

## Article

# User Needs Analysis for the Definition of Operational Coastal Services

Serena Geraldini <sup>1,\*</sup>, Antonello Bruschi <sup>1</sup>, Giorgio Bellotti <sup>2</sup> and Andrea Taramelli <sup>1,3</sup>

<sup>1</sup> Institute for Environmental Protection and Research (ISPRA), via Vitaliano Brancati 48, 00144 Roma, Italy; antonello.bruschi@isprambiente.it (A.B.); andrea.taramelli@isprambiente.it (A.T.)

<sup>2</sup> Department of Engineering, Roma Tre University, Via Vito Volterra 62, 00146 Roma, Italy; giorgio.bellotti@uniroma3.it

<sup>3</sup> University Institute for Advanced Study of Pavia (IUSS), Palazzo del Broletto, Piazza della Vittoria 15, 27100 Pavia, Italy

\* Correspondence: serena.geraldini@isprambiente.it; Tel.: +39-06-5007-4681

**Abstract:** According to the global growth of the “Blue economy”, coastal zones are under pressure from both land and marine side economic activities. The fragmentation of sectorial interests and legislation along the coasts has led to the need for bridging knowledge (data/information and methods/tools) and governance (decision-makers at every level) in order to ensure sustainable economic development and social and ecosystem resilience. This poses the need for an interaction process that associates user needs to the European and national legislative framework to create a policy-oriented demand of Copernicus Earth Observation services in coastal areas. Such goals need a strong and effective system to monitor compliance and to assess the progress of the legislation. This study aims at identifying potential gaps in the current Copernicus product offer for the monitoring of the coastal sector through the elicitation of stakeholder requirements. The methodology is applied to the Italian landscape of users, but it is scalable at European level. The results provide a clear overview of the coastal user requirements, highlighting the common need of integrated information for the management, and represents the basis for defining the coastal services.

**Keywords:** copernicus; user needs; requirements analysis; coastal services; earth observation; remote sensing; gap analysis



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## 1. Introduction

In Europe, approximately 40% of the population lives within 50 km from the coast. Coastal zones are densely populated, exhibit high rates of inhabitant’s growth and urbanization, concentrate economic assets and critical infrastructures, support green and blue economy and, as a consequence, experience huge socio-economic and environmental changes.

According to “The Organization for Economic Co-operation and Development” (OECD) by 2030, the ‘Blue Economy’ could outperform the growth of the global economy as a whole, both in terms of added value and employment. In the coming decade, marine energy, marine biotechnology, coastal tourism, transport and food production sectors could offer unprecedented development and investment opportunities [1]. However, such growth relies on the same marine resources that unsustainable economic activities are eroding. Pollution and overexploitation are compromising the marine and coastal environment; human activities such as shipping, resource extraction, urbanization, and fishing produce habitat loss, pollution, and accelerated coastal erosion; climate change effects (e.g., sea level rise) make coastal zones more vulnerable.

To solve the conflict between economic development and protection of the environment long-term strategies are adopted to regulate the sustainable growth in the marine and maritime sectors, at European level with the “Blue Growth” while, at United Nations level, with the United Nations Convention on Law of the Sea (UNCLOS) [2].

The protocol on Integrated Coastal Zone Management (ICZM) aims for the coordinated application of the different policies affecting the Mediterranean coastal zone, related to nature protection, aquaculture, fisheries, industry, offshore wind energy, shipping, tourism, development of infrastructures, as well as mitigation of and adaptation to climate change [3]. However, as a consequence of the legal weakness of a “protocol”, EU legislation to protect and to manage the marine environment has been progressively implemented with several protocols, conventions and directives in many specific thematic areas, resulting in a fragmented and sectorial approach, each with its own obligations, data metrics and needs. These range from Directives mainly aimed at protecting the environment and guaranteeing a good environmental status (Water Framework Directive-2000/60/EC [4], Marine Strategy Framework Directive-2008/56/EC [5], Urban Waste Water Treatment Directive-91/271/EEC [6], Nitrates Directive-91/676/EC [7], Integrated Pollution Prevention and Control-2010/75/EU [8], Priority Substance in the field of water policy Directive-2013/39/EU [9], Habitats Directive-92/43/EEC [10] and Birds Directive-2009/147/EC [11]), to risk prevention Directives (Bathing Waters Directive-2006/7/EC [12], Floods Directive-2007/60/EC [13], Directives related to the navigation safety-2009/45/EC [14], 2003/25/EC [15], 98/41/EC [16]) to Directives and policies mainly devoted to the planning and regulation of anthropic activities (Maritime Spatial Planning Directive-2014/89/EU [17], Common Fisheries Policy [18]).

The Copernicus Programme, established with the legally stronger Regulation (EU) No 377/2014 (former GMES, Regulation (EU) No 911/2010), was designed “to provide accurate and reliable information tailored to the needs of users and supporting Union policies, relating to the internal market, transport, environment, energy, civil protection and civil security”, on the basis of a multi-annual financial framework, for the maximization of socio-economic benefits through the core services component [19,20]. The information provided by the Copernicus services can be used by users for a wide range of applications: urban area management, sustainable development and nature protection, regional and local planning, agriculture, forestry and fisheries, health, civil protection, infrastructure, transport and mobility, as well as tourism [21–23]. Moreover, big data, new analytics, and high performance computing (HPC) technologies allow to process and integrate huge amounts of data coming from heterogeneous platforms, creating the conditions for the development of radically innovative services, also considering the five new European DIAS (Data and Information Access Services) developed to support user uptake, providing centralized access to Copernicus data and information and additional commercial satellite or non-space data sets, as well as processing tools.

Boosting the use of EO data and of the Copernicus Programme is one of the main priority highlighted in the EU Space Strategy (published in October 2016) [24] and many scientific research works have highlighted the positive opportunities given by EO data to monitor coastal cover properties and habitats [25–29], land-use and coastal loss [30–34], beach profiles and coastline [35–38], coastal geomorphology and morphodynamics [39–41], emergent and submerged wetlands mapping [42–44], water quality [45–47], algal bloom [48–50], storm surge risk assessment, hazard mitigation, disaster response and flood monitoring [51–54], coastal bathymetry [55–57] maritime safety and security issues, such as vessel detection [58,59], oil spill detection [60,61], sea-state forecasting and sea level change [62–64], and marine spatial planning [65]. The optimization and best use of complementary observations means, by combining EO, in situ and modeling, especially for not easily accessible coastal areas, provide spatial-temporal information required for historical analysis and current status mapping, giving the possibility to observe global and local processes and phenomena and to monitor highly dynamic and vulnerable environmental system and to proper manage them, with an ecosystem-based approach [23,66].

Nonetheless the adoption of Copernicus data and information at non-technical local & regional governmental authorities remains low [67]. This gap between offer and demand is due to the fact that: (1) demand is not well defined and user's needs are not clearly identified; (2) harmonization at national level is insufficient, so the demand is highly fragmented, without any possibility for the market development; (3) users need tailored services and information for application more than the data itself, hard to use for not EO expert; (4) users need dynamic offers to satisfy the evolution of management duty and governmental needs.

To fill the gap between offer and demand, a technology transfer is needed, from data to information for specific applications, by developing tailored downstream services, taking advantage of the Copernicus ecosystem (satellite and in situ data, Core Services and DIAS) and providing suitable spatial and temporal resolution and specific parameters required by end-users and ensuring the development of a services industry market. The need for development of services tailored for coastal zone is even more important because of the lack of a dedicated Coastal monitoring Core service: Copernicus Marine Monitoring Service (CMEMS) and Copernicus Land Monitoring Service (CLMS), at present, provide separately information on the sea and land side, respectively. This is why a RoadMap for the evolution of CMEMS and CLMS, was presented by DG for Defense Industry and Space (former DG GROW), to better serve coastal users facilitating in accessing and using the relevant data and information, considering a cross service approach, with a short-term strategy in order to improve existing products and a long-term strategy for the coordination between Copernicus Core services and Member States downstream coastal services [68,69]. Thus, the importance of users involvement and information needs understanding and analysis is becoming widely recognized, as an integral part of information and systems design, given the importance that stakeholder involvement is taking in EU policy formulation and implementation [24,70].

In the context of the Italian Copernicus User Forum, a thematic working table, dedicated to "Coastal" issues, have been set up with the aim of identifying the requirements of users for the development of operational services, bringing together non-technical end-users, especially institutional ones, the geospatial, ICT-HPC, and commercial industry and research sector to build a win-win situation.

Software engineering defines a requirement as the "condition or capability needed by a stakeholder to solve a problem or achieve an objective" and Requirements Engineering as "the systematic process of developing requirements through an iterative process of analyzing a problem, documenting the resulting observations, and checking the accuracy of the understanding gained" [71–73].

Over the past years, many systems development methodologies have been proposed to identify and analyze user requirements [74,75], to understand stakeholders' expectations with respect to functionality of products and services and constraints limiting choices and options and translating them into specific measurement requirements [22,76].

A proper understanding of users' requirements derives from a step-by-step systematic process of elicitation, selection, analysis, specification, prioritization, modeling, verification, validation and management of the requirements [71,74,77]. The first step is the audience identification and the background information gathering. Requirements elicitation encompasses understanding of the stakeholders' needs overcoming the users' difficulty in articulating completely, precisely, and correctly their requirements. User needs can be identified by means of different methods: (1) written user surveys; (2) focus discussion groups; (3) interviews; (4) use cases. Requirements analysis determines whether they are clear, complete, and unambiguous and requirements specification and matching with available data and products allows translating user informal needs into technical formal requirements specification model, gradually improved by a cyclic approach. Requirements validation ensures that the produced formal specifications model satisfies the users' needs and the last phase guarantees the management of requirements and their future changes due to the system development [74–82].

Requirements prioritization is an approach to decide which requirements maximize stakeholders' satisfaction and need to be implemented first, for its high market value, high quality, urgency of implementation or legal obligation [80,83,84].

Given the extensive number of specific requirements and applications for coastal monitoring, conservation and sustainable development, and the difficulty to define their technical properties, a good interaction between heterogeneous stakeholders for information needs understanding is the precondition for an efficient integrated coastal zone management and wise decision making [81,85].

Taking into account the above, the research described in the present work developed an innovative methodological standard for: (1) the collection of heterogeneous needs of the entire national context of institutional users operating in coastal areas and dealing with various thematic issues, (2) the analysis of the requirements and (3) the definition of operational coastal services to be implemented, in line with the Copernicus Coastal roadmap, with a systematic and homogenous approach, on the basis of a products gap analysis. This work was based on a joint collaborative action of Institutional and Regional users, EO experts and coastal processes experts who work together in an interactive and iterative way defining the information needs, the technical requirements and the related priority downstream services.

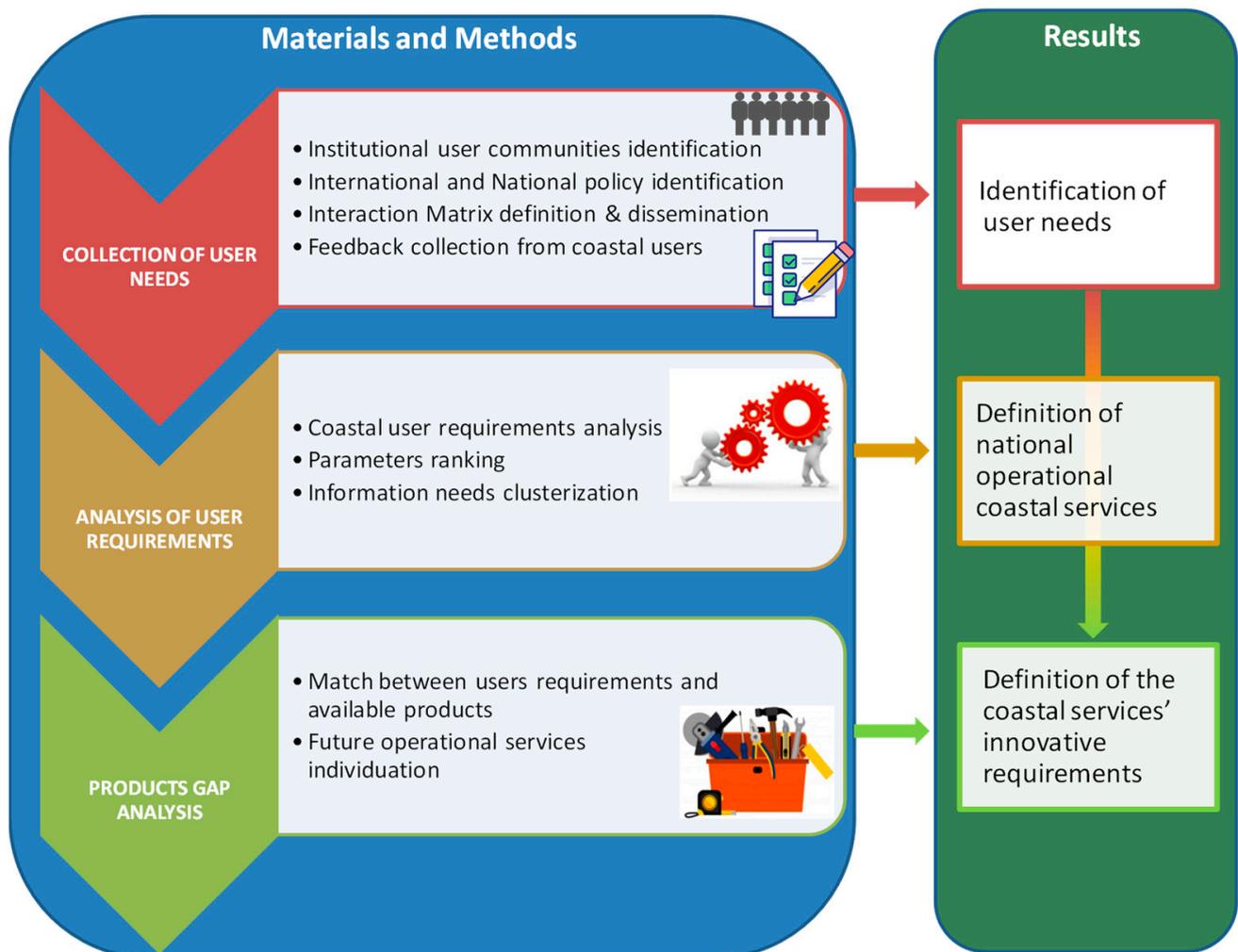
The article is organized as follows. Section 1 is the introduction. Section 2 is focused on the description of the methodology developed for the: collection (§2.1) and analysis (§2.2) of coastal user requirements and the definition, on the basis of a products gap analysis, of the operational services to be developed at national level for coastal application (§2.3), Section 3 reports the results of the whole research: the identified institutional user needs on the basis of the user needs collection (§3.1), the defined national operational services on the basis of the user requirements analysis (§3.2), and the specific coastal services' innovative requirements defined on the basis of products gap analysis (§3.3). Section 4 contains the discussion of the results and Section 5 contains the conclusion coming from the whole research and the future perspectives.

## 2. Materials and Methods

The methodology applied for coastal users' consultation and national operational services identification was defined following the steps listed below:

1. identification of the institutional users to be interviewed;
2. organization of the questionnaire to be submitted to the institutional users selected in the previous phase;
3. collection and homogenization of the survey answers, grouping them by type of user and their institutional duties, based on regulations;
4. analysis of the gathered users' requirements on the basis of regulations and requested parameters typology;
5. prioritization of parameters based on the number of users and reference regulations;
6. definition of the operational services to be implemented at national level, considering the gap between the needs and the available products (Copernicus services products and others).

Figure 1 shows the procedure for user requirements analysis adopted in this work.



**Figure 1.** Methodology scheme for user requirements analysis and operational coastal services definition.

### 2.1. Collection of User Needs

The first step was to identify the users to be interviewed for collecting the needs for operational services for applications in coastal areas.

Priority was given to institutional users operating in coastal areas, who need operational services to carry out their institutional tasks, in line with the existing regulations and infrastructures, representing a qualified demand for the services' market development.

Table 1 shows the institutional users, operating in coastal areas, that have been involved in the consultation process for the collection of their information needs, and their tasks in relation to coastal areas.

**Table 1.** Institutional coastal users involved in the consultation and their tasks in relation to coastal areas.

Institution, Authority, Group Name	Acronym	Institution and Authority Participant	Task
National Environmental Protection System	SNPA	Institute for Environmental Protection and Research (ISPRA) and Regional coastal Agencies (ARPAs): Emilia Romagna (ARPAe), Liguria (ARPAL), Veneto (ARPAV), Puglia (ARPA Puglia) Friuli Venezia Giulia (ARPA FVG)	Environmental characterization, monitoring and protection
National Table on Coastal Erosion	TNEC	Ministry of Environment and Protection of the Territory and the Sea-MATTM, Emilia Romagna, Marche, Tuscany, Calabria Regions and Environmental Agencies and river Po and Calabria District Basin Authorities (ADBD)	Evaluation of the morphological variations of the coast, estimation of coastal erosion, planning of management interventions
Coast Guard-Port Authority	MIT	Ministry of Infrastructures and Transports	Civil use of the sea regarding Infrastructures, Transports and environment
National System of Civil Protection	SNPC	Department of Civil Protection and Regional systems	Risk prediction and prevention, relief to the affected populations, contrast and overcoming the emergency and risk mitigation
Ministry of Defence	MD	Navy	Safety of human life, navigation and transport and of activities that take place in ports and along the coasts
Ministry of Agricultural, Food and Forestry Policies	MIPAAF (former MIPAAFT)	Ministry of Agricultural, Food, Forestry and sea fishing Policies	Sea fisheries and aquaculture management and policies
Ministry of Cultural Heritage and Activities and Tourism	MIBAC (former MIBACT)	Ministry of Cultural Heritage and Activities and Tourism	Monitoring and protection of cultural heritage and tourism management and policies

Some Ministries and environmental Agencies have a good EO experience and knowledge of Copernicus core services and they are already running operational services. They defined requirements for innovative services in order to satisfy their operative needs, bridging the gap between monitoring needs and the existing products. In other cases, National and local Authorities are not EO experts and they were asked to point out specific information needs for the fulfillment of their tasks, linked to the legal obligations. The interaction with users had the purpose of identifying the functional and operational objectives of the required coastal monitoring and management services, with the aim of improving the current method of acquiring the information necessary for carrying out their duties.

A four-part questionnaire was presented to institutional users. The different parts of the questionnaire were grouped as follows:

- information about the user who answered the questionnaire, such as the name of the Institution or Authority, the specific department, and the individual contacts;
- recognition of the European Directive, the relevant Copernicus core service and application domain and the legislative implementation at national level;
- definition of the required operational service by identifying the objective of the service, the need for provision in real or deferred time, the input data and the output to be obtained, with an indication of the relative spatial and temporal resolution, accuracy and coverage of the requested service. It should be noted that these requirements refer to the functional characteristics of the requested services and to the information to be acquired (not earth observation expert based) and do not represent the technical requirements that must be identified in a second phase by EO experts;
- information on the financial investments used at present for the provision of the specific service and possible cost estimation for its innovation.

Figure 2 shows the structure of the survey submitted to the users.

Institution/Authority				Department				Contact name			
EU directives				Copernicus				National laws			
				Application domains		Core services					
Goal	Operational service	Real or delayed time	State of art	Input data and products	Output	Service requirements					
						Spatial resolution	Temporal resolution	Accuracy	Cover		
Budget				Future budget				Note			

Figure 2. Questionnaire structure.

### 2.2. Analysis of User Requirements

About eighteen Institutions and Authorities (Table 1) answered to the survey, with a geographical distribution covering the entire national coasts (Figure 3).

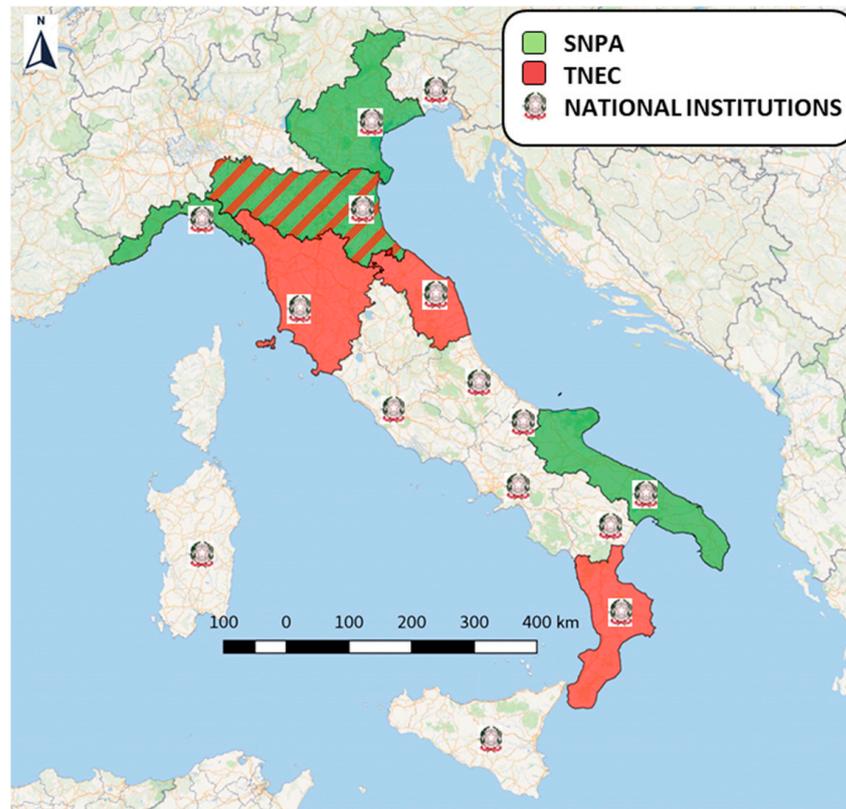


Figure 3. Geographical distribution of the Institutions' responses.

The survey responses were collected, homogenized and clustered on the basis of the contents. Then the parameters required by users as output information of the needed services were extrapolated and linked to the European directives for which they were requested.

The specific parameters coming from the user needs survey are further being grouped into categories (Supplementary Table S1, Figures S1 and S2), such as:

- biogeochemical;
- physical;
- geomorphologic;
- hydrometeorological;
- transport of pollutants;
- land cover;
- land use.

The relative value of each parameter was calculated by a normalized sum of:

The number of directives that require specific parameter monitoring

$$\begin{aligned} & \text{Parameter value linked to directives} \\ &= \frac{\sum \text{EU directives linked to the parameter}}{\sum \text{EU directives}} \end{aligned} \quad (1)$$

and the number of users who requested it

$$\text{Parameter value linked to users} = \frac{\sum \text{Users who requested the parameter}}{\sum \text{Users}} \quad (2)$$

The following formula was used to rank the parameters:

$$\begin{aligned} & \text{Total parameter value} \\ &= \frac{\sum \text{EU directives linked to the parameter}}{\sum \text{EU directives}} \\ &+ \frac{\sum \text{Users who requested the parameter}}{\sum \text{Users}} \end{aligned} \quad (3)$$

Since the users representing the national and regional Agencies and Institution for environmental monitoring and protection (ISPRA, five Environmental Agencies, Regions belonging to the TNEC and the Ministry of Environment) were numerically more for the same application domain than the other Authorities and Ministries applied in various thematic fields (Coast Guard, Port Authority, the Ministry of Infrastructures and Transports, National System of Civil Protection, Ministry of Defense, Ministry of Agricultural, Food and Forestry Policies, Ministry of Cultural Heritage and Activities and Tourism), if they had been considered individually they would have had a greater overall weight in determining the priority of the requirements. Therefore, in order to correctly compare all the collected answers, a preliminary prioritization of the parameters expressed by the environmental agencies was made, applying the Formula (3), to determine the most requested parameters by the environmental component (Figure 4). Then, the overall result was compared and analyzed with the responses of the other Authorities for the determination of all the operational services required as tool for complying with all the duties and regulations concerning the coastal application domain.

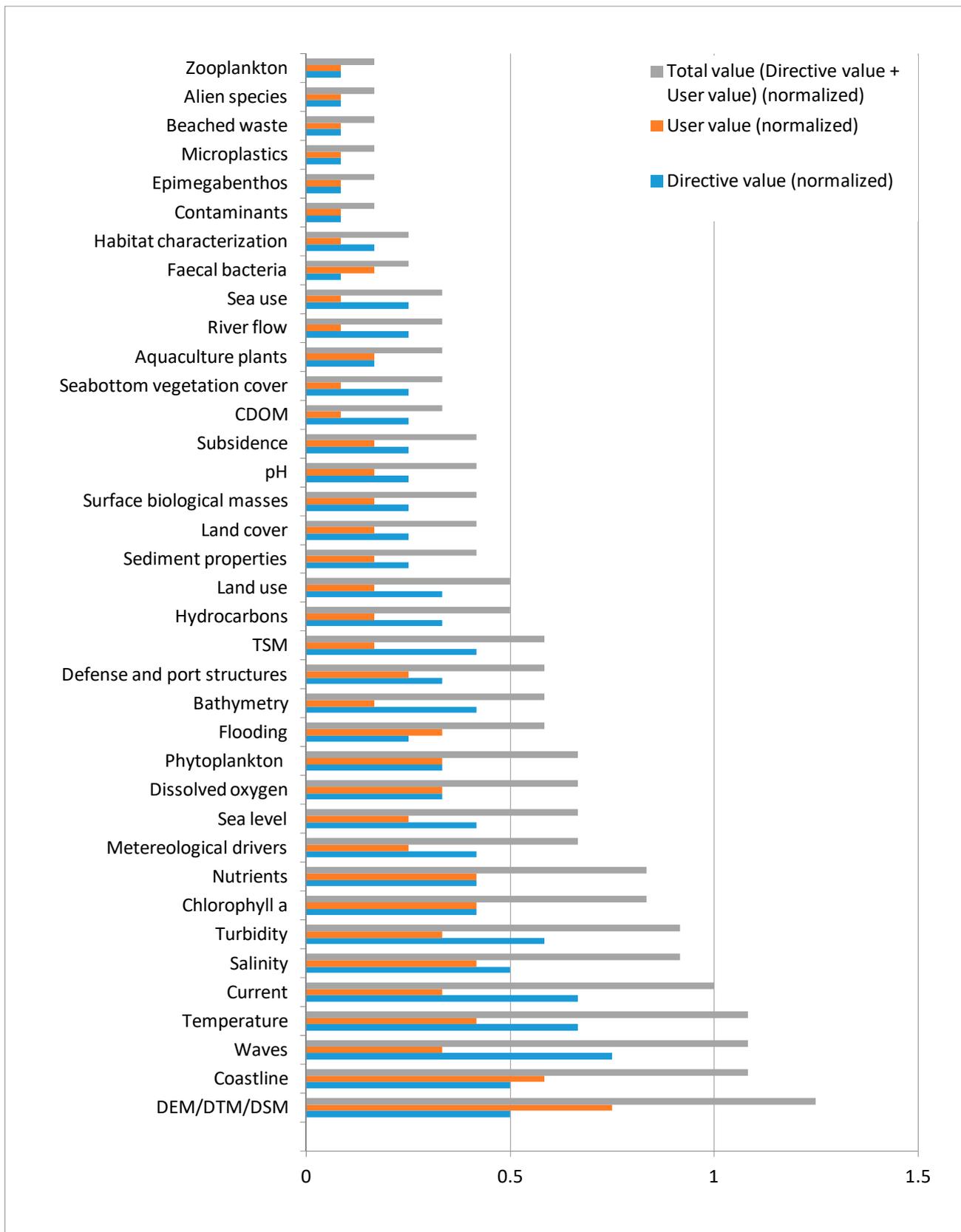


Figure 4. Parameter values calculated with the Formula (3).

To organize the complex requirements dataset and to analyze it in a systematic way, the results of the survey and the link between parameters, directives and users were represented through Sankey diagrams.

A Sankey diagram is a particular type of flow diagram, in which variables (nodes) are represented by rectangles connected by lines (flow) whose width expresses the quantitative relationship between them [86]. Sankey diagrams allow a fast user-friendly visualization of a complex system of data.

### 2.3. Products Gap Analysis

A comparative assessment of the parameters requested by national users and the parameters provided at European level by Core Copernicus or other services was carried out. Firstly, common parameters (those requested by users and provided by European services) were identified and selected, then the relative spatial and temporal resolution were extrapolated and compared.

To understand and visualize the gap between the two series of parameters, the relative spatial resolutions were clustered and compared. The chosen spatial resolution classes were: 1–5 m, 5–25 m, 25–50 m, 50–250 m, 250–500 m, 1–5 km and 10–15 km.

Products gap analysis was the driver to define the services in detail. The identification of the gap between the services state of the art and the user needs allowed to define the technical requirements of the services. The criteria followed for the definition of the coastal services were:

- start from the European and national regulations (optimizing the monitoring of the parameters required by users in compliance with the different laws);
- systemize common parts to multiple services;
- consider the integration of remote, in-situ and modeled data and products;
- insert only consolidated products in terms of reliability of results and ready for pre-operation or operation applications;
- define the processing level of the products delivered by each service: “level 1” for services that not depend from others, instead “level 2” for services that have in input one or more products coming from “level 1” services, for example for peculiar needs;
- specify if the services are based on space data processing or on models application;
- indicate the required products delivering way for each service: “real time” or “deferred time”, “regular” or “on demand”;
- give priority to data validation and accuracy, fundamental for institutional responsible use to make decisions.

## 3. Results

### 3.1. Identification of User Needs

As result of user requirements analysis, the required parameters were extrapolated, grouped in different typology classes (Supplementary Table S1) and linked to the European directives and national laws under which those parameters are required by public institutions, as shown in Table 2 and in the Sankey diagram in Supplementary Figure S2.

**Table 2.** Link between the parameters required by institutional users and the reference legislation.

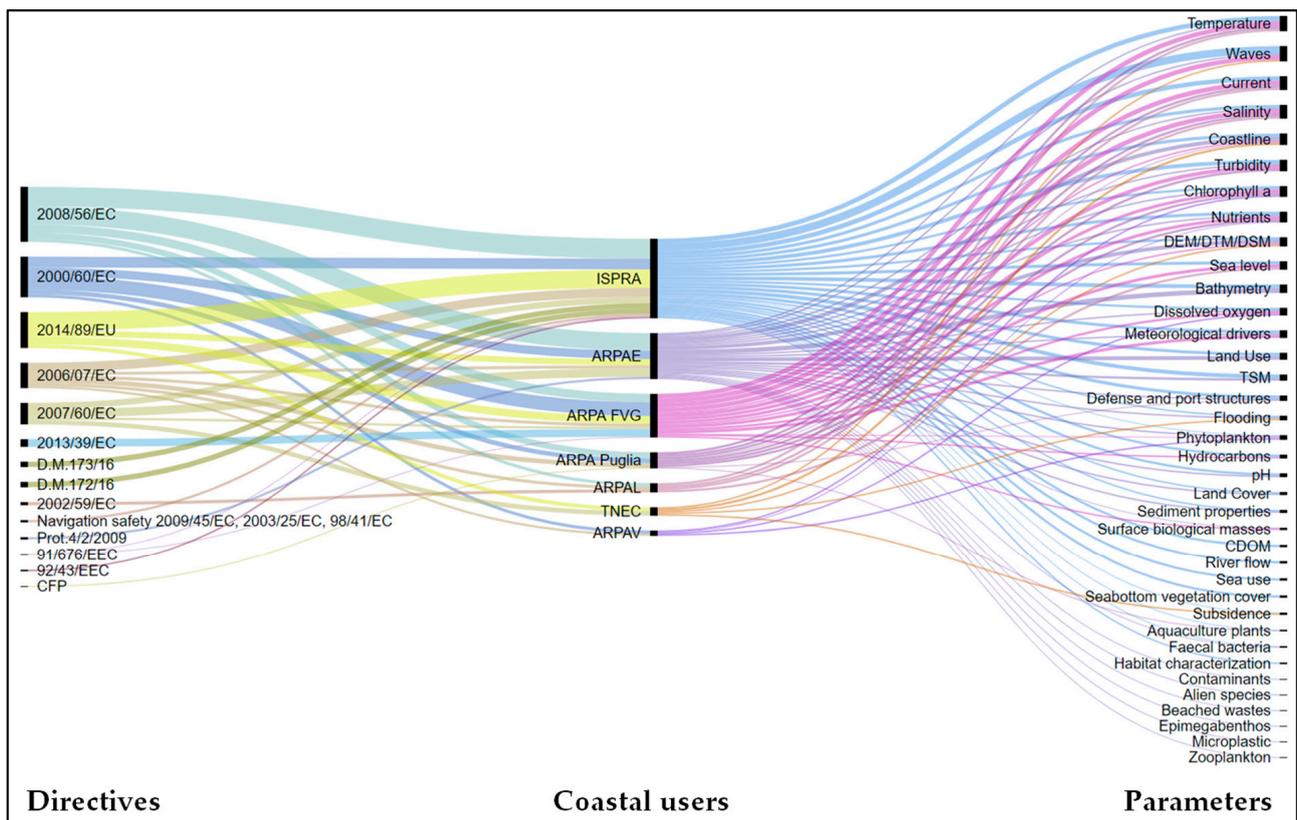
Name	European Directive	National Law	Parameters Typology	Parameters
Nitrates Directive	91/676/EEC	D.Lgs. 152/1999	Bio-geo-chemical	Nutrients
Habitat Directive	92/43/EEC	D.P.R. 120/2003	Land Cover	Habitat characterization, Seabottom vegetation cover
Waters Directive	2000/60/EC	D.Lgs. 152/2006, D.M. 260/2010	Bio-geo-chemical, Physical, Geomorphologic, Hydro-meteo, Pollutants transport	Bathymetry, CDOM, Chlorophyll a, Current, DEM/DTM/DSM, Meteorological drivers, Hydrocarbons, Coastline, Surface biological masses, Waves, Nutrients, Dissolved Oxygen, pH, Salinity, Phytoplankton, Temperature, Turbidity, TSM
Bathing Directive	2006/07/EC	D.Lgs. 116/2008, D.M. 30/03/2010	Bio-geo-chemical, Physical, Geomorphologic, Hydro-meteo, Pollutants transport, Land use and man made structures	Bathymetry, Faecal bacteria, Chlorophyll a, Current, Meteorological drivers, Coastline, Sea level, Waves, Nutrients, Defense and port structures, Dissolved Oxygen, River flow, Salinity, Phytoplankton, Temperature, Turbidity, Land use
Flood Directive	2007/60/EC	D.Lgs. 49/2010	Physical, Geomorphologic, Hydro-meteo, Land use and man made structures	Flooding, Bathymetry, DEM/DTM/DSM, Meteorological driver, Coastline, Sea level, Waves, Defense and port structures, Subsidence, Land use
Marine Strategy	2008/56/EC	D.Lgs. 190/2010	Bio-geo-chemical, Land Cover, Physical, Geomorphologic, Hydro-meteo, Pollutants transport, Land use and man made structures	Flooding, Bathymetry, Sediment properties, Habitat characterization, CDOM, Chlorophyll a, Land cover, Seabottom vegetation cover, Current, DEM/DTM/DSM, Meteorological drivers, Hydrocarbons, Coastline, Sea level, Waves, Nutrients, Defence and Port structure, Dissolved oxygen, pH, Salinity, Phytoplankton, Subsidence, Temperature, Turbidity, TSM, Land use
Priority substances	2013/39/EU	D.Lgs. 172/2015	Bio-geo-chemical, Physical, Geomorphologic, Pollutants transport	Chlorophyll a, Current, DEM/DTM/DSM, Hydrocarbons, Coastline, Surface biological masses, Waves, Salinity, Temperature, Turbidity
Maritime Spatial Planning	2014/89/EU	D.Lgs. 201/2016	Bio-geo-chemical, Land cover, Physical, Geomorphologic, Hydro-meteo, Pollutants transport, Land use and man made structures	Flooding, Bathymetry, Sediment properties, CDOM, Chlorophyll a, Land cover, Seabottom vegetation cover, Current, DEM/DTM/DSM, Meteorological drivers, Hydrocarbons, Aquaculture plants, Coastline, Sea level, Waves, Nutrients, Defence and Port structure, Dissolved oxygen, pH, Salinity, Subsidence, Temperature, Turbidity, TSM, Land use, Sea use
Common fisheries policy	CFP	Various	Land use and man made structures	Aquaculture plants
Maritime Security	2005/65/EC, 2002/59/EC, 2009/45/EC, 2003/25/EC, 98/41/EC, Reg. EC 725/2004, Hamburg Convention 1979	D.Lgs. 187/2008, D.Lgs. 65/2005, D.Lgs. 25/2018, D. Interm. 14/07/2003, D.Lgs. 286/1998, D.P.R. 662/94, D.Lgs 4/2012, D.Lgs. 203/2007, L. 979/1982, D.Lgs. 196/2005, R. D. 327/1942, D.Lgs. 145/2015	Physical	Current, Sea level, Waves, Salinity, Temperature
ICZM	Prot. 4/2/2009		Land cover, Geomorphologic	
Sediment dredging		D.M. 172/16, D.M. 173/16	Bio-geo-chemical, Physical, Hydro-meteo, Land use and man made structures	Current, Waves, River flow, Temperature, Turbidity, TSM, Sediment properties, Sea use

Supplementary Table S2 describes the main European Directives and Italian Laws, grouped for topic.

The total value for each parameter calculated with the Formula (3) allowed to analyze their ranking. To assess the relative weight to the value of the directives and the users, the parameter values, calculated with the three Formulas (1)–(3), are represented in Figure 4.

Thereby, a comparison between the different parameters is possible.

The complexity of the System is represented by the numerous intersected lines, indicating, for example, that one directive can require monitoring of one or more of the parameters that have been indicated as necessary by the users and, on the other side, the same parameter can be listed by one or more directives and by one or more coastal users even if for different applications (Figure 5).



**Figure 5.** Sankey diagram representing the complexity of the connections between Directives (on the left), Coastal users (in the middle) and Parameters required by institutional users (on the right).

In Supplementary Figure S2 the links between laws and required parameters have different colors depending on the main directives topic: blue for directives linked to environmental protection, red for directives linked to risk and human health; yellow for directives linked to anthropic activities management.

### 3.2. Definition of National Operational Coastal Services

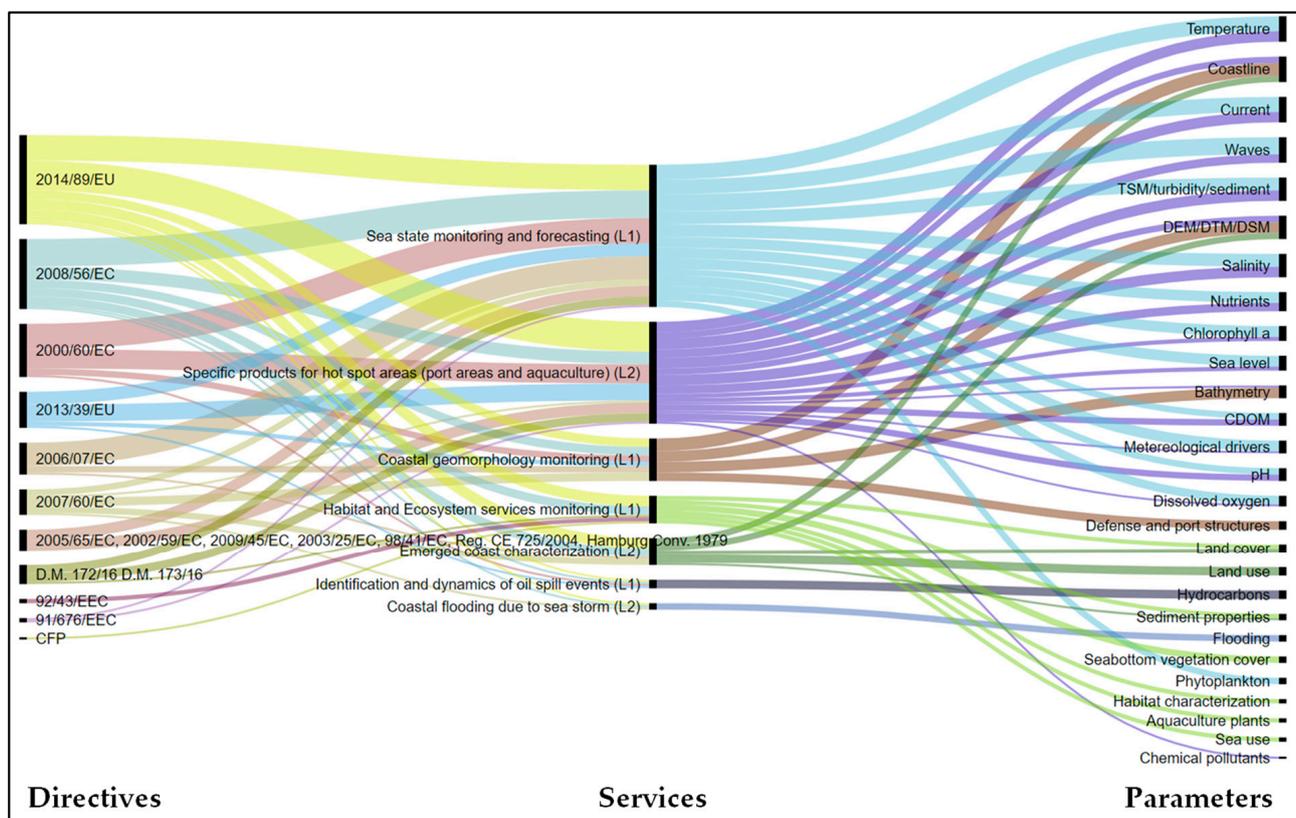
Requirements from the different actors have been evaluated, in order to share knowledge and needs on common requirements in coastal areas and to identify complementary services.

The services were organized in a hierarchic way, defining “level 1” to indicate a service that did not depend on others, and “level 2” for services that have in input one or more products coming from “level 1” services.

The specific services and products defined as coastal user requirements are (the services hierarchy is reported in brackets for each service):

- sea monitoring and forecasting (Level 1);
- coastal geomorphology monitoring (Level 1);
- emerged coast characterization (Level 2);
- habitat and Ecosystem services monitoring (Level 1);
- specific products for hot spot areas (port areas and aquaculture) (Level 2);
- identification and dynamics of oil spill events (Level 1);
- coastal flooding due to sea storm (Level 2).

The links between the identified national operational services, the provided parameters, and the European directives are shown by means of a Sankey diagram, in Figure 6.



**Figure 6.** Sankey diagram connecting the European Directives (on the left), the identified national operational services (in the middle) and the provided parameters (on the right).

Once identified the National operational services, the parameters provided by each service were defined to reach the users’ information needs, considering the regulatory obligations and indications, matching them with the available services and the delivered products. Table 3 shows the parameters provided by each service required by national institutional users.

**Table 3.** National coastal services required by institutional users and relative provided parameters.

National Coastal Services						
Sea state Monitoring and Forecasting (L1)	Coastal Flooding Due to Sea Storm (L2)	Specific Products for Hot Spot Areas (Port Areas and Aquaculture) (L2)	Identification and Dynamics of Oil Spill Events (L1)	Coastal Geomorphology Monitoring (L1)	Emerged Coast Characterization (L2)	Habitat and Ecosystem Services Monitoring (L1)
CDOM	Flooding	Bathymetry	Hydrocarbons	Bathymetry	Coastline	Aquaculture plants
Chlorophyll a	Risk maps	CDOM		Coastline	DEM/DTM/DSM	Habitat characterization
Current		Chlorophyll a		Defense and port structures	Land cover	Land cover
Dissolved oxygen		Coastline		DEM/DTM/DSM	Land use	Sea use
Phytoplankton		Chemical pollutants			Sediment properties	Seabottom vegetation cover
Meteorological drivers		Current				Sediment properties
Nutrients		DEM/DTM/ DSM				
pH		Dissolved oxygen				
Salinity		Phytoplankton				
Sea level		Meteorological drivers				
Temperature		Nutrients				
TSM/turbidity/sediment		pH				
Waves		Salinity				
		Sea level				
		Temperature				
		TSM/turbidity/sediment				
		Waves				

The parameters required by national users were also correlated to those highlighted as priority in the RoadMap for the evolution of Copernicus marine and land core services [68]. Supplementary Table S3 shows the parameters provided by each service of the RoadMap.

The Sankey diagram representing the relations between European Directives, thematic services identified in the Copernicus Marine-Land RoadMap and provided parameters is reported in Supplementary Figure S3.

### 3.3. Definition of the Coastal Services' Innovative Requirements

A comparative assessment of the parameters requested by national users and the available parameters provided at European level by the Core Copernicus services or the EMODnet (European Marine Observation and Data Network) is shown in the Figure 7, from which it would appear that only few parameters (TSM, Sediment properties, sea use, river flow, land cover, flooding, faecal bacteria, beached waste) have not an available Core services product while others do. However, the Table 4, that reports the relative spatial and temporal resolution for each needed product and the available ones from Copernicus Core services and EMODnet, shows an important gap, especially for the spatial resolution, that is too low for the available products compared to the requests. EMODnet is an EU-DG MARE initiative that features a portal that collects and publishes existing field data for specific areas, so a homogeneous spatial and temporal resolution cannot be defined, for A bathymetry product that is interpolated from in situ data.

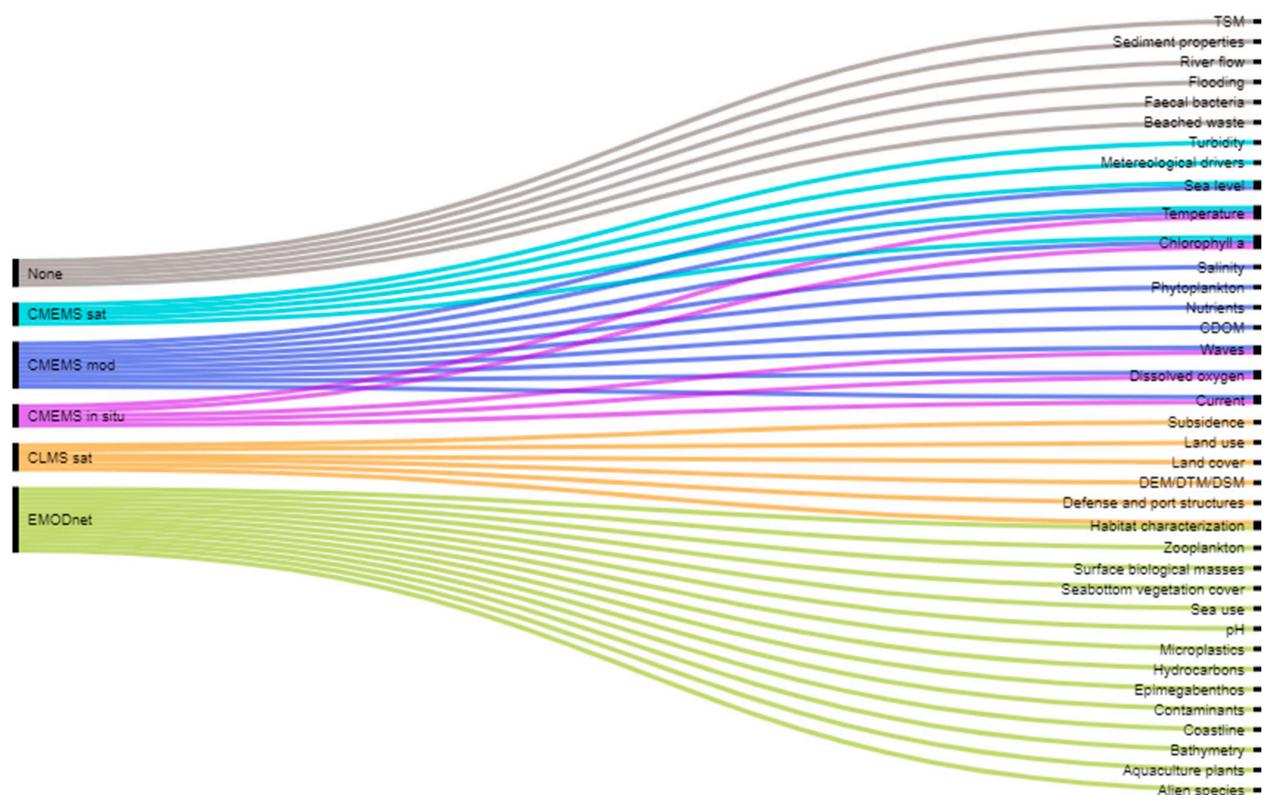


Figure 7. Parameters provided by Copernicus Core services and EMODnet.

**Table 4.** Comparison between spatial and temporal resolution required for national coastal services and provided by Copernicus Core services and EMODnet data.

Parameters	National Coastal Services			Copernicus Core Services (Med Sea) and EMODnet Data								
	Coastal Services	Spatial Resolution	Temporal Resolution	Satellite Product	Spatial Resolution	Temporal Resolution	In Situ Product	Spatial Resolution	Temporal Resolution	Modelling Product	Spatial Resolution	Temporal Resolution
Aquaculture plants	Habitat and Ecosystem services monitoring (L1)	NA	NA				EMODnet	NA	NA			
Bathymetry	Specific products for hot spot areas (port areas and aquaculture) (L2)	5 m/25 m	ns				EMODnet	250 m	NA			
Bathymetry	Coastal geomorphology monitoring (L1)	1 m/250 m (depth 5 m)	6 mts/3 yrs				EMODnet	250 m	NA			
CDOM	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h	CMEMS sat	1 Km	1 d						
CDOM	Specific products for hot spot areas (port areas and aquaculture) (L2)	5 m/25 m	1 h	CMEMS sat	1 Km	1 d						
Chlorophyll a	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h	CMEMS sat	1 Km	1 d	CMEMS in situ			CMEMS mod	4 Km	1 d
Chlorophyll a	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d	CMEMS sat	1 Km	1 d	CMEMS in situ			CMEMS mod	4 Km	1 d
Coastline	Coastal geomorphology monitoring (L1)	1 m	6 mts/3 yrs				EMODnet	NA	NA			
Coastline	Emerged coast characterization (L2)	1 m	6 mts/3 yrs				EMODnet	NA	NA			

Table 4. Cont.

Parameters	National Coastal Services			Copernicus Core Services (Med Sea) and EMODnet Data								
	Coastal Services	Spatial Resolution	Temporal Resolution	Satellite Product	Spatial Resolution	Temporal Resolution	In Situ Product	Spatial Resolution	Temporal Resolution	Modelling Product	Spatial Resolution	Temporal Resolution
Current	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				CMEMS in situ			CMEMS mod	4 Km	1 h
Current	Specific products for hot spot areas (port areas and aquaculture) (L2)	5 m/25 m	1 h				CMEMS in situ			CMEMS mod	4 Km	1 h
DEM/DTM/DSM	Coastal geomorphology monitoring (L1)	1 m	6 mts/3 yrs	CLMS sat	25 m							
DEM/DTM/DSM	Emerged coast characterization (L2)	1 m	6 mts/3 yrs	CLMS sat	25 m							
Dissolved oxygen	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				EMODnet	NA	NA	CMEMS mod	4 Km	1 d
Dissolved oxygen	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d				EMODnet	NA	NA	CMEMS mod	4 Km	1 d
Phytoplankton	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				CMEMS in situ			CMEMS mod	4 Km	1 d
Habitat characterization	Habitat and Ecosystem services monitoring (L1)	NA	NA	CLMS sat	10 m/25 m	6 yrs	EMODnet	NA	NA			
Hydrocarbons	Identification and dynamics of oil spill events (L1)	1 m	first available satellite detection				EMODnet	NA	NA			

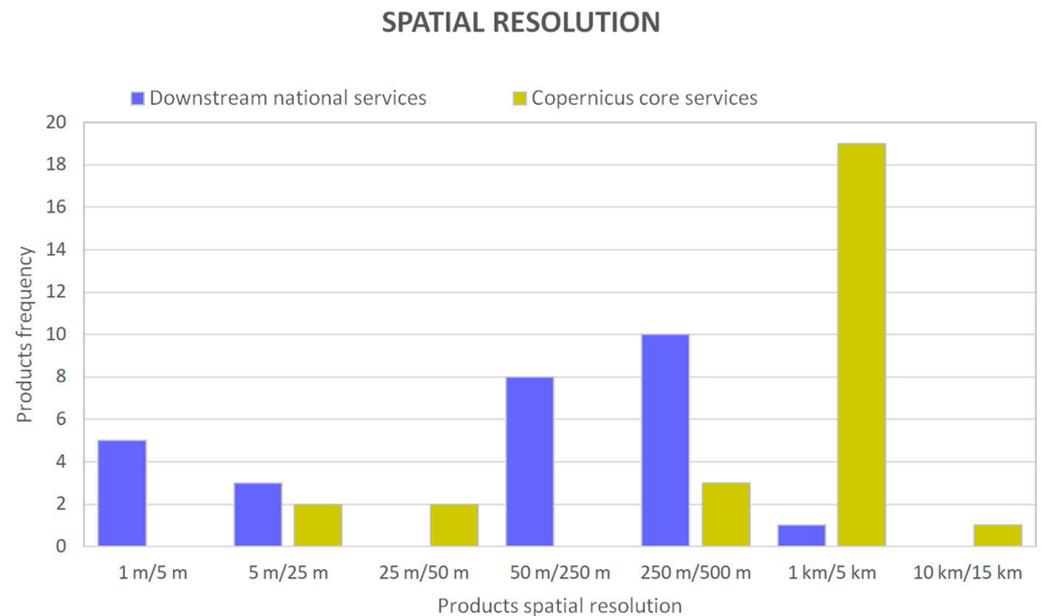
Table 4. Cont.

Parameters	National Coastal Services			Copernicus Core Services (Med Sea) and EMODnet Data								
	Coastal Services	Spatial Resolution	Temporal Resolution	Satellite Product	Spatial Resolution	Temporal Resolution	In Situ Product	Spatial Resolution	Temporal Resolution	Modelling Product	Spatial Resolution	Temporal Resolution
Land cover	Emerged coast characterization (L2)	0.5 m	3 yrs	CLMS sat	10 m/25 m	6 yrs						
Land cover	Habitat and Ecosystem services monitoring (L1)	1m/10m	3 yrs	CLMS sat	10 m/25 m	6 yrs						
Meteorological drivers	Sea state monitoring and forecasting (L1)	2–5 Km/<1 Km	ns	CMEMS sat	12.5 Km	1 d ist	CMEMS in situ					
Meteorological drivers	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d	CMEMS sat	12.5 Km	1 d ist	CMEMS in situ					
Nutrients	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				EMODnet	NA	NA	CMEMS mod	4 Km	1 d
Nutrients	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d				EMODnet	NA	NA	CMEMS mod	4 Km	1 d
pH	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				EMODnet	NA	NA			
pH	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d				EMODnet	NA	NA			
Salinity	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h				CMEMS in situ			CMEMS mod	4 Km	1 h

Table 4. Cont.

Parameters	National Coastal Services			Copernicus Core Services (Med Sea) and EMODnet Data								
	Coastal Services	Spatial Resolution	Temporal Resolution	Satellite Product	Spatial Resolution	Temporal Resolution	In Situ Product	Spatial Resolution	Temporal Resolution	Modelling Product	Spatial Resolution	Temporal Resolution
Salinity	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d				CMEMS in situ			CMEMS mod	4 Km	1 h
Seabottom vegetation cover	Habitat and Ecosystem services monitoring (L1)	1m/10m	3 yrs				EMODnet	NA	NA			
Sea level	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h	CMEMS sat	7 Km	ist	CMEMS in situ			CMEMS mod	4 Km	1 h
Sea level	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d	CMEMS sat	7 Km	ist	CMEMS in situ			CMEMS mod	4 Km	1 h
Sea use	Habitat and Ecosystem services monitoring (L1)	1 m–10 m/1 Km <sup>2</sup>	15 d/3 yrs				EMODnet	NA	NA			
Temperature	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h	CMEMS sat	1 Km	1 d	CMEMS in situ			CMEMS mod	4 Km	1 h
Temperature	Specific products for hot spot areas (port areas and aquaculture) (L2)	5 m/25 m	1 h	CMEMS sat	1 Km	1 d	CMEMS in situ			CMEMS mod	4 Km	1 h
Waves	Sea state monitoring and forecasting (L1)	250 m/500 m	1 h	CMEMS sat			CMEMS in situ			CMEMS mod	4 Km	1 h
Waves	Specific products for hot spot areas (port areas and aquaculture) (L2)	<250 m	1 d	CMEMS sat	7 Km	ist	CMEMS in situ			CMEMS mod	4 Km	1 h

To compare the above reported spatial resolutions a defined temporal range clustering was made as reported in Supplementary Table S4. The histogram in the Figure 8 highlights the gap existing between the requested national services and the Copernicus Core products, outlining the baseline of the EU level with respect to the system needed at national level.



**Figure 8.** Spatial resolution gap between downstream national services (blue), Copernicus Core services (green).

The gap analysis of the available products state of the art and the information needs of the coastal users, allowed to define in detail the characteristics of the required national coastal services and of their products, described in the Table 5. Although, in fact, the Copernicus services provides European coverage, their numerical modeling systems are not well fine-tuned to analyze the state of coastal areas at local scale, that requires the improvement of spatial resolution and the assimilation of local conditions and in situ data. Spatial resolution appears to be the major limitation to the application of existing core services products, and therefore the identified services have the purpose of bridging this gap with a suitable one. The integration of EO data with in situ measurements is another key factor to validate the products and their accuracy. Moreover, the services must take into account the limits of remote sensing, such as the possibility of determining mainly superficial parameters, for example for water quality.

**Table 5.** The characteristics of the identified innovative national coastal services. The details of each product released by the Services are listed in Table 4.

Service Name (Level)	Proposed Service	Service Requirements
<b>Sea monitoring and forecasting</b> (Level 1)	<p>The proposed service will operate to produce data related to the main physical and bio-geochemical parameters. The service will integrate in situ observations, remote sensing and high-resolution numerical modeling, in order to create homogeneous products between the coastal line and the limit of 12 miles from the baseline (as defined in article 5 of United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982) on the entire coastal domain of interest.</p> <p>The model will produce analysis, reanalysis for long past periods and will operate in forecasting mode to provide daily hourly estimates for the next 5 days.</p>	<p>Model driven Real time Regular delivery</p>
<b>Coastal geomorphology monitoring</b> (Level 1)	<p>The service will provide regular updates of the information regarding the near coast bathymetry, the digital terrain model (DTM) of the emerged surface, shoreline and coastal interventions (e.g., coastal defenses and infrastructures).</p> <p>The service will consider the integration of remote sensing (satellites and drones) and in situ measurements (including Hydrographic Institute data) for the validation.</p>	<p>Space data driven Deferred time Regular delivery</p>
<b>Emerged coast characterization</b> (Level 2)	<p>The service's aim is the definition of the limits of the beaches, the geo-morphological characterization of the emerged coast, the quantification of beach sediment volumes and changes, the mapping of land use and their changes and the shoreline evolution monitoring. Furthermore, the service will collect the images produced by the national coastal environmental video-monitoring systems, in compliance to specific data protocol.</p>	<p>Space data driven Deferred time Regular delivery</p>
<b>Habitat and Ecosystem services monitoring</b> (Level 1)	<p>The service provides information about the characterization of coastal habitats the monitoring of associated ecosystem services and their evolution. To this end, the service will also have to provide maps of land and sea cover and use that allow the assessment of the influence of human activities in the coastal area.</p>	<p>Space data driven Deferred time Regular delivery</p>
<b>Specific products for hot spot areas (port areas and aquaculture)</b> (Level 2)	<p>This service provides specific products, using as input the products deriving from the sea monitoring and forecasting service (level 1 service), aimed at supplying integrated monitoring of the marine-coastal waters quality in port areas and near aquaculture plants.</p> <p>The service includes the production of:</p> <ul style="list-style-type: none"> <li>turbidity and suspended solids parameters, water temperature and marine currents at a higher spatial and temporal resolution with respect to the Service Sea monitoring and forecasting in selected Italian harbors. Specific in situ measurements have to be carried out for data validation;</li> <li>information related to physical-chemical parameters for selected areas vocated to aquaculture with the aim of monitoring the quality of water bodies, forecasting potential impacts, plant performance, defining climate change adaptation scenarios and for the identification of suitable areas for aquaculture.</li> </ul>	<p>Model driven Real time Regular/On demand delivery</p>
<b>Identification and dynamics of oil spill events</b> (Level 1)	<p>This service should identify the areal extension, the characterization of the spilled contaminant typology and the dynamic direction, with a spatial resolution from mid to high and a very high temporal resolution using physical parameters produced by the sea monitoring and forecasting service (level 1 service).</p>	<p>Space data and model driven Real time On demand delivery</p>
<b>Coastal flooding due to sea storm</b> (Level 2)	<p>The aim of this service is to forecast storm surge events, to evaluate the coastal risk and define the relative management. The service requires a coastal flood awareness system linking the hazard on coastal areas with the risk of impact and probable extension of the flooding effects. It will provide maps of areas exposed to flooding due to sea storm (forecast, during and post-event).</p>	<p>Model driven Deferred time On demand delivery</p>

All the products from the national coastal services must be validated and a comprehensive estimation of reliability of results has to be carried out. Data quality reports are required every 6 months, describing through several statistical tools the error associated with each product. Waves products validation to be carried out on a monthly basis and reports to identify areas where upgraded modelling or in-situ data are required.

#### 4. Discussion

The processes and procedures required to convert user expectations and needs into measurable technical requirements have the function to define the technical features of required products and allow to define the entire development chain, from the products that should be provided by European core services as input to the Member States downstream processes and the instrument specifications for the satellites program design, ensuring that satellite missions serve both the scientific and user communities [68,70,74,87].

The collection and analysis of user requirements performed in this work has allowed to have a clear wide overview of the national needs of operational services to be implemented in order to provide useful information to coastal area managers for their legal and institutional duties. Institutional users represent a services' qualified demand arising from regulatory obligations and directives implementation needs. A key step is the stakeholder interaction with the scientific community: defining services based on user needs and recommendations not only ensures relevant and sustainable development of services and relative products but it also serves to engage, educate, and animate the wider community with regard to the capabilities of EO [23,76,88–91]. The applied method has been followed to establish the specific technical requirements of services in order to enable the delivery of specific high-level products for coastal applications, at the expected level of quality. The continuous and cyclic interaction with users and the requirements elicitation permitted to specify properly the key information needs [74,76,77]. Each identified coastal service reflects the Institutional users' current ability to summarize their needs by identifying clusters of instruments, partly existing and used but still to be improved, partly to be implemented ex novo, there is the need for technical specification of each service and relative product to be delivered. In this context, the scientific community plays the key role of translating the expectations and practical needs of the users and customers into measurable technical requirements, developing the algorithms and methods to be implemented for the systematic generation of products by the integration of multiple data (remote, in situ and modeled).

The results represent in details the entire heterogeneous national needs, building, for the first time, an integrated system of interconnected thematic modules. The core result of the user requirements analysis carried out is represented by the Sankey diagram in Figure 6, connecting the identified national operational coastal services, the provided parameters and the European directives [86]. Figure 6 clearly shows that the most requested Level 1 services are: "sea monitoring and forecasting" and "coastal geomorphology monitoring", followed by "Habitat and Ecosystem services monitoring". Those services are mainly linked to the Maritime Spatial Planning Directive (MSPD) and the Marine Strategy Framework Directive (MSFD) [17,29]. This result highlights the link to the strategy defined in the RoadMap for the evolution of Copernicus marine and land services [68], in which the main identified services are "monitoring the status and pressures on the coastal environment" and "monitoring land sea interaction including coastal erosion" (Figure S3 and Table S3), confirms the results of the present study on the relevant need for setting services for marine-coastal monitoring in terms of physical drivers and water quality and issues linked to the morphodynamic processes. The RoadMap includes also the need of products for the "protective function of coastal zones" service, requested also by the Italian institutional users, despite the lack of a specific law on coastal risk [68,69], for a coastal flood awareness system in the preparedness phase, considering, for the emergency and post-event phase, the products delivered by the Copernicus Emergency Management Service (CEMS) for the assessment of the impact and of the flooded areas extension. This is also in line with the

common need of an integrated multitask information for the management of coastal area, as desired by the ICZM recommendations [3], in line with the action plan foreseen by the European Green Deal aimed at promoting the efficient use of resources by moving to a clean and circular economy, restoring and protecting biodiversity and reducing pollution.

Moreover, the gap analysis carried out in order to check the availability of suitable core Copernicus products for the national needs pointed out the lack of many products and those that are provided by Copernicus core services have a too low spatial resolution compared to that requested by the national users (Figure 8). The same might apply for other users, not directly listed in the present research, like for example private engineering companies. Typically, their activities are based on the detailed knowledge of the same parameters of interest for the national users. The integration of field measurements allows validating the products, even if the limits of remote sensing especially for the water quality parameters allow the estimation only on the surface and with a limit of determination accuracy that is not suitable for comparison with tabular limits imposed by laws. The products gap filling of the paper suggests an integration of multi-sources data, algorithms, models, tools and products to design operational processing chains that, leveraging on the Copernicus ecosystem (satellite data, services and DIAS), can provide validated information for operative support to decision makers [23,29,35–38,44–48,92].

Specifically, from the comparison of the parameter values, function of the frequency of users requests and the reference directives, the requirements prioritization was carried out to maximize the stakeholders' satisfaction [80,82]. The parameters that assume a greater importance are those related to the morphodynamic processes (for which the greater weight to the value is related to the users' requests) and those related to the physical state of the sea and to the quality of the sea water (for which the greater weight is given by the directives). The investment in term of costs and time required for an extensive in situ monitoring and the natural evolution of coastal processes that could make the data useless in a few years, lead to the research for new methodologies that use EO data for the study of the morphology of the coast and its dynamics, for the monitoring of the habitat cover and of the physical and quality state of the sea [25,26,28,35–37,41,45,46,62,63].

The data and products management and interoperability, or the ability for heterogeneous systems or system components to communicate, exchange resources, or work together, is a key factor to be considered in the services implementation [66,93,94] and geospatial web services and platforms are being rapidly developed to assist managers, decision-makers, and scientists [66,90–92,95]. Moreover, considering that users' requirements do not represent a static element, the services should have the capability of updating with the evolution of the communities and their context and needs and progress in the scientific and technological development of the EO data-based algorithms and products [74,93,96,97]. Once downstream services are implemented, it is important to educate the user community on the information content, limitations and usability [85].

Thus, the developed method can become the benchmark for the definition:

- at the European level, of the products that must be provided by Core Copernicus services as input to national downstream processes, ensuring coordination between the various Copernicus components and the RoadMap for the evolution of Core Marine and Land services aimed to the identification of the products of interface between base core services and specific downstream systems tailored on member states users' demand;
- at EU Member States level, of the harmonization procedure of user requirements analysis and operational coastal services definition to be implemented intra-State and inter-States, encouraging the use, reuse and accessibility of information and harmonizing products between the different Countries to favor the acquisition of a complete and homogeneous picture of coastal areas and trans-national effects for government management.

## 5. Conclusions

The strength of the presented methodology is due to the heterogeneity, representativity, and transdisciplinary nature of the interviewed users and of their main thematic tasks and legislative duties, ranging from environmental and civil protection, security and defence, fishing and resources management, to cultural heritage and infrastructure, reaching in this way a different perspective. Moreover, the thematic applications and needs are geographically distributed throughout Italy. This makes the developed method an important tool to overpass the fragmentation due to the sectorial legislation, the specific thematic purposes and the geographic applications. The priority choice of institutional users allowed having a highly qualified picture of national requirements, arising from regulatory obligations and directives implementation needs.

The method is based on the synergic interaction between coastal end-users (needs compliant with the laws), EO experts (technology) and coastal processes experts (scientific research), around the so called “Coastal table”, in the Italian Copernicus User Forum and Space Economy Mirror Copernicus context. The defined coastal operational services, that integrate satellite products with in situ data and models, can usefully support Blue Growth policies and Green Deal strategies allowing to observe the evolution of the state of the environment (with a continuous temporal monitoring on large areas), to plan maritime and coastal activities in an optimized way and to give Authorities a better picture of what is happening at coastal-marine areas for maritime management.

The strength and innovativeness of the research and its results lie in the fact that for the first time, at national level, the needs of national institutional users for the development of coastal application services have been analyzed and defined. The approach is systematic, integrated, qualified, representative and homogeneous, overcoming the sectorial, geographical and legislative coastal fragmentation. Specifically:

- systematic and integrated, since the same procedure has been used to define all the thematic operational services developed in the space economy context, creating a system of integrated and interconnected modules.
- qualified, since the demand comes from institutional users who has to carry out their own tasks linked to the international and national legislation, so representing the anchor customer for the institutional and commercial services’ industry market.
- representative and homogeneous, since the interviewed coastal users are geographically distributed and cover all the different thematic issues, providing a complete overview of the national needs for coastal operational services.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/2073-4411/13/1/92/s1>, Table S1. Parameters grouped into specific typology defined by their properties; Figure S1. Sankey diagram representing relation between directives and different typology of parameters; Figure S2. Sankey diagram connecting required parameters and European Directives; Table S2. Description of the main European Directives and Italian Laws, grouped for topic; Figure S3. Sankey diagram representing the relations between European Directives (on the left), thematic services identified in the Copernicus Marine-Land RoadMap (in the middle) and parameters (on the right); Table S3. Copernicus Marine-Land RoadMap services and relative parameters provided; Table S4. Comparison between the clustered spatial resolution of Italian downstream services and Copernicus Core services.

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