS sensors. This product is remapped at 1 km spatial resolution using cylindrical equirectangular projection.

Regarding CHL products, surface chlorophyll concentration at 1 km spatial resolution (Table 3.3) is derived from multi-sensor (MODIS-AQUA, NPP-VIIRS, MERIS) and Sentinel3-OLCI Rrs spectra. In particular, the chlorophyll (Chl-a) product is obtained combining two different regional algorithms (BSAlg). The first is a band-ratio algorithm (B/R) (Zibordi et al., 2015) that computes Chl as a function of the slope of Rrs values at two wavelengths (490 and 555 nm) using a polynomial regression that captures the overall data trend. The second one is a Multilayer Perceptron (MLP) neural net based on Rrs values at three individual wavelengths

(490, 510 and 555 nm) that features interpolation capabilities helpful to fit data nonlinearities. The merging scheme (Kajiyama et al., 2018) has been designed to use the B/R algorithm and the MLP neural net in waters exhibiting lower and higher optical complexity, respectively. For multi-sensor observations, single sensor Rrs fields are band-shifted, over the SeaWiFS native bands (using the QAAv6 model, Lee et al., 2002) and merged with a technique aimed at smoothing the differences among different sensors. Also for this product, the BRDF correction was applied to OLCI prior to band shifting and multi sensor merging.

The related Level-4 product (both monthly averaged daily interpolated chlorophyll field with no data voids, excluding OLCI dataset), are at 1 km spatial resolution, obtained from the multi-sensor (MODIS-Aqua, NPP-VIIRS, MERIS) and single sensor Sentinel3-OLCI Level-3 chlorophyll concentration. The interpolated gap-free Level-4 Chlorophyll concentration is estimated by means of a modified version of the DINEOF algorithm by GOS (Volpe et al., 2018). The other L4 datasets (monthly) are the time averages of the L3 fields (including standard deviation and the number of observations). These products quantify the average chlorophyll content of the surface layer as defined by the first optical depth. Also for the Black Sea area the reprocessed CHL products are based on the CCIv4 1997-2018 time series, which incorporates NASA R2018.0 reprocessing for MODIS-AQUA, SeaWiFS and VIIRS, and POLYMER atmospheric correction for MERIS.

3.3.5. Use cases in CMEMS Regional areas

Here we provide a non-exhaustive list of relevant users of CMEMS regional products that play a crucial, local role in coastal monitoring, marine conservation, as well as monitoring and assessing water quality. The list of users encompasses the above mentioned CMEMS geographic areas, i.e., North Atlantic, Baltic Sea, Mediterranean Sea and Black; many of these users operate in different areas, covering different sectors:

Deltares, NL, is an independent institute for applied research in the field of water. In particular, their focus is on deltas, coastal regions and river basins, working closely with governments, businesses, other research institutes and universities. The main CMEMS use case regards an interactive web-mapping service for a chlorophyll indicator, based on satellite data. MSFD-Eutro facilitates the use and interpretation of ocean colour data for public authorities working on the European MSFD. Statistics (such as multi-year mean and maximum) as well as trend analysis of CHL are performed to help with the MSFD reporting.

Cefas, UK, made significant contributions to environmental assessment of North East Atlantic Ocean, and the Oslo and Paris Convention for the protection and conservation of the North-East Atlantic (OSPAR). Cefas leads the development and application of marine ecosystem indicators and provides assessments to support the implementation of the MSFD that requires EU Member States to take the necessary measures to achieve a good coastal and oceanic environmental status by 2020. Satellite data from the CMEMS are used to offer customised data products to support assessments in relation to hydrographical conditions, water quality and eutrophication, biodiversity and marine food webs.

The **European Environment Agency** (EEA) provides sound, independent information on the environment. The use case, relevant for CERTO Project, concerns the WISE-Marine infrastructure, which has an aim to share the information and knowledge gathered or derived through the MSFD process and other key marine policy drivers. WISE-Marine has developed a GIS map viewer, displaying different layers originating from various sources, among which salinity and Chlorophyll-a from the Copernicus Marine Service.

AZTI, SP, is a technological centre based in Spain whose expertise is focused on marine research, covering several issues related to marine ecosystem functioning, marine and coastal environmental management, sustainable fisheries and aquaculture management and marine technologies. In particular, AZTI developed the CHLO4MSFD web portal service, focused on satellite data to answer the MSFD in all European Marine Regions. CHLO4MSFD encourages and supports the use of chlorophyll-a values from satellites, in their monitoring and assessment processes.

DEIMOS Engenharia, PT, is a private Portuguese Aerospace Engineering company, coordinating the SIMOcean project. This project helps the Portuguese government in its decision making and management process in 3 areas: Fishing area characterization, sea state index for harbor areas and Diagnostic of met-ocean fields. Several datasets will be brought together in an Open Data system to be exploited by three flagship value added services. Of interest for CERTO goals are the CMEMS data, specifically Ocean Colour, which are crucial for Fishing Areas Characterization Service, since they are used as environmental variables to model the sardine and mackerel possible distribution.

Telespazio is a private company built as a joint venture of Leonardo and Thales. It is a world-leading supplier of satellite-based services. In particular, Telespazio has developed a near-real time service for coastal to nearshore waters to warn users and stakeholders about water quality sanitary risk. They have developed a downscaling modelling suite where the Copernicus Marine Service model is used to provide boundary conditions for a higher resolution ocean model to monitor turbid plumes. Fed by CMEMS data, numerical models and optical imagery processing are coupled in order to improve the forecasting capacity. This service produces alerts in case of risk resulting in an efficient optimization of preventive beach closure, pollutant source identification, and finally aims to improve sewer system management. It also helps public stakeholders regarding health-care issues and limits impact on coastal zone economic activities, especially during the touristic summer period.

IFREMER, FR, is a French institute that undertakes research and expert assessments to advance knowledge on the oceans and their resources, monitor the marine environment and foster the sustainable development of maritime activities. IFREMER is one of the national agencies in charge of implementing such measures. In this regard, the Copernicus Marine Service Ocean Colour Satellite data as well as in-situ data are key inputs for monitoring some of the MSFD Descriptors, especially Descriptor 5, which deals with eutrophication. IFREMER aims to improvement coherence in eutrophication assessments, based on full resolution satellite-derived chlorophyll provided by CMEMS.

European Maritime Safety Agency (EMSA) is one of the EU's decentralised agencies based in Lisbon, cooperating with Member States and the Commission to provide technical, operational and scientific assistance for the purpose of ensuring maritime safety, security, prevention and response to pollution. EMSA is the Entrusted Entity responsible for delivering the Copernicus Maritime Surveillance service (CMS), in the framework of the Copernicus Security Service, which includes: supporting the fisheries control activities, maritime safety and security, law enforcement, customs activities, marine environment monitoring (pollution) and other operations.

Links MT s.p.a. is a consulting company, providing services and Information Technology solutions for the banking sector, the public administrations and enterprises, making use of emerging technological solutions. **CMCC Foundation** (Fondazione CMCC- Centro Euro-Mediterraneo sui Cambiamenti Climatici) is a non-profit research institution whose mission is to investigate and model our climate system and its interactions with society and the environment. Both LINKS SPA and CMCC have combined their respective skills in order to

develop sea situational awareness services for users in various sectors. CMEMS provides satellite ocean colour data useful for an initial assessment of met-ocean conditions in the Mediterranean.

ColomboSky develops remote sensing products for ocean and coastal monitoring. Through the study of innovative optimization processes, ColomboSky exploits remote sensing information to address the needs of key ocean industries, such as marine aquaculture, tourism and energy, reducing risks and economic losses. ColomboSky developed and implemented JellyX, an advanced web mapping tool for large scale monitoring of jellyfish swarms and their drift, based on oceanographic data provided by the Copernicus Marine Service. JellyX combines remote sensing data with in-situ ground-truth and oceanographic models, leveraging advanced machine learning techniques.

The **University of Malta** is the highest teaching institution in Malta and it developed a web platform including a dashboard presenting daily information on key marine parameters in the Maltese coastal areas from observations and numerical models. The Malta CMEMS Service Platform was created to serve local users with online access to dedicated products and services derived from the Copernicus Marine data. The products and services cover the marine domain close to the Maltese Islands. Users have access to the information in a user-friendly system that allows the browsing, viewing, selection and extraction of information (such as statistical metrics) by direct elaboration online.

The **Italian National Institute for Environmental Protection and Research**, (ISPRA) gathers the duties of the Environment Protection Agency, the National Institute for Wildlife and the Central Institute for Scientific and Technological Research applied to the Sea. In Italy, ISPRA is one of the national agencies in charge of implementing measures for both MSFD and WFD. In particular, ISPRA is in charge in the provisioning of merged satellite information along with in situ information at national level.

3.3.6. CMEMS/OCTAC System Evolution Plan

We finally provide some additional info regarding the 3-to-6 year CMEMS/OCTAC System Evolution Plan in order to frame the novel targeted products and outcomes of CERTO project within the future action of Copernicus.

The CMEMS/OCTAC serves users across the scientific and operational oceanography communities, commercial providers focused on the use of marine resources, and public agencies focused on environmental monitoring, with interests in products that across cover oceanic, shelf and coastal waters. Depending of their applications, these users require different spatial resolutions i.e. ~1km in ocean, 300m over the shelf, down to 10’s of metres in coastal waters. In 2018-2021, the OC data streams shifted from relying on science missions to the operational OC data stream from two OLCI and two VIIRS sensors. Since mid 2020, OCTAC has relied also on the operational high resolution imagers: Landsat8 OLI and the two Sentinel 2 MSI, this will enable provision of high resolution products for the coastal zone of all European waters. The continuous and sustained operational data stream for both observational classes, i.e. OC and high resolution imagers, is foreseen to continue beyond 2030.

Future work will investigate data fusion between data from the two observational classes to provide multi-resolution products with different resolution depending on location i.e. ~1km in ocean, 300m over the shelf, down to 10’s of metres in coastal waters. This may lead to the

development of experimental daily products at 10 m resolution, combining the spectral and temporal resolution of VIIRS and OLCI with the spatial resolution of S2/MSI +L8/OLI.

3.4. Stakeholder analysis

A cross-case study, cross-sector, and cross-environmental matrix analysis of the stakeholders relevant to CERTO project objectives has been performed. The base of the analysis has been the information gathered in the case study areas during the one-to-one discussions with users, stakeholders and the AB members. Further efforts will be undertaken to update or enlarge the list of users and stakeholders during the lifetime of the project.

In particular, we identified intermediate and final users in all sectors that will benefit from CERTO products and outcomes (Section 3.2), also taking into account the three main geographical regions that are of interest of the project: marine, transitional, inland water. All sectors considered covered the six main Copernicus services thematic areas: Land Monitoring, Emergency Management, Marine Monitoring, Atmosphere Monitoring, Security, Climate Change.

Moreover, we dedicated a specific section below for the Copernicus regional areas (i.e., North Atlantic Sea, Mediterranean Sea, Black Sea, Baltic Sea) by providing details on uses (based on Copernicus info) and also the nature of the regional satellite products and their related algorithms.

The sector of “Water pollution” is the most represented (Table 3.4), since it is active in all test case areas and fourteen of the eighteen users (among final and intermediate). This result is expected since it is the main focus of the CERTO project.

The exchange of information among users has enabled a better understanding of their needs in terms of specific information requirements (see following Section 4).

Table 3.4. *Updated table of CERTO case studies and their respective sectors that could also benefit from the project outcomes: Danube Delta (Black Sea), Venice Lagoon and North Adriatic Sea (Mediterranean Sea), Tagus Estuary (Atlantic Ocean), Plymouth Sound (English Channel), Elbe Estuary and German Bight (North Sea), Curonian Lagoon (Baltic Sea).*

User-case areas/Sectors	1. Danube Delta	2. Venice Lagoon and North Adriatic Sea	3. Tagus Estuary	4. Plymouth Sound	5. Elbe Estuary and German Bight	6. Curonian Lagoon
Maritime safety	X	X	X	X	X	
Water pollution	X	X	X	X	X	X
Offshore Energy				X	X	
Tourism & Recreation	X	X				
Coastal protection	X	X	X		X	X

Ports & Shipping	**X**	**X**	**X**	**X**	**X**	
Sustainable Marine living Resources	**X**	**X**	**X**			**X**
Weather & Climate	**X**	**X**		**X**		
Basic and applied research	**X**	**X**	**X**	**X**	**X**	**X**
Other	**X**	**X**		**X**	**X**	

4. User requirements

Starting from the list of final and intermediate users in the targeted sectors we contacted in CERTO, an analysis of their needs in terms of information and specific requirements has been performed. Yet, the gathering of the information has been performed at the level of the sectors. However, here the analysis of the needs and requirements is integrated by test case areas. Thus, specificities for the case studies working are provided.

Three main aspects have been covered:

- Specific regional characterization. For each test case areas we provide the main geographical and environmental characteristics, also highlighting particular issues regarding the main sectors that are considered in the project and the eventual gaps in data, information and knowledge.
- Information needs and implications. For each test case areas we explain what information is needed and what are the main reasons behind the need of information. We also briefly describe how the decisions are taken now and how/what could be improved.
- Technical readiness level. Here we provide information on the ability of the users in using a computer-based tool, receiving large quantities of data, connecting to the internet in a regular basis, and using new technologies.

For each test case area we then provided schematic tables in which the requirements have been classified in terms of the temporal scales needed for an effective action using the following three categories: what are the needs in terms of parameters, spatio-temporal coverage and resolution? Needed response time?

4.1. User requirements for test case areas

4.1.1. Razelm-Sinoe Lagoon System (Danube Delta – Black Sea)

4.1.1.1. Specific regional characterization

Located in the southeast part of Romania, the Razelm Sinoe Lagoon System represents the southern part of the Danube Delta Biosphere Reserve (North Long 44º 54' 6"; East Lat 28º 55' 19"). It is the largest lagoon in Romania, with an area of around 1000 square kilometres. The lagoon system is divided in two units (Razelm and Sinoe) formed by semi-independent lakes. Razelm has an area of 415 km^2 and a maximum depth of 3.2m and Sinoe has 171 km^2 and a maximum depth of 2.2m. Regarding the physical and administrative boundaries, the lagoon shares its southern, western and eastern limits with the Danube Delta Biosphere Reserve boundaries, the north-western limit being represented by transitional areas (ponds, marshes, wetlands and channels). The lagoon was almost closed from the sea in the 1970's, to be a strategic resource of freshwater. Nowadays, there is only one inlet, at Edighiol, that allows exchange with the sea. Water level in the lagoon fluctuates with the Danube water level. Due to its hydrology and morphology, Razelm-Sinoe behaves like a large, eutrophic lake. Eutrophication, also enhanced by inputs from agricultural activities inland, affects water quality, mainly in the spring and summer, leading to a decrease in fish stocks. Fishing is one of the traditional occupations in the region and traditional food is one of the main tourist attractions in villages bordering the lagoon along with ancient sites located in the west, fishing and boat trips all around the lagoon. So far, there is very little knowledge about

eutrophication, its phenology and controlling factors in the Razelm lagoon and its effects on the ecosystem.

4.1.1.2. Information requirements and implications

The Razelm-Sinoe Lagoon System and the coastal area of the Black Sea, part of the Danube Delta Biosphere Reserve, have seen an increase in human-induced pressures over the last 20 years, related mostly to tourist activities, fishing and reed harvesting. After consultations (presentation of the purpose of the project and additional information and tailored interviews) with the two main end-users, Jurilovca local administration (City Hall) and the Danube Delta Biosphere Reserve Authority (DDBRA), a list of needed parameters was identified: concentration of Chlorophyll-a, Total Suspended Matter, Turbidity, surface Temperature and Salinity, Dissolved Organic Matter, blooms of toxic algae, Nutrients and other type of pollution (plastic and hydrocarbons), and vegetation cover.

The Danube Delta Biosphere Reserve Authority is the main authority in charge of monitoring water quality in the Danube Delta in general and the lagoon in particular. They also manage tourism and associated navigation activities, fish stock and reed harvesting. The main information needed by the interviewed users, for the Razelm-Sinoe Lagoon System, is related to water quality and quantity and sediment fluxes. Their specific tools for monitoring these activities inside the lagoons, and the delta in general, are sometimes limited, due to a limited budget for monitoring and research. They receive scientific information from entities, which work in the area, and gather their own data, when possible; however, sometimes, the information is incomplete in time and space or not in an easy to access format. This increases the time needed for taking decisions and implementing measures to maintain a good environmental status in the Danube Delta and the coastal zone, to maintain navigable channels and adequate water flow, etc. For example, clogged channels hinder tourism activities in certain areas and interrupt water flow to spawning grounds for fish. In the coastal area, quality of bathing waters and beach areas is also important for tourism. Erosion is very marked in certain areas, especially on the littoral bar that closes the lagoon in the East. Geomorphologic information is, hence, very much needed in this area. They require high-level, L4 integrated data, in a near-real time, operational system. They are familiar with GIS-like interfaces, Excel files and tools, statistical analysis tools, data integration and interpretation, forecast systems.

Jurilovca City Hall (JCH) is the local administration for one of the villages bordering the lagoon and an important tourism and fishing hub in the area, the gateway to one of the most appreciated beach areas at the Black Sea, Gura Portitei. Maintaining good water quality both in the lagoon and coastal area, for both tourism and fishing, identifying clogged channels and managing beach areas are priorities. They also work with the DDBRA to get permission for such activities. They do not monitor or collect any scientific information; however, they collaborate with scientists who work in this area. They take informed decisions, based on expert advice, and they are used to working and knowing environmental regulations. They require simple, easy to access information, grouped in maps, reports, summaries, recommendations, online portals for forecasts.

Tourism related activities are growing in intensity in the Danube Delta - Black Sea area, with direct consequences and pressures on the natural environment. Climate change and other anthropic activities exacerbate certain effects, like eutrophication.

This information is needed to develop better tools for a more efficient management and an improved environmental evaluation of the Lagoon system and the Danube Delta- Black Sea coastal area, to implement the principles and objectives of the WFD, MSFD, conserving and protecting the natural environment but also considering all development activities in the area, to develop tools for improved hydrodynamic connectivity of the delta, fishing and local development.

Table 4.1.1. *Details of specific requirements needed in the Danube Delta case study*

		Jurilovca City Hall	Danube Delta Biosphere Reserve Authority
Environmental matrix	Marine water		
	Transitional water		
	Inland water		
General name of the Targeted product	CHL		
	TSM		
	Water turbidity		
	Rrs		
	SST		
	DO		
	Nutrients		
	Shoreline limits		
	pH		
	REE		
	SSH		
	Microplastic		
Type of service/ frequency	Operational		
	On demand		
Processing level of targeted product	L2		
	L3		
	L4		
	Static map		
	Report		
	Forecast		

Production mode	**Real-time**		
	Not real-time		
Temporal resolution	**Hourly**		
	Daily		
	Weekly		
	Monthly		
	Any		
Spatial resolution (m)	**10-50**		
	50-100		
	100-500		

4.1.1.3. Technical readiness level

The two key users and stakeholders in the Razelm-Sinoe Lagoon System have different levels of technical readiness for handling environmental data.

The DDBRA has limited experience with water colour products (TSM, Chlorophyll-a) and services. They are familiar with computer systems and web applications that they use in everyday activity and to some extent to systems and applications for data visualisation and analysis, like GIS systems and Excel. They also have very limited knowledge regarding data derived from satellite images and associated services. However, they have the technical readiness and skills to use them. The presentation of CERTO and user interview was a good opportunity for them to get information about this. They would benefit from finding a better way to handle and integrate complex environmental data from land, transitional water, marine areas.

The JCH has a basic technical readiness level to deal with complex and big sets of environmental data, but they do not have the time or the staff available to do so. Being a local administration they are used to working with laws and regulations so they need interpreted data in the context they require it. Their advantage is, however, being very opened to listening and learning from expert opinions and advice. They would benefit from ready to use maps, forecast systems, reports and informative materials, such as brochures.

4.1.2. Venice Lagoon (Northern Adriatic Sea)

4.1.2.1. Specific regional characterization

The Northern Adriatic Sea (NAS) is one of the most nutrient-rich areas in the Mediterranean Sea, due to the input from the Po and other rivers discharging into this area, whose drainage basins extend from the Central to the Eastern Arch of the Alps. This semi-enclosed basin is, indeed, characterized by a large number of rivers that discharge waters with different biogeochemical and optical properties. These river inputs act in a limited spatial extent and strongly influence the physical and biogeochemical properties of the basin itself. Located in the north-west sector of the NAS, the Venice lagoon with a total surface of ca. 550 km^2 is a

very shallow coastal environment with a mean depth of 1m and a spring-tidal range up to 1m. It maintains a connection to the northern Adriatic Sea through the inlets of Lido, Malamocco, and Chioggia.

The Venice Lagoon is a complex system of major historical and environmental interest that is under pressure from anthropogenic factors and global scale processes. Its heterogeneous morphology is characterized by a complex pattern of major (navigable) and minor channels, salt marshes, tidal flats and islands, which have been artificially modified throughout the centuries. In response to the increasing frequency of floods, determined by natural and anthropogenic subsidence and sea level rise, the last significant intervention is the construction of a system of mobile barriers at the tidal inlets, known with the acronym of MoSE. In a future scenario of rising sea level, the MoSE will transform the lagoon in a regulated system, due to the intensification of management actions, which will result in changes in hydrodynamics and in the transport of sediments, contaminants and organisms.

Like all shallow water transitional areas, the Venice lagoon is a constantly evolving environment, where the exchanges at the tidal inlets drive biogeochemical and morphological processes in dynamic key areas such as mudflats, wetlands, and the dense network of channels influencing coastal erosion and accretion patterns. The knowledge of the processes at the lagoon-sea interface represents a focal point for the safeguard of Venice, the lagoon and the functionality of the ecosystem. In situ monitoring in the lagoon, the inlets and the coastal waters is carried out by several agencies and a regional observing system to support environmental monitoring and reporting is currently set up.

4.1.2.2. Information requirements and implications

The Venice Lagoon is a complex system where a significant amount of biogeochemical, eco-geomorphological, and anthropogenic processes occurs. In such a context, several users (CORILA, THETIS, AMA, DANUBIUS) highlighted the need of a gap analysis and harmonization of data and info, in particular, in the field of monitoring the ecosystem services and their functionalities, as well as the impacts of pollutant inputs from industrial and touristic sectors. Integrated coastal zone management, climate change adaptation, contaminated site remediation are also crucial sectors that, currently, are largely affected by a lack of synoptic and long-term information. Therefore, ad hoc satellite products should (directly or indirectly) support the provisioning of information and advice on the sustainable management of human activities affecting, and affected by, marine ecosystems. This should also include the assessment of concentration and dynamics of pollutant loads, the develop early warning systems for oil spill and DSS for coastal land use

Through the LTER-Venice site (LTER-Italy; www.lteritalia.it), ecological observations are carried out by CNR-ISMAR at the multi-decadal scale. LTER represents one of the main tools for analysing how ecosystems change over time, and for describing and interpreting natural variability as opposed to ‘man-made’ variability. The resulting requirements from this user concern a specific synergy with satellite data for assessing trends of algal bio-mass and, thus, monitoring of nutrients and dissolved oxygen. These datasets will be also crucial for the investigation of aquatic phanerogams and blooms of macroalgae, in the light of the variability of environmental and anthropic parameters. All this should reinforce and support monitoring activities for the assessment of Good Environmental Status (i.e., WFD/MSFD monitoring), as well as the improvement of hypoxia/eutrophication indices.

The NAS DANUBIUS Supersite provides a facility for investigation of dynamics of the lagoon and river delta systems, including natural and anthropogenic variations. From this research infrastructure we recognized a particular need of near-real time ocean colour data (e.g., total suspended matter as well as water turbidity) for modelling storm surges and, in general, hydro-sedimentary processes. Synergy of Ocean colour, sea-surface salinity (SSS) products and hydrologic modelling for the investigation of river plume evolution, as well as fate and dispersion of river loads, will be crucial for monitor river plume extension and evolution, salt intrusions, as well as to assess climate projection for local applications and sediment budgets.

Finally, the NAS and the Venice lagoon are characterized by several mariculture activities (mostly Mediterranean mussel, *Mytilus galloprovincialis*), spread along the coastline. These are placed in a range of bathymetric, hydrographic, sediment and nutrient conditions. As pointed out by the user involved in this field (i.e., AMA), ad hoc satellite products would help the shellfish aquaculture sector of this area to better manage operations and reduce risks. In particular, there is a specific need for statistical analysis and monitoring tools from ocean colour full resolution satellite products (e.g., chlorophyll-a, TSM), also integrating operational modelling and remote sensing data to develop maps of suitability conditions and to develop alerting system for hazardous conditions such as heat waves and oxygen depleted conditions (i.e., eutrophication).

Table 4.1.2. *Details of specific requirements needed in the Venice Lagoon case study*

		AMA	THETIS	DANUBIUS	CNR-ISMAR	CORILA
Environmental matrix	**Marine water**					
	Transitional water					
	Inland water					
General name of the Targeted product	**CHL**					
	TSM					
	Water turbidity					
	Rrs					
	SST/SSS					
	DO					
	Nutrients					
	Shoreline limits					
	pH					
	REE					
	SSH					
	Microplastic					
Type of service/	**Operational**					

frequency	**On demand**					
Processing level of targeted product	**L2**					
	L3					
	L4					
	Static map					
	Report					
	Forecast					
Production mode	**Real-time**					
	Not real-time					
Temporal resolution	**Hourly**					
	Daily					
	Weekly					
	Monthly					
	Any					
Spatial resolution (m)	**10-50**					
	50-100					
	100-500					

4.1.2.3. Technical readiness level

The key users and stakeholders from the Venice Lagoon have, in general, experience with OC products and services and are familiar with computer systems and web applications. However, different readiness levels for the use of technology and information have been reported for the stakeholders in this area. In particular, although the users had experience with remote sensing and model data, they might not be able to handle large volumes of data and, notably, they might not be familiar with Metadata Conventions and thus manage CF-compliant formats. The key users will operate from a PC and/or Tablet and SmartPhone, connected to the internet on a regular basis, and will be able to manage to use a user-friendly web-portals.

4.1.3. Tagus Estuary (Atlantic Ocean)

4.1.3.1. Specific regional characterization

The Tagus estuary is a good example of the need to achieve sustainable use of a coastal ecosystem, as it is located next to Lisbon, the capital city of Portugal. A variety of services exist within the Tagus estuary including the Port of Lisbon, as well as scientific, industrial, agricultural, fisheries and tourism activities, whilst encompassing a natural park where wading birds are an iconic feature. This estuary is one of the largest in Europe, with a broad

shallow bay covering an area of about 320 km^2. It is meso-tidal with semi-diurnal tides. The Tagus river is the main source of freshwater to the estuary.

An in situ monitoring program, funded by Valorsul who operate a waste treatment plant, has taken place since January 1999 with monthly sampling at 4 sites comprising Chlorophyll-a and other photosynthetic pigments by HPLC, total suspended matter (TSM), in water PAR radiation, Secchi disk, nutrients content, and in some years has also included phytoplankton cell counts. The average chlorophyll-a is 3.8 µg L^{-1} in the four measured sites, with a wide range of 0.5 – 24 µg L^{-1}. Chlorophyll-a values peak consistently during spring or summer, while minimum values are found in winter months. Several publications have identified the driving forces, which control phytoplankton biomass and productivity (Gameiro & Brotas, 2010; Gameiro et al., 2011) and characterizing seasonal and interannual patterns (Brito et al., 2015).

4.1.3.2. Information requirements and implications

Despite its importance as a major natural reserve and proximity to a European capital city with an important sea port, there is a significant lack of data in the Tagus estuary on the physical, chemical and biological structure of its waters, as well as the geomorphology that comprises its bathymetry and coastline delimitation. A wide variety of information is needed on marine, fresh, and transitional waters in the Tagus, and users are generally eager to receive data. Currently, users report are limited to their own means of obtaining data, such as sampling with very basic materials and searching for freely available datasets online, which generally do not comply with their specific needs. While some exchange between the University of Lisbon and the interviewed users has happened in the past, a lack of funding to these study efforts has limited data availability. Currently, some bio-chemical data are being provided through academic studies at the University of Lisbon and through regular sampling campaigns in the Tagus, though not always on a regular schedule.

The interviewed end users (APA, ARH, ICNF, IPMA, LNEC and the Fishermen's Union) have reported their needs directly to CERTO scientists. Generally, they require high-level, processed data (Level 4) for Marine Water, Fresh Water, and some River/Seabed data, mostly as an *operational* service and not in real-time. This includes Marine Water parameters within the Tagus such as salinity, dissolved oxygen, temperature, pH, Chlorophyll-a concentration, harmful algae concentration, and total suspended matter – either as data available from within a dedicated platform, or, preferably, as integrated *water quality indicators* combining the various parameters into individual references.

The intended use of such variables varies from implementation of water monitoring systems (for example, for a proposed monitoring system of the unexpected discharges that may cause problems for bathers), for licensing purposes, as well as for local and international reports, evaluations, and directives on water quality (EU directives such as the Water Framework Directive, the Marine Strategy Framework Directive, and the Urban Waste Water Treatment Directive). These would generally be provided in user-friendly CSV, Microsoft Excel, or GIS formats, preferably spatially-integrated. Some users (IPMA, LNEC) seek data for scientific research, such as for implementation into hydrodynamic models, validation and forecasts, which can be provided in lower processing level format (Level-2) as NetCDF or Ascii files, and on an *on-demand* basis.

Additionally, geomorphological data is highly sought-after in the Tagus estuary. Intertidal zone delimitation, margin delimitation, and bathymetry all are important to operations within and along the entire Tagus estuary. These data are important for a number of ongoing, planned, and potential projects, such as the feasibly of construction of a new international airport at the margin of the Tagus—a major, ongoing project that is currently under intense scrutiny in part due to a lack of geomorphological data.

Table 4.1.3. *Details of specific requirements needed in the Tagus estuary case study*

		ARH	APA	LNEC	ICNF	FU	IPMA
Environmental matrix	**Marine water**						
	Transitional water						
	Inland water						
General name of the Targeted product	**CHL**						
	TSM						
	Water turbidity						
	Rrs						
	SST						
	Salinity						
	DO						
	Nutrients						
	Shoreline limits						
	pH						
	REE						
	SSH						
	Microplastic						
	Bathymetry						
Type of service/ frequency	**Operational**						
	On demand						
Processing level of targeted product	**L2**						
	L3						
	L4						
	Static map						
	Report						

	Forecast						
Production mode	**Real-time**						
	Not real-time						
Temporal resolution	**Hourly**						
	Daily						
	Weekly						
	Monthly						
	Any						
Spatial resolution (m)	**10-50**						

4.1.3.3. Technical readiness level

Of the six potential end-users that were interviewed for CERTO in the context of the Tagus estuary, only IPMA and LNEC can be considered to have moderate-to-high technical readiness for handling data. The remaining four (ARH, APA, ICNF and the Fishermen's Union) are considered as having little readiness, with only basic capabilities for receiving and processing scientific data.

IPMA is a public scientific research institute that competes for national and international funding proposals in the realm of scientific and environmental research, forecasting, and weather prediction. IPMA is well equipped with highly knowledgeable scientific staff (e.g. marine biologists, physical and satellite oceanographers, etc.) that can publish findings in high-level academic journals and work with complex data in multiple formats. They are equipped with large-scale computing power and can process data in raw format and are responsible for a variety of weather models. They have experience with ocean data and can readily accept data in most technical aspects.

LNEC as a civil engineering laboratory is composed of a number of high-level scientific staff and engineers that are accustomed to working with satellite data. While LNEC is not focused on producing scientific research but rather on the application of scientific results, they have a high competency for receiving most data. Being mostly focused on applications, LNEC is technically well prepared for receiving raw data. However, LNEC personnel are generally focused on highly specified areas of work, and are more likely to make use of data if provided in processed format.

ARH, APA, and ICNF have only a basic level technical readiness, and do not have the necessary resources—human or technical—to work with complex marine or environmental datasets. Data must be as user friendly as possible for these agencies to be able to take advantage of its availability, and cannot involve high-level, or even moderate-level computing resources. Data should be limited to summarized format that can easily be interpreted or processed through basic computing, such as maps, or excel spreadsheets.

The same is valid for the Fishermen's Union (FU), although FU would benefit from general maps of the Tagus estuary zone that clearly depict data and presents current status or forecasts to be used in a short time period for the explicit purpose of fishing and aquaculture.

4.1.4. Plymouth Sound (English Channel)

4.1.4.1. Specific regional characterization

Plymouth Sound is part of the Western Channel Observatory (WCO) situated on the north-west European Shelf. The marine laboratories in Plymouth have sampled at several sites within the western English Channel for over a century in open shelf (e.g. station E1) and coastal (e.g., station L4) waters. Both stations are seasonally stratified, generally from mid-April until September and the biological response changes from year to year being regulated by subtle variations in temperature, light, sea-water chemistry and meteorology. Station L4 is characterised by summer nutrient depletion, although intense summer precipitation increasing riverine input to the system results in pulses of increased nitrate concentration and surface freshening. Both stations have both a spring and autumn bloom, although at station E1 the autumn bloom tends to dominate in terms of chlorophyll concentration. Two autonomous scientific data buoy systems are deployed in the WCO and provide high frequency, quality-assured data sets. Powered from the environment in which they monitor and equipped with the latest sensor technology these systems provide data on atmospheric and oceanographic parameters. Regular in situ field calibrations provide assurance of the hourly measurements, which in turn have unveiled the dynamic nature of the WCO stations.

Plymouth “Smart Sound” is a validation and demonstration facility for innovative maritime technologies providing direct waterfront access to a large and diverse marine environment. Co-ordinated through the Marine Business Technology Centre, Smart Sound provides affordable trials on state-of-the-art offshore facilities with considerable expertise in autonomous systems and environmental sensor technologies. Multi-platform trials are delivered through large offshore buoy platforms, autonomous vessels and towed sensor arrays all engineered to facilitate prototype evaluation. Subsurface trials can also be accommodated with offshore water depths of 75m, providing an environment for multi-platform mission trials.

4.1.4.1. Information requirements and implications

The approach taken in the Plymouth Sound differs from the other test sites in that the entities contacted are both brokers of services that are then offered to end users. These are exemplars of how Copernicus upstream services or downstream service providers could feed data into entities that “bundle” packages of local in situ, model and satellite information to provide solutions for end-users. Potentially, through this route, a significant number of end-users could benefit from outputs of CERTO and thence the Copernicus Services. The information requirements are, therefore, those that the entities consider could be of benefit as part of their wider offer to end-users: this is distinct from end-user requirements *per se*; however, it is likely that such bundling could be a major user of Copernicus service outputs.

The Marine Business Technology Centre led by Plymouth city council (https://www.marinebusinesstechnologycentre.co.uk/) “is the gateway for accessing comprehensive research and development support as well as cutting-edge facilities and expertise. Providing services up to the bleeding edge of advanced marine technology development, the MBTC is supporting Devon-based SMEs through research, testing, proving and production.” Through European Regional Development Fund (ERDF) funding it is able to offer services free of charge for eligible businesses.

MBTC has a focus on five areas:

- Advanced marine autonomy
- Clean propulsion: electric propulsions
- Advanced manufacturing materials
- Environmental monitoring and modelling including environmental impact of vessels
- Cybersecurity: connectivity of the internet of things (IoT) in the Sound and Big Data

They are in contact with a wide community of companies in the area. They could foresee interest from prospective users in high resolution imagery from Sentinel 2 ocean colour products close to shore and are also interested in complementing in-situ observations (time series from a buoy or spatially with autonomous vessels) with remote sensing, with a view to increase the offer of interlinked data streams available for companies to use the area to test their equipment.

The Thales UK Ltd contact is the Maritime Autonomy Systems Business Lead. They are creating a digital twin of the region and are interested in digital data to drive under water vehicles. They are mainly interested in turbidity, and other indicators of water clarity, such as horizontal and vertical visibility, vertical attenuation coefficient (K_d). They are also interested in detection of features and structures to avoid in the water such as phytoplankton blooms and areas of sudden changes in optical properties such as fronts along the edges of river plumes in transitional waters. In terms of spatial resolution, currently they are aware of Copernicus Marine Services, however, due to the current coarse spatial resolution (1km) their use is limited for underwater vehicles operations. Higher spatial resolution (10-20m GSD) would be beneficial. In particular, the combination of coarse resolution (for boundary conditions) and high resolution (for data assimilation) was highlighted as a way to improve planning and supporting tests to equip autonomous vehicles with greater autonomy on their operations so that they can automatically adapt to changing environmental conditions.

Table 4.1.4. *Details of specific requirements needed in the Plymouth Sound case study*

		MBTC	Thales
Environmental matrix	**Marine water**		
	Transitional water		
	Inland water		
General name of the Targeted product	**CHL**		
	TSM		
	Water turbidity		
	Rrs		
	SST		
	DO		

	Nutrients		
	Shoreline limits		
	pH		
	REE		
	SSH		
	Microplastic		
Type of service/ frequency	**Operational**		
	On demand		
Processing level of targeted product	**L2**		
	L3		
	L4		
	Static map		
	Report		
	Forecast		
Production mode	**Real-time**		
	Not real-time		
Temporal resolution	**Hourly**		
	Daily		
	Weekly		
	Monthly		
	Any		
Spatial resolution (m)	**10-50**		
	50-100		
	100-500		

4.1.4.3. Technical readiness level

Since the targeted end-users are drawn from all levels of industry it can be assumed that there is very wide range of skill levels. In the case of the MBTC, the users are mainly in the maritime industry, meaning that they are able to deal with highly synthesised information, and likely to welcome data obtained through interactive data portals. Some of the users, would be able to make their own assessments of satellite products with their own in situ data, as they have instruments already in operation (such as the LISST optical instrument). On the other hand, Thales UK has an advanced technical readiness level to adopt remote sensing data, as the data are intended to be used in a Digital Twin of the area in combination with modelling outputs. The users will be able to receive datasets at a more native form (i.e. with no data portal) and ingest directly in their data and model system.

Despite the high technical level in Thales, it seems that the user is not familiar with satellite products and, therefore,

has the requirement to know more about the characteristics of the remote sensing data available potentially through CERTO (i.e. temporal, spatial, spectral, derived products, formats).

4.1.5. Elbe Estuary - German Bight (North Sea)

4.1.5.1. Specific regional characterization

The German Bight and the river Elbe estuary are highly impacted by anthropogenic pressures, and, at the same time, comprise a very sensitive ecosystem including the Unesco World heritage Wadden Sea. The port of Hamburg is the third busiest port in Europe and 15th-largest worldwide. In 2014, 9.73 million TEUs (20-foot standard container equivalents) were handled in Hamburg, all ships passing through the German bight and the river Elbe to reach the port located 110 km distance from the North Sea. Between the coast and the open North Sea, the Wadden Sea is located, which is the largest unbroken system of intertidal sand and mud flats in the world. It is a large, temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, sea-grass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. The area is home to numerous plant and animal species, including marine mammals such as the harbour seal, grey seal and harbour porpoise. The Wadden Sea is one of the last remaining large-scale, intertidal ecosystems where natural processes continue to function largely undisturbed. The German Bight at the southeast of the North Sea is bounded by the Netherlands and Germany to the south, and Denmark and Germany to the east. It is heavily used for shipping, fisheries, and recently for wind energy: 19 wind parks are already in operation, and another 10 are under construction or planned. In such a heavily used area, marine spatial planning and monitoring of environmental status is of critical importance.

The parameters required for the Elbe river case study are Chlorophyll, Turbidity and Suspended Matter. Depending on usage, daily averaged products are the basis and are asked for in near real time frequency. The resolution required is ~300m for the more open parts of the estuary (and going in the German Bight). For the Elbe itself, the higher the resolution, the better, i.e. 20-60m would be best.

4.1.5.2. Information requirements and implications

The principal information requirements in the Elbe estuary and the German Bight are on water quality and sediment fluxes. The main requirements are for help in general environmental monitoring aside from in situ gathered by the users, in advancing the scientific understanding of marine ecosystems, and providing information, knowledge, and advice on the sustainable management of human activities affecting, and affected by, marine ecosystems. The end users contacted, mainly from federal and national institutes (BSH, BAW), reported that there is a need for spatial information on water quality products such as turbidity or suspended matter to assess good environmental status and river outflows, but also monitor sediment fluxes from more anthropogenic influences, such as dredging activities. The city of Hamburg, which is very close to the Elbe river mouth is a very large commercial harbour and the deepening of the main channel to allow bigger ships to reach

Hamburg is raising concerns as to the environmental impacts and how the removed soil shall be dealt with. As of now, in situ data (ad hoc and from either dedicated campaigns or fixed monitoring stations) are the main source of information for decision making. Interest in remote sensing data exists but users still sometimes need convincing in the quality (correctness) of the data that would be provided. This convincing process can take years and many interactions/demonstrations via dedicated projects.

Additionally to these concerns there is also the wish by BSH to use remote sensing data in their reporting duties for the Marine Strategy Framework Directive (MSFD). BSH uses their own in situ data from the federal monitoring system and looks to integrate remote sensing water quality products such as chlorophyll and suspended matter. There are also requirements of a more research-oriented point of view, such as using remote sensing data (suspended matter or chlorophyll) as input to, or comparison with, geophysical and geo-biochemical modelling. For both these requirements, the willingness to use remote sensing data exists, and users have already understood the worth of adding remote sensing data to their datasets. However, for the monitoring agencies, budgeting problems can be an issue: depending on how budget is allocated, adding a new data stream to the monitoring sometimes means decreasing access to another data stream (in this case decreasing in situ budget in order to use satellite product services).

T**able 4.1.5.** *Details of specific requirements needed in the Elbe estuary case study*

		BAW	**BSH**
Environmental matrix	**Marine water**		
	Transitional water		
	Inland water		
General name of the Targeted product	**CHL**		
	TSM		
	Water turbidity		
	Rrs		
	SST		
	DO		
	Nutrients		
	Shoreline limits		
	pH		
	REE		
	SSH		
	Microplastic		
Type of service/	**Operational**		

frequency	**On demand**		
Processing level of targeted product	**L2**		
	L3		
	L4		
	Static map		
	Report		
	Forecast		
Production mode	**Real-time**		
	Not real-time		
Temporal resolution	**Hourly**		
	Daily		
	Weekly		
	Monthly		
	Any		
Spatial resolution (m)	**10-50**		
	50-100		
	100-500		

4.1.5.3. Technical readiness level

Some of the key users have experience with OC products and services, others less so and would need an introduction in what those products are and how to use them. All key users and stakeholders are familiar with computer systems and web and table applications.

4.1.6. Curonian Lagoon (Baltic Sea)

4.1.6.1. Specific regional characterization

The Curonian Lagoon is a transboundary water shared between Russia and Lithuania and separated from the Baltic Sea by the Curonian Spit. With a surface area of 1,584 km^2, it is the largest lagoon in Europe. The lagoon is a shallow (mean depth 3.8 m) and mainly freshwater ecosystem. The main tributary is the Nemunas river that provides the main inflow, both in terms of the amount of water, nutrients and persistent pollution. The Curonian lagoon is a hypereutrophic environment often dominated by cyanobacteria blooms in summer. According to long term monitoring data (2001–2012) collected by Marine Research Department of the Lithuanian Ministry of Environment, monthly average chlorophyll a (chl-a) concentrations reach 47 ± 14 µg L^{-1} during the spring diatom bloom and 96 ± 56 µg L^{-1} during the summer bloom. Cyanobacteria blooms appear in the summer, due to combination of favourable nutrient stoichiometry (N and Si limitation), elevated water temperature, low wind speed and low grazing pressure (Bartoli et al., 2018). Several publications have

analysed the hypereutrophic condition of Curonian Lagoon (Zilius et al., 2014; Bresciani et al., 2014), the Curonian water impact on the quality of Baltic Sea (Vaiciute et al., 2012) and the higher concentration of CDOM in the Nemunas river Delta (Vaiciute et al., 2015).

Fishing and small-scale fish processing had traditionally provided an important economical basis for many small communities around the lagoon; also, tourism, port activities, and agriculture play an important and continuously growing role. The water-quality management and nature conservation system in the Lithuanian part of the Curonian Lagoon is based on both national legal acts and on EU directives, particularly the WFD and the Habitat Directive (HD, 92/43/EEC). In the Russian Federation, the protection and management of water resources is regulated by the Water Code, adopted in 2006.

4.1.6.2. Information requirements and implications

Information is needed to develop better tools for a more efficient management and an improved environmental evaluation of the Lagoon system and coastal area, to implement the principles and objectives of the WFD, MSFD, to evaluate the Ecological status assessment, conserving and protect the natural environment, but also consider all development activities in the area. The products will be compared with existing and established EO-based Chl-a products.

The possibility of having spatial and continuous data will be of great importance in order to better understand the extremely fast ecological dynamics that characterize the Curonian lagoon, with considerable repercussions on the organization of in situ measurements, the possibility of managing the bloom of cyanobacteria and the possibility of interacting with local authorities for activities such as fishing and the management of wild fauna (e.g. bird colonies) and port and tourist activities.

Table 4.1.6. *Details of specific requirements needed in the Curonian Lagoon case study*

		KU
Environmental matrix	**Marine water**	
	Transitional water	
	Inland water	
General name of the Targeted product	**CHL**	
	TSM	
	Water turbidity	
	Rrs	
	SST	
	DO	
	Nutrients	
	Shoreline limits	
	pH	

	REE	
	SSH	
	Microplastic	
Type of service/ frequency	**Operational**	
	On demand	
Processing level of targeted product	**L2**	
	L3	
	L4	
	Static map	
	Report	
	Forecast	
Production mode	**Real-time**	
	Not real-time	
Temporal resolution	**Hourly**	
	Daily	
	Weekly	
	Monthly	
	Any	
Spatial resolution (m)	**10-50**	
	50-100	
	100-500	

4.1.6.3. Technical readiness level

The key users and stakeholders from the Curonian Lagoon have experience with OC products and services and are familiar with computer systems and web, table applications. In the last few years users participated in FP7 and H2020 projects based on satellite data analysis and products. Recently they have also equipped themselves with scientific instruments for radiometric measurements. Although their skills are above all ecological and are based on in situ data collection and analysis, in recent years they have acquired excellent skills in the sector of the use and analysis of satellite data.

5. Conclusions

Provision of optical water-quality data between the three Copernicus services has largely evolved independently. Indeed, transitional waters “fall between” the remits of the three relevant services producing water-quality information. As a consequence, different user requirements and also technical and satellite capabilities have led to methodological differences and gaps in data provision, most notably in complex near-shore and inshore environments that include estuaries, lagoons, bays and large rivers. In such a context, potential users are often not able to judge which sources are most relevant to their needs or, even worse, they have no data available from Copernicus services

With this particular issue in mind, we performed a cross-regional and cross-sector analysis of stakeholders and users relevant to CERTO project objectives. In particular, we identified intermediate and final users in the main sectors that will take advantage of CERTO products and outcomes (Maritime safety, Water pollution, Offshore energy, Tourism and recreation, Coastal protection, Ports and shipping, Sustainable marine living resources, Weather and climate, Basic and applied research), also exploring the geographical regions (inland, transitional, marine waters) in which CERTO aims to fill gaps in terms of upstream products. Exchanges with these users have enabled a better understanding of their needs in terms of information and specific requirements.

Our stakeholder and user requirement analysis shows a good balance among geographical regions in terms of internal and final users: about 55% of the eighteen users operate in marine-to-transitional environments and the remaining 45% operate in inland-to-transitional water environments. Moreover, all sectors are covered in the majority of the test case areas.

The sector of “Water pollution” is the most represented (Table 3.4), since it is active in all test case areas and by fourteen of the eighteen users (among final and intermediate). This result is expected since this area is the main focus of the CERTO project. Regarding the targeted products, in general, we recognize a strong need for higher spatial resolution Ocean Colour products to be provided in a daily level-3 fashion. This, indeed, fully matches with the analysis we provided for the CMEMS regional products (Section 3.3); in particular, our analysis highlights the need to improve CMEMS regional products in terms of data spatial resolution and a more homogeneity in the availability of bio-optical products.

The CERTO Advisory Board (AB) provided feedback in terms of global and cross-regional needs, that is, emerging requirements from several coastal ocean communities. In particular, the interaction with the AB is helping the project in narrowing the potential targeted products, which should be designed as key, upstream input data able to trigger and fully support suitable downstream services for monitoring and assessing the environmental state of transitional waters.

Further efforts will be undertaken to update or enlarge the list of users and stakeholders during the lifetime of the project, as well as to incorporate requirements from the communities that are represented by the AB.

Specific technical requirements will be provided in the next D2.2 deliverable of CERTO Project.

6. References

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