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Space4Maritime: diving into space-based solutions for the maritime domain. Challenges and opportunities to foster the collaboration between service providers and maritime end- users' communities

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Abstract

Blue Economy encompasses those sectors and activities related to oceans, seas, and coasts, such as fisheries, energy, aquaculture, natural resources, logistics, safety and security, transport, port activities, tourism, and shipbuilding repairs. Europe represents one of the leading maritime powers in the world. In 2018, the EU Blue economy generated €750 billion in turnover and €218 billion in gross value added and directly employed about 5 million people. Satellite applications bring an added value in creating innovative and sustainable growth path for many industries, as in the maritime domain. In this context, satellite technology provides marine operators with reliable real-time information while ensuring coverage of vast and unreachable areas. In recent years, maritime operators are facing new challenges: from coastal management to navigation assistance, as well as biodiversity protection and disaster response and management. Satellite data provides a plethora of reliable and easy-to-use solutions for aquaculture, fisheries, algal bloom, safety and security, and coastal development, to name a few. Nevertheless, the take-up of satellite-based solutions is far from being achieved. Scepticism persists from the end- users' side due to a series of factors as a lack of clear communication with service providers; a poor understanding of the benefits related to the integration of satellite-based solutions in their workflow; financial constraints; and a lack of knowledge and competencies for implementing and using satellite-based services efficiently. Recently, Eurisy launched the initiative Space4Maritime. The objective is to identify and understand the needs of European maritime end-user communities, facilitating the dialogue with the space industry and the uptake of satellite services. In this frame, Eurisy started a series of interviews with end-users identified in the blue world. The result of these interviews is the core of the paper. The overall objective is to identify the existing operational solutions applicable in the maritime domain through practical examples, as well as the bottlenecks that harness the potential of satellite applications for the sustainable growth of the Blue Economy. The paper will mainly address service providers and public authorities, providing them with a set of recommendations on how to foster cooperation with maritime operators. But it also targets potential new end-users interested in adopting satellite solutions in their workflow. The case studies will be complemented furtherly by additional information collected through desk research and the organization of thematic webinars.
Keywords: Blue Economy, Satellite Applications, Maritime, Fishery, Coastal Management, Safety

1. Blue Economy state-of-the-art in Europe

Blue Economy refers to all economic activities that are using directly or indirectly the sea, and that will be heavily affected or inexistent without the sea. Framing a definition and concept of blue economy at global level is not easy. It usually varies according to the region considered, even though the sectors that are usually covered are convergent. Generally, it can be stated that Blue Economy encompasses all those industries and sectors related to the oceans, seas, and coasts, both in the marine environment and on land.[1] It is possible to distinguish between established maritime industries, that are traditionally contributing to the blue economy, and emerging ones, for which reliable data are still developing. Generally, the emerging industries are the most innovative ones, and they could generate new investment opportunities and keep a large potential for the development of coastal communities.

Blue Economy industries	
Established Sector	Emerging Sector
Marine Living Resources (Primary production-processing of fish products-distribution of fish products)	*Blue Bioeconomy & biotechnology*
Marine Non-Living Resources (Extraction of crude petroleum, natural gas and salt and support activities)	*Marine Minerals*
Marine Renewable Energy (offshore wind energy)	*Ocean Energy*
Port Activities (Cargo and Warehousing and storage-port and water projects)	*Desalination*
Shipbuilding and Repair	*Maritime Defense,*

(shipbuilding- equipment and machinery)	*Security and Surveillance*
Maritime Transport (passenger and freight transport- services for transport)	*Infrastructure and maritime works* (submarine cables- ultra deep-water oil and gas extraction- seabed mining)
Coastal Tourism (accommodation- transport)	*Research & Education*

Figure 1. Established and emerging maritime industries. Sources: EC DG MARE and OECD. Eurisy table elaboration.

Regardless of the region observed, blue economy can be considered as a broad and fast-moving economic segment. This is demonstrated by the growing number of emerging and innovative industries that are populating the sector, such as blue bioenergy, autonomous shipping, and navigation. The blue economy model aims at improving human wellbeing while protecting the value of marine ecosystems. [2] According to the estimation of the Organization for Economic Co-operation and Development (OECD) presented in the report "The Ocean Economy in 2030" (2016), the global blue economy in 2010 generated USD 1.5 trillion, approximately 2.5% of the world Gross Value Added (GVA), also generating about 31 million jobs. The economic activity of maritime-based industries is rapidly expanding driven by development in global population, economic growth, climate, and environment, and finally technology. According to the projections of OECD, by 2030 in a "business-as-usual" scenario- not considering the effects of COVID-19- the blue economy can double the contribution to the global GVA, reaching over USD 3 trillion. [3]

1.1 Blue Economy in Europe

According to the 2021 EU Blue Economy Report, the contribution of the blue economy to the EU-27 economy in 2018 was about 1.5% in terms of GVA and 2.3% of the employment market.

Figure 2. Contribution of the Blue Economy of the overall EU economy. Sources: Eurostat and EC

The core is represented by the contribution of the established industries, that from 2013 until 2018 grew in terms of GVA of about €176.1 billion with a turnover of €649.7 billion, directly employing 4.5 million people, 12% more than in the year 2017. Coastal tourism represents the driving force of this growth, due to the high relevance of this industry for most of the European Member States. Other growing sectors, as maritime transport and port activities increased respectively by 12% and 14.5%, as well as the marine living resources sector, mainly fisheries and aquaculture industry, generating €7.3 billion of profits in 2018.

According to the European Commission DG MARE report "The EU 2021 Blue Economy Report", in 2018 the established sectors contributed to the job market generating 4.5 million jobs, with 1% increment compared to 2017. The driving force is coastal tourism, contributing with 45% of the overall employment confirming a growing and uniformed trend. Over the next years, additional contributions will come from some emerging industries as renewable energy, that in 2018 created 15% more jobs than the year before. Maritime renewable energy represents one of the fast-growing blue industries, with considerable potential in terms of technological development and employment opportunities that explains the possible growth of this sector. This is true also considering the role that renewable energy will have in meeting the objective of carbon-neutrality by 2050, as defined by the European Green Deal. [4]

2. Space technology in the maritime domain

The role of space technology in the maritime domain is not recent but has solid roots in the past. Satellites and space technologies are serving the blue world for 40 years now: initially satellite observations were providing mariners and the navy with improved meteorological forecasts, while satellite telecommunications were used to improve maritime safety by enhancing navigation accuracy, environmental monitoring, and security. [5]

Today, the challenges posed by climate change and their effects on the industries involved in the sector, makes space technology an enabler for the sustainability and growth of the blue economy. Traditionally, satellite communication has been the most utilised technology in the maritime domain. The reason can be found in the need to provide in-land communication ship-to-shore for emergency and rescue, maritime surveillance, and border controls. Compared to satellite communication, terrestrial communications cannot always ensure a high-level quality service when in high-sea or far from the coasts.

Maritime satellite communication systems today are also contributing to the improvement of radio maritime communication. In fact, the development of maritime mobile satellite communication system networks is facilitating the communications among headquarters of shipping companies, ports, fleets, enabling the ship monitoring, navigation, and surveillance. [6]

Connecting crew and passengers, as well as cruise and merchant shipping sectors can optimise the exchange of data between ships and shore, improve the navigation safety and reduce emissions. During COVID-19 pandemics, the use of satellite connectivity in high seas served as a key asset for those merchants that needed a telemedicine service while navigating. The contact tracing and telemedicine services in high seas could be, in the post-pandemic era, a key asset to also relaunch the recreational cruises. In fact, vacations in high seas can take advantage of satellite communication also to develop connected telemedicine services that could provide passengers with medical consultations with experts onshore.

In the future it might be possible to assist to the emergence of a more connected maritime world driven by autonomous ships and navigation solutions. In this frame, the quality and availability of signals will improve thanks to the deployment of 5G mega-constellations providing backhaul connectivity to terrestrial network poised to drive the modernisation of ports infrastructures and logistics. [7]

GNSS-enabled solutions are also aiding maritime operations, especially vessels monitoring. According to the European Union Agency for the Space Programme (EUSPA), in 2019, 15,000 fishing vessels were equipped with GNSS systems: 80% of the maritime receivers were EGNOS-based and 20% Galileo enabled. Among the established maritime sectors, logistics relies more than any other on GNSS. [8] The Satellite-based Automatic Identification System (S-AIS), a satellite-tracking system that uses transceivers on ships and used by vessel traffic services, is widely employed to collect from marine vessels identification, location, speed, and course. The Long-Range Tracking and Identification (LRIT) system, that is the international tracking and identification system incorporated by the International Maritime Organisation (IMO) to ensure an accurate tracking system for ships to enhance security of shipping and for the purposes of safety and marine environment protection, has a similar goal but is mostly used to track cargo ships. In the European Union it is more common to integrate on boat the Vessel Monitoring System (VMS), a satellite surveillance system relying on satellite communication primarily used to monitor the location and movement of commercial fishing vessels. The VSM helps in observing fishing activities in compliance with fishery regulations of the EU, at the point of becoming a pre-requisite for large to medium fishing vessels to operate in European waters. [9]

Satellite navigation and hydrometeorological data integrated in modern route planning systems can facilitate the identification of the best route on different weather conditions to reduce fuel consumptions and time. [10]

Often used in combination with GNSS technology, Earth Observation (EO) finds its application in the marine domain for the identification of coastal issues as coastal erosion, marine accidents, fishery, and for measuring and assessing climate change effects. Environmental monitoring is the field where EO is mostly exploited, especially in the case of oil spills or boat discharges: satellite imagery and radar data are used to monitor the spreading and floating of the pollutants at sea and towards the coasts, and to define *ad hoc* measures thanks to near-real-time information that could be accessible to decision-makers. EO is often used for predictions and modelling especially for fishery and aquaculture, because imagery and data allows the observation of sea level rise, ocean acidification, and algal bloom.

The use of satellite images in the maritime domain heavily relies on the services and images available via Copernicus and its dedicated services Copernicus Marine Service (CMEMS).

3. Space4Maritime: identifying operational solutions to foster Blue Economy

To identifying operational solutions in support of the development of Blue Economy, Eurisy launched the initiative “Space4Maritime”. The topic of maritime is not new to the organization: back in 2014 Eurisy introduced it through the workshop “Blue Economy & the Geo-Information Services” organised under the patronage of the Italian Presidency of the European Council. This event aimed at highlighting the relevance of satellite applications for the maritime sector, mainly in the Mediterranean Region. In the following years, several other topic-related initiatives saw the participation or contribution of Eurisy such as the Mini-colloque “La mer et l’espace” (2018), the European Space Agency (ESA) Workshop “Atlantic from Space” (2019), and the 4th International Space Forum at Ministerial Level – The Mediterranean Chapter “Space Technology and Applications meet Mediterranean Needs” (2019), organised by the International Astronautical Federation (IAF), the Italian Space Agency (ASI) and the University of Reggio Calabria.

In 2020, the Space4Maritime initiative was revamped to continue and foster the positioning of Eurisy in this domain to better support its members with strategic and economic interest in the maritime field and to potentially co-design projects and targeted activities (webinars, reports, articles, conferences). The objective of this initiative is firstly to identify and understand the needs of European maritime end-user communities, facilitating the dialogue with the space industry to favor the uptake of satellite services; as well as to categorize the existing operational solutions applicable in the maritime domain through practical examples. Eventually, the initiative aims also at spotting the bottlenecks harnessing the potential of satellite applications for the sustainable growth of the Blue Economy.

3.1 Take-up of satellite-based solutions: challenges and benefits

In recent years, maritime operators are facing new challenges: from coastal management to navigation assistance, as well as biodiversity protection, and disaster management and response. Satellite data provides a plethora of reliable and easy-to-use solutions for aquaculture, fisheries, algal bloom, safety and security, and coastal development, to name a few. Nevertheless, the take-up of satellite-based solutions is far from being achieved.

This difficulty is related to a series of obstacles that could hinder the integration of satellite data in the workflow of the maritime end-users' communities and that could have an impact on the development of a sustainable Blue Economy. In the past months, Eurisy joined forces with the European Space Agency (ESA) Blue World Task Force. Officially kicked-off in 2019 as part of the ESA's regional initiatives, the Blue World Task Force covers the principal maritime geographic areas in Europe. [11] The Eurisy/ESA collaboration resulted in the webinar series "The challenges of the Blue World". The objective of the three webinars was discussing the existing challenges maritime stakeholders face and how satellite-based solutions respond to their emerging needs. Each webinar gathered local authorities, NGOs, research centers, and industrial clusters from space and maritime domains. [12]

Following the webinar series, Eurisy started with the identification of early adopters of satellite-based solution in the maritime domain across Europe. The objective was to collect relevant information on the use of satellite-based services in the maritime domain. The group of interviewees was composed by 20 users. The interviewing period lasted between April and July. Most of them were contacted with the support of service provides, also interviewed to elaborate on the development of the service or product available on the market.

The interviews lasted about 1-hour. During each of those, the interviewees were asked a set of pre-defined questions, to provide an initial quality assessment of the existing challenges and needs in the maritime domain. Similarly, the questionnaire drafted by Eurisy aimed at mapping the available solutions. The questionnaire was divided into four sections:

- 1st section: user profile. The questions included in this part aimed at describing the user's mission, its region of activity, its beneficiaries, and the short-medium term strategic objectives.
- 2nd section: identification of the challenge/need. During the interview the user is invited to introduce its challenge and impacts on the relations with their beneficiaries as well as on the working team.
- 3rd section: description of the satellite-based solution. The questions of the 3rd section focus on the adoption of the solution to respond to the need/challenge previously described. In this segment, the users present from their perspective the solution, the data used, and the challenges faced by the employees in working with new technology.
- 4th section: benefit assessment questions. In this last section, the user is invited to describe how the satellite-based solution impacted on the daily workflow, if and how it changed the user's strategic priorities. The user is also invited to provide its insights on the economic impact of the solution, if aware of it.

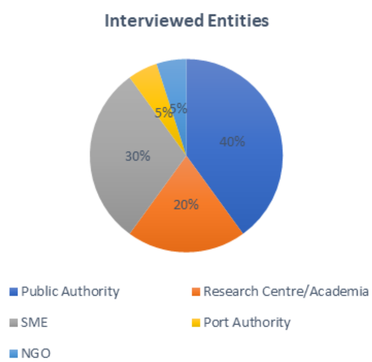

Figure 3. User Type Classification. Eurisy data and table elaboration.

The interviewees were mostly public authorities at regional and local level operating in the field of environmental protection. 30% of the interviewees were SMEs that are integrating satellite solutions in their workflow, especially for citizenship engagement, through mobile apps. Research centers are often using satellite data. A smaller group is represented by port authorities, using satellite data for the management of port areas and stocking logistics. Similarly, NGOs have been identified in the domain of safety and security, especially in relation with the identification of environmental crimes like oil spills, dark ships detection related to illegal fishing.

The interviewees' working field have been categorised according to seven maritime economic sectors:

- Environmental sector: pollution, water supply management, water quality, marine biodiversity, marine resources management, algal bloom, species protection and flora.
- Food production and security: fishery, aquaculture, management of fish shoals, pelagic fish stocks.
- Transport and navigation: autonomous shipping and driving, bathymetry, maritime situational awareness, and shipbuilding and repair.
- Connectivity: integration with terrestrial systems, shore2shore communications, ship2shore communications, ship2ship communication, and IoT technologies.
- Safety and security: search and rescue, illegal fishing, environmental crimes, dark ships detection, piracy, smuggling, natural disasters.
- Energy sector: renewable energy, wind and wave tidal measurements, energy infrastructure management. Port and coastal development: port development, stocking
- logistics, coastal development, traffic management, tourism, coastal flood hazards and risks.

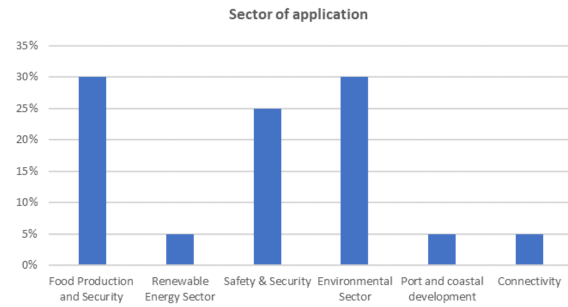

Figure 4. Elaboration of the main sector of application. Eurisy data and table elaboration.

The interviewees were mostly working in food production and security, mainly in fishery and aquaculture. Users active in the environmental sector have also been identified and interviewed. The interviewed early adopters are facing challenges in fighting against marine pollution, especially plastic pollution, algal bloom, and the protection of marine biodiversity.

Users of satellite-based services have been also found in the safety and security domain. In particular, the interviewees adopted satellite-based solutions to respond to specific issues, such as the dark ships detection and illegal fishing. In this frame, satellite applications can help in ensuring the control of the coasts and to respond to regulatory issues, such as overfishing or forbidden fishing techniques.

Less users have been identified in the sectors of port and coastal development, renewable energy, and connectivity.

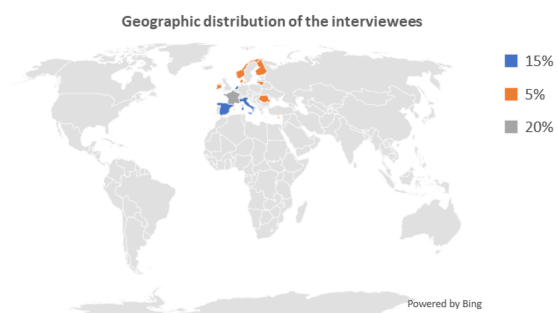

Figure 5. Geographic distribution of the interviewees. Eurisy data and table elaboration.

The identified users are all located in Europe. Most of them are based in Mediterranean area, and more specifically in France, Italy and Spain. The only exception is represented by the Netherlands. During the identification of end-users, Eurisy tried to cover additional marine areas around Europe, and more specifically Lithuania, Denmark, Norway, Finland, Romania, Cyprus, and Ireland.

Among the interviewees, the majority is currently using mostly EO applications, especially in the fields of food production, and safety and security. The 30% of the interviewees are relying on GNSS-based solutions especially in the environment sector, where satellite-solutions come in hand to track vessels, identified illegal ships, and for port logistics. Often, GNSS and EO solutions are used jointly, as in the case of marine pollution to track the movement of the supposed polluter and to picture the extent of the damage. The satellite communication seems to be less adopted, except in the case of search and rescue in high-sea, when satellite-based communications enabled remote healthcare solutions for commercial vessels.

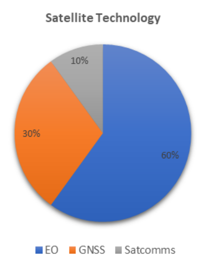

Figure 6. Categorisation of the Satellite Technology adopted by end-users. Eurisy data and table elaboration.

During the interviews, the users reported on facing challenges in the uptake of satellite applications. The challenges have categorized as follow:

- Administrative challenges: references are made to the lack of a legal framework that aims at favouring the use of satellite-based solutions; the absence of a policy support that could help in identifying the benefits of using the data; the poor dialogue with potential user communities in the maritime domain.
- Organisational challenges: comprising the lack of ad hoc personnel in the organization to manage the data; the poor dialogue with service providers; the difficulty in expressing the needs and challenges; poor communication.
- Economic challenges: covering the lack of a dedicated budget to allocate; the lack of funds for training; the high-cost of the solution on the market; the high-cost for maintenance and further costs development; the lack of regional supporting funding schemes.
- Technical challenges: including the lack of expertise; skepticisim towards space technologies; lack of dedicated infrastructures.

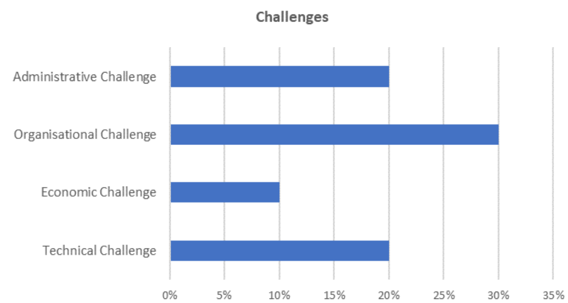

Figure 7. Interviewees' identified challenges. Eurisy data and table elaboration.

The challenges identified by the interviewees were mainly organizational. More specifically, the users reported difficulties in expressing their needs to the service providers. This is especially because of a difference in the language used- not technical from the user's side, while very technical for the service providers. Besides this, the users stated that in their working teams specialized personnel is missing. The lack of expertise, classified as technical challenge, leads to a sort of skepticism towards the adoption of satellite-based solutions. According to the interviewees, skepticism is the result of a poor knowledge and trust toward a technology that is not always considered close the matters of the Earth.

Administrative challenges have been also mentioned by the interviewees. Legal and regulatory bottlenecks have been recognized as limiting in the uptake of satellite-based solutions. Also, in terms of policy, the public authorities interviewed stated that there is not a supporting policy, or a dialogue put in place among institutions that could help in understanding the benefits of satellite-based solutions.

Finally, the interviewees recognized the existence of financial issues, that refers to the absence of a specific budget to be used to support the uptake of satellite-enabled solutions. The interviewed stakeholders also stated that, in case of a participation to a funded project during which a service is tested, outside the project's framework the full uptake of the solution is complicated. This because, the cost of the solution is not always sold at an affordable price on the market, the staff needs training, and an additional development of it requires financial resources. In very few cases, the interviewees were able to secure regional funds that allow to continue using the satellite-based solution.

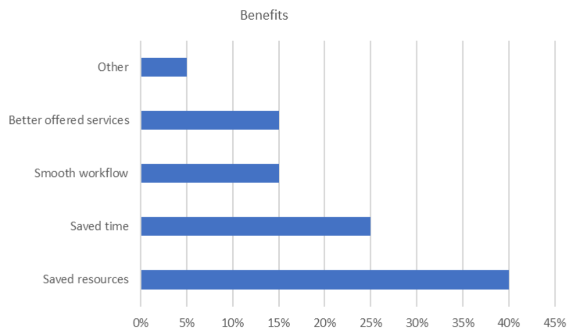

Figure 8. Interviewees' benefits derived from the take-up of satellite-based solutions. Eurisy data and table elaboration.

For those end-users who fully integrated the satellite-based solutions in their daily workflow, the benefits are usually on the economic side. The users can optimize their resources that could be re-allocated for other purposes. The optimization is also related to the time management of the users' operations, that thanks to satellite data can become faster in their response or in providing to their clients' quality products in due time. Such benefits, not always economically quantifiable, should act as a stimulus for those end-users interested in improving their workflow.

3.2 Space4Maritime case studies

Three case studies have been selected to showcase how satellite-based solutions were used to respond to specific challenges, such as the mitigation of climate change effects on the aquaculture of mussels in the Adriatic Sea; the preservation of the Spanish coasts from the threats of environmental incidents; the audit of Cypriot beaches and the phenomenon of coastal erosion.

3.2.1 Aquaculture. Precision Aquafarming using Earth Observation

Aquaculture represents a source of sustainable and high-quality sea food products. As for the agriculture sector, aquafarming companies are looking for detailed and precise information to plan the optimal time to harvest and sell their products. Besides this, climate change effects are impacting the production and seasonal trends related to the harvesting of molluscs. Companies working in aquaculture are now searching for innovative solutions to collect information to monitor environmental parameters (water temperature, sea-level rise, water eutrophication, etc.), and associated risks, to optimise the management of the production sites. Satellite imagery proves to be a useful tool to collect timely information on a specific maritime area and to develop cost-effective solutions for aquafarmers.

BIVI Srl is an Italian micro-enterprise active in the aquaculture sector and mainly responsible for molluscs offshore farming. The company counts five employees and is based on the Italian Adriatic coast, in Civitanova Marche. BIVI Srl focuses its production mainly on mussel farming and partially on oyster farming. Every year, the company produces an average of 4-6 tons of cupped oysters and 150 tons of mussels. The company operates mainly in Italy, specifically in the Marche region, and its customers are both local wholesalers and companies from the Ho.Re.Ca. (Hôtellerie-Restaurant-Café) supply chain.

Back in 2019, BIVI Srl — as a member of the Italian Association of Mediterranean Aquafarmers (AMA) — participated in a project funded by the Italian Ministry of Agriculture, Food and Forestry Policies (MIPAAF), which aimed at fostering the adoption of new technologies in the aquaculture sector. Within this framework, the Italian SME Planetek, in collaboration with Blue Farm -a spin-off of the Ca' Foscari University- developed a service platform for fish farmers called Rheticus Aquaculture, oriented towards molluscs harvesting.

The service is a subscription- and cloud-based solution providing geospatial information data, and forecasting models and statistics, based on information derived from satellites and in situ observations. It provides weekly information on parameters, such as chlorophyll concentration and temperature trends, mussels' weight, and growth prediction: based on these indicators the software models projections on the economic value of the harvest. The information included in the Rheticus service is a combination of satellite images, cartographic and environmental information available online as open data. Great support to the service comes from the software MITILAB, which provides in one single platform all the information on the work done and stocks on the harvesting area, such as maps and harvesting techniques.

Satellite data represent the main component of Rheticus Aquaculture. Sentinel-3 images and Copernicus CMEMS data are integrated into the platform. Beside this, Blue Farm developed an algorithm based on Earth Observation data enabling the assessment of mussel's growth rate. The purpose of the system is to provide mussels farmers with data and forecasts that can be downloaded from the platform and easily understood even without a technical background.

Rheticus Aquaculture was used by BIVI Srl and other aquafarms along the Adriatic coast between 2019 and 2020, exclusively for mussels farming. The solution provided the company with clear and periodical information on chlorophyll levels in the Adriatic Sea and a forecast of the expected growth of mussels. The service helped BIVI Srl to optimise time and to better plan the harvesting season. BIVI relied on the information related to the weekly mussels' growth, including seeding data, stocking dates, 7-day forecast of mussel growth, and the comparative analysis between the current growth rate and the previous growing season. Moreover, BIVI Srl retrieved historical data on chlorophyll concentrations over the last 10 years, which were very useful to better understand the on-going climate change effects on the harvesting.

3.2.2 Safety and Security. Protecting Spanish Coasts from environmental incidents

One of the major threats for coastal regions is represented by oil spills and illegal discharges from ships. The consequences of these incidents on marine environment could be catastrophic, endangering aquatic and terrestrial biodiversity for long periods. In fact, due to the composition of most oil pollutants, oil spills tend to remain on water surface while spreading in large areas carried by currents reaching, sometimes, coasts with significant impacts on economic sectors such as fishery and tourism.

The Sociedad de Salvamento y Seguridad Marítima- SASEMAR (the Maritime Safety and Rescue Agency) is a Spanish public authority working under the Spanish Ministry of Transport, Mobility and Urban Agenda through the Directorate of Merchant Marine. Created in 1992 by the Law of State Ports and the Merchant Marine, SASEMAR became operative in 1993. Its mission is to ensure the protection of human life at sea, as well as the pollution prevention and response, being also in charge of maritime traffic control and training. Since the Prestige oil spill incident in November 2002 in Galicia, the importance of a steady response to a pollution-related incident is a priority for SASEMAR and the local coastal authorities.

Throughout the years, SASEMAR developed a preparedness and response system that combines marine, and air unites to map the incident's area. SAR operators run trajectory models to predict the drift induced by the effect of ocean currents, waves, and winds and to define the search area. The accuracy of a drift prediction is highly dependent on met-ocean forecast's data used to predict the trajectory model. Therefore, SAR operators need reliable methods to assess, within the shortest possible time, which model is likely to provide the most accurate prediction.

IBISAR relies on multiple datasets including satellite-tracked surface drifters, high-frequency radar data combined with ocean models from the Copernicus Marine Service and complementary databases, that provide information on the surface currents at high spatial-temporal resolution in coastal areas. In addition to real-time satellite tracking for the surface drifters, satellite technology is used to assess and improve the ocean models integrated in the service. IBISAR consists of a web-based platform composed of a database; the OceansMap Viewer, a customisable GIS-based graphical user interface; and the Skills Assessment functionality that helps the user in verifying the models' accuracy.

The IBISAR Skill Assessment service allows the visualization, comparison, and evaluation of model performance in the Iberia-Biscay-Ireland (IBI) regional seas. It is a science and satellite-based downstream service launched in 2019 coordinated by the Balearic Island Coastal Observing and Forecasting System (SOCIB) in partnership with AZTI and RPS Ocean Science and with the collaboration of the Spanish Port System. IBISAR provides user-oriented skill metrics to evaluate the accuracy of Search and Rescue models, helping coastal authorities, to identify the most accurate ocean current dataset in a specific area and period of interest improving search and rescue and pollution control operations.

SASEMAR through the introduction of IBISAR achieved its goal to increase the preparedness and reaction in case of an emergency at sea of its operators. By selecting the most accurate data, SASEMAR optimises its response's time to maritime emergencies, benefiting from a single access point to multiple datasets served in a user-friendly platform.

IBISAR supports SASEMAR and emergency responders to improve SAR and pollution control operations, by minimizing its response time, optimizing the search area planning, while contributing to a cleaner and safer seas and coasts.

3.2.3 Coastal Management. Inspecting Cypriot beaches to improve coastal management and prevent environmental damages

The island of Cyprus is well known for its extensive seashore and its touristic attractiveness. Coastline and beaches are also the habitats of many flora and fauna species, some of which are considered endangered species by the International Union for Conservation of Nature (IUCN). During summer, Cyprus attracts hundreds of tourists. Tourism represents a relevant resource for the country's economy, but at the same time could be a threat when it becomes massive, as often happens in Cyprus. The attractiveness of the island's beaches and the demand for new touristic infrastructures can lead to an uncontrolled installation of new buildings.

The Cyprus Audit Office is an independent State Authority of the Republic of Cyprus. It is responsible for auditing the accounts of the central government, ministries, local administrations, and national public organisations.

The mission of the Office is to conduct documented financial, performance and compliance audit in the wider public sector, for the purpose of public reporting, and optimal management of public resources. The Office aims to contribute to an efficient and effective management of public resources, reducing the mismanagement of public funds and corruption.

To ensure effective coastal management by the public authorities, in 2019, the Audit Office conducted an audit to evaluate the measures enforced by the local authorities to protect the coastline and contain the effects of the potential threats related to mass tourism and illegal activities.

The audit, which lasted about nine months, focused mainly on the measures taken to protect the coast from recreational marine vessels' discharges, water quality, eutrophication, and coastal erosion. The audit also focused on illegal buildings that are furtherly damaging the coasts, contributing to generate coastal erosion.

The audit relied on multiple tools ranging from questionnaires shared with local authorities of the islands, on-site visits to collect in-situ data, to interviews with citizens and economic actors working in the touristic field. In addition, the Audit Office extensively used satellite data and images of the island, especially Sentinel-2 images provided by the Cypriot Government, to draw an accurate temporal perspective on the evolution of the coastline.

The satellite images are included in the digitised cadastral maps developed by the Cyprus Department of Lands and Surveys and are freely accessible online. The Cyprus Audit relied on GIS technology to obtain information on land ownership and coastal protection zones evaluating multiple criteria, especially with regards to coastal erosion and the potential link with the illegal building.

Thanks to GIS and Earth Observation data was possible to verify the evolution of coastal erosion and illegal building sprawl phenomena in the last years and to estimate potential economic impacts in the long run. During the audit, the team collaborated with local NGOs active in the field of environmental protection to verify the effects of mass tourism on protected and endangered species. EO proved to be a reliable tool to monitor birds' movements and behavioral patterns.

The use of satellite data allowed the Audit Office to perform a broad inspection activity. The use of satellite data and GIS technology helped the Office in reducing drastically the timeframe of the auditing, as well as to contain the costs associated with the overall activity. Satellite imagery reduced the expenses related to in-situ observations, put in place only to assess contrasting data and information, and the staff costs. In this case, the staff devoted to the beaches auditing was composed of three experts with previous knowledge in imagery analysis.

Satellite imagery provided the Auditor with an objective and reliable source of information, that increased the context awareness while providing a broad vision of the geographic area surrounding the island and portion of the wider sea. The exploitation of satellite imagery during the audit allowed to perform targeted on-site surveying when the image was not clear enough or additional data were needed.

The audit of the Cypriot beaches helped in identifying non-compliant or insufficient mechanisms within the environmental legislation regarding the management of the national coastline. Besides this, multiple infrastructures have been identified and demolished, while high fares have been imposed on the owners of the structures. Satellite imagery proved to be a relevant tool also in assessing illegal financial activities on the beaches, namely the counting of exceeding numbers of sunbeds and umbrellas in contrast with the National Beach Usage Plan.

4. Conclusions

Satellite-based solutions are starting to be increasingly adopted by different end-users (NGOs, public institutions, local authorities, port authorities, etc.) in multiple economic fields ranging from aquaculture, fisheries, search and rescue, transport, logistics, port, and coastal development, to renewable energy.

As showed by the round of interviews performed by Eurisy on a non-representative champion of end-users, provide a sneak-peak of the status of the art on the adoption of satellite applications in the field. While on one side satellite-based solutions are improving the daily workflow of the interviewees also helping in optimizing time and resources, on the other side there are some obstacles to the uptake of satellite-based solutions. A miscommunication between end-users and service providers prevents the users to understand the benefits of the application. Such limitation is mostly related to a wrong perception of space often considered detached from earth challenges. In addition to this, financial constraints also represent an impediment to the uptake of satellite-based solutions. What emerged from the interviews performed is that available solutions for maritime operators are sometimes not affordable on a market price. In cases where the users have the opportunity of adopting a satellite-based solution for a trial period (between 9 months and 1 year), the users rarely tend to integrate the solution in the long-term. This is due to high prices and limited available funds allocated to technology development.

On the other side, the existing success stories demonstrate that satellite-based solutions could be considered the preferred solutions for end-users, especially in the fields of fishery and aquaculture. In this case, satellite data can help aquafarmers and fisherman in optimizing their roots and in monitoring the water health and potential threats. Also, safety and security rely on satellite imagery, especially when it comes to environmental incidents as oil spills. Rescuers can monitor the trajectory of the pollutants and the polluters to respond quickly and to limit potential damages. Finally, EO in conjunction with in-situ observation can serve as a law enforcement tool to preserve coastline and beaches, often overexploited due to mass tourism. The possible driving force for this exploitation of EO satellite-based solutions could be explained by the availability of Copernicus and Sentinel images and the business opportunities launched by EUSPA and the Copernicus Marine Service, led by Mercator Ocean.

In conclusion, it is important to map all the challenges and needs from maritime end-users to create match-making opportunities and to favor the dialogue both with service providers and public authorities. The dialogue should be relaunched by using a common language between end-users and service providers, oriented to define with clarity the benefits that derives from the use of satellite-based services in the maritime domain.

Acronyms

AMA Associazione Italiana Acquacoltori
ASI Agenzia Spaziale Italiana
CMEMS Copernicus Marine Service
EC European Commission
EGNOS European Geostationary Navigation Overlay Service
EO Earth Observation
ESA European Space Agency
EU European Union
EUSPA European Union Agency for the Space Programme
GIS Geographic Information System
GNSS Global Navigation Satellite System
GVA Gross Value Added
Hô.Re.Ca. Hôtellerie-Restaurant-Café
IAF International Astronautical Federation
IBI Iberia-Biscay-Ireland
IMO International Maritime Organisation
IUCN International Union for Conservation of Nature
LRIT Long-Range Tracking and Identification
MIPAAF Ministero delle politiche agricole, alimentari e forestali
NGO Non-Governmental Organisation
OECD Organization for Economic Co-operation and Development

S-AIS Satellite-based Automatic Identification System
SAR Synthetic Aperture Radar
SASEMAR Sociedad de salvamento y seguridad maritima
SMEs Small and Medium Enterprises
SOCIB Balearic Island Coastal Observing and Forecasting System

VMS Vessel Monitoring System

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