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D5.5 Report on the gap analysis of biological and ecosystem observations

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1. INTRODUCTION

Oceans and water need to be monitored to improve climate change forecasts, manage marine resources, mitigate the effects of natural disasters, and ensure sustainable use of coastal areas and oceans. Measurements of the status and trends of key indicators for ocean and marine life are also needed to inform policy and management in relation to increasing human use of marine resources, coastal development, and climate change.

Reducing biodiversity and averting dangerous changes in biodiversity are international goals, reaffirmed by the Parties to the United Nations (UN) Convention on Biological Diversity (CBD) in the Aichi Targets for 2020.

In this context, two synergistic efforts identify specific priority variables for biodiversity and ecosystems monitoring: Essential Ocean Variables (EOVs) by the Global Ocean Observing System (GOOS), and Essential Biodiversity Variables (EBVs) by the Group on Earth Observations Biodiversity Observation Network (GEO BON).

Many EOVs are also Essential Climate Variables (ECVs): a physical, chemical or biological variable or a group of interrelated variables, that contribute critically to the characterization of Earth's climate[1]. The concept of "Essential Climate Variables" evolved in the late 1990s to focus resources on collecting a minimal number of "key variables" for which data records were necessary to understand the status and trends of climate variability. The ECVs were selected after assessing readiness, feasibility, and impact on societal needs. The ECVs are now fundamental information for negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

The EOVs/ECVs are critical for describing the ocean behaviors interpreting the links between the ocean and atmosphere, biosphere, hydrosphere, cryosphere, and anthroposphere. In addition, ECVs provide the necessary scales for understanding and predicting climate evolution, guiding mitigation and adaptation actions. ECVs are identified based on the following criteria:

1. Relevance: The variable is critical for characterizing the climate system and its changes.
2. Feasibility: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
3. Cost effectiveness: Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage, where possible, of historical datasets.

GOOS is engaged in a continuous process of refining and expanding the list of essential variables and has added biogeochemical and biological variables, called "bio-eco EOVs" to the set of EOVs.

Following this example, GEO BON proposed a set of EBVs that can be used in monitoring programs and to understand patterns and changes in Earth's biodiversity. The EBVs have been grouped into six classes or subcategories: genetic composition, species populations, species traits, community composition, ecosystem structure, and ecosystem function.

The bio-eco EOV definitions include "Complementary Variables," i.e. other EOVs and/or EBVs needed to fully describe the phenomena or understand impacts on EOVs of natural and anthropogenic pressures. This provides a link between the EOVs from GOOS and the EBVs proposed by GEO BON.

[1] https://gcos.wmo.int/en/essential-climate-variables/about

The need for more automated sampling and analysis for biochemical and biological parameters has already been recognized at the European level, namely in the 2018 Landscape Analysis of the European Forum for Research Infrastructure - ESFRI[2]. The analysis highlighted that 99% of habitable marine areas lack basic biodiversity knowledge for their management and advocated for more efforts to employ new sensors and samplers that can be mounted on observing autonomous platforms – buoys, gliders and profilers – to also collect biological parameters.

In this direction, the WP5 of the ITINERIS project has the specific objective (OBJ2) to start filling the gaps in biological and ecosystem observations at the national level and to increase the measurements of bio-eco EOVs and EBVs as national contributions to the European Ocean Observing System (EOOS), GOOS and GEO BON.

ITINERIS follows the ESFRI proposals by exploiting both automated and innovative technologies for monitoring bio-eco EOVs and EBVs. ITINERIS will use automated platforms that acquire different spatial scales and conduct high-frequency and continuous observations. They can also operate under bad-weather conditions, which may be the most interesting conditions for ecosystem responses. New biogeochemical sensors will also be deployed in key sites to improve observational capabilities, understanding of the marine ecosystems and assessment of their status and changes over time and space. ITINERIS recognizes that a proper integration between oceanographic and biological/ecological parameters is essential to broaden the range of observational activities, with the concept of ecological connectivity as a key driver of marine ecosystem functioning.

This deliverable D5.5 corresponds to the ITINERIS Intermediate Objective IO5.4 and aims to provide the landscape of available observations of bio-eco EOVs and EBVs for several RIs considered in WP5 – Marine domain and allowing to identify gaps. Within the ITINERIS project, the plans to strengthen the different RIs in terms of bio-eco EOVs and EBVs, in connection with their specific scientific research questions, will also be provided.

The RIs considered in D5.5 are eLTER-RI, EMSO-ERIC, Euro-Argo ERIC, and JERICO-RI, as they have ongoing and targeted actions for implementing the observation of bio-eco EOVs and EBVs within the ITINERIS project.

eLTER-RI Integrated European Long-Term Ecosystem, Critical Zone & Socio-Ecological Research Infrastructure

eLTER-RI is a pan-European *in-situ* research infrastructure whose mission is to study long-term ecological changes in terrestrial, freshwater and transitional ecosystems through a holistic "whole system" approach, based on the integration of different environmental disciplines, to understand the role and interactions of multiple and complex ecosystem variables.

The RI consists of 26 national networks, 500 research sites and 50 LTER platforms, providing broad and systematic coverage of key European ecosystems, integrating the socio-ecological components. eLTER-RI comprises National Research Infrastructures (NRIs), and European level Central Services (CS), such as data access, training and harmonized methods and parameters (standard observations).

[2] ESFRI (2018), Strategy Report on Research Infrastructures – Roadmap 2018, printed on behalf of ESFRI by Dipartimento di Fisica - Università degli Studi di Milano, ISBN print: 978-88-943243-2-7, ISBN pdf: 978-88-943243-3-4

eLTER is now in the preparatory phase on the way to becoming a fully-fledged RI and ERIC (presumably in 2025) and is funded by the European Commision through the H2020 projects eLTER PPP and eLTER PLUS.

The Italian participation in eLTER-RI is coordinated by the CNR and involves various Italian institutions including universities, research bodies and local authorities. The LTER-Italy network consists of 72 research sites spread all over the territory and representative of the main ecosystem typology of our country. 19 of these sites represent the marine and transitional water component of the Italian eLTER-RI.

EMSO ERIC- European Multidisciplinary Seafloor and water column Observatory

EMSO ERIC is a distributed infrastructure whose observation facilities are in key sites of the European seas, from the northern and north-eastern Atlantic, to the Mediterranean and the Black Sea, in various climatic zones, from the sub-arctic zone to the sub-tropical zone. EMSO's mission is to support scientific and technological research to understand the complex interactions between the geosphere-biosphere-hydrosphere through the acquisition of long time-series of observables by means of fixed platforms in the deep marine environment, related to different disciplinary sectors (from oceanography to seismology and biology) to offer a data suitable for promoting a multidisciplinary approach for studying climate and marine ecosystems evolution, and the outbreak and evolution of extreme events both of natural and anthropic origin.

The acquisition of measurements in extreme environments such as the deep marine environment requires very specific knowledge of marine technologies and extensive field and logistics experience; these skills, acquired by the technical-scientific personnel who take care of the functioning of the facilities, are made available to scientific and industrial users who require physical and remote access to the infrastructure for purely scientific or for commercial purposes.

EMSO's vision is to position the RI among the leading institutions in the marine sciences, and among the main actor in the landscape of European Environmental research infrastructures and providing scientific and technological services to address the environmental challenges that affect the quality of life on our planet.

EMSO has been included in the ESFRI Roadmap since 2008 and was established in the legal form of European Research Infrastructure Consortium (ERIC) in 2016 by the governments of 8 Countries: France, United Kingdom, Greece, Ireland, Italy, Portugal, Romania, Spain to which Norway joined in 2021. EMSO is currently recognized in the latest ESFRI Roadmap as a 'Landmark' infrastructure, i.e., it has entered the operational phase.

Euro-Argo ERIC – European contribution to the Argo programme

Euro-Argo ERIC is part of the international Argo programme (for more details, see http://www.argo.ucsd.edu), that was initiated in 1999 as a pilot project endorsed by the Climate Research Program of the World Meteorological Organization, GCOS and GOOS, and the Intergovernmental Oceanographic Commission. The Argo network is a global array of more than 3500 autonomous instruments, deployed over the world ocean, reporting 0-2000m subsurface ocean properties to a wide range of users via satellite transmission links to data centers.

The initial target of the Argo international programme was to achieve data coverage of 1 float per 3x3° grid cell and month over the global ocean. This data coverage is deemed to be sufficient to resolve many of the important global climate signals and support the enhanced real-time requirements of operational modelling applications in oceanography and meteorology.

Euro-Argo aims to provide, deploy and operate ¼ of the global Argo floats array and Italy is one of the countries contributing to this goal. Started in January 2008 as a European project involving 25 organizations from 12 countries, Euro-Argo gained the status of a European Research Infrastructure Consortium (ERIC) in May 2014.

The Euro-Argo ERIC focuses to provide enhanced coverage in the European regional seas, to implement the new phase of Argo, with extensions towards biogeochemistry (BioGeoChemical-Argo), greater depths (Deep-Argo) and high latitudes and to provide quality controlled data and access to the data sets and data products to the research (climate and oceanography) and operational oceanography (e.g., Copernicus Marine Service) communities.

Argo must be considered in its ensemble: not only the instruments, but also the logistics necessary for their preparation and deployments, field operations, the associated data streams and data centers. That's why Euro-Argo establishes a high level of cooperation between partners in all implementation aspects:

- operation at sea,
- array monitoring and evolution,
- technological and scientific developments,
- improving data access for research and operational oceanography (Copernicus Marine Service),
- link to the international management of the Argo programme,
- promote Argo, enlarge the Argo data user community and help answering its needs.

The Italian participation in Euro-Argo ERIC is coordinated by OGS (National Institute of Oceanography and Experimental Geophysics) and involves the CNR (National Research Council), and aims to sustain Argo, BGC-Argo and Deep-Argo with a focus on the European regional seas.

JERICO-RI - Joint pan-European Research Infrastructure for Coastal Observations

The objective of JERICO-RI is to formally design, implement and operate a pan-European Research Infrastructure, dedicated to set up a system of observation and related services for European coastal seas, thus empowering European research excellence and expertise for the benefit of society.

JERICO-RI is an essential component of the worldwide efforts to a better understanding of coastal marine systems. JERICO-RI also aims at being the future coastal component of the European ocean observing effort, as part of the Global Ocean Observing System, GOOS. Through multidisciplinary pan-European observations, JERICO-RI seeks to improve the knowledge on how coastal marine systems respond to global and local drivers. By doing so, JERICO-RI is strengthening the interactions between observations, experimentations and numerical modelling.

Since 2011, JERICO-RI has developed conceptual and practical expertise aimed at providing high-quality coastal observations and services to the marine scientific community and to a range of local, regional and European end-users.

JERICO-RI, as an integrative system working across coastal disciplines, is progressing towards the definition of a sustainable infrastructure, harmonized at EU level with capabilities to deliver high-quality environmental data, access to solutions and facilities as services for researchers and users of the coastal domain.

JERICO-RI benefits from both national efforts, put forth to better address the national coastal priorities, and other European initiatives. It aims at closing the critical gap of not having an integrated European Research Infrastructure addressing the complexity of marine coastal systems. JERICO-RI

is proposing to bridge the existing continental, atmospheric and open ocean RIs, thus filling a key gap in the ESFRI ecosystem.

The JERICO-RI consortium is coordinated by the French lead partner IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) and is currently working on two active projects, JERICO-S3, which provides access to marine infrastructures and their data and experimentation at the transnational level, and JERICO-DS, for the design of the ESFRI phase.

The Italian participation in JERICO-RI is coordinated by the CNR (National Research Council) and involves the OGS (National Institute of Oceanography and Experimental Geophysics), making a fundamental contribution thanks to the long and strong traditions of research on marine issues and technological innovation assets related to the monitoring of the marine coastal environment of both institutes.

2. CURRENT MEASUREMENTS FOR EACH RI: GAPS IN BIO-ECO EOVs AND EBVs.

The same survey conducted among all WP5 participants and described in deliverable D5.3 was used to collect information about the status of bio-eco EOVs and EBVs measured by the different RIs. As already highlighted in deliverable D5.3, attention must be paid to the accuracy of this initial piece of information provided by the WP5 participants, as replies may contain errors and be incomplete.
The survey collected information from facilities that are both fixed (e.g., platforms, buoys, moorings) and mobile (e.g., autonomous vehicles like gliders and Argo floats). WP5 participants were asked to provide the following information:

- Typology of variable.
- Corresponding ECV, EOV and EBV.
- Measuring depth or range.
- Ownership of the sensor/equipment measuring the variable.
- Accuracy.
- Temporal resolution and coverage.
- Spatial coverage (if any).
- Equipment (brand and year, average lifetime).
- Data format (standards, metadata).
- Typology of access (time needed for data release, quality control, options of access).

The facilities considered in the survey, together with the full lists of sensors based and sample based measured variables are reported in deliverable D5.3. The total number of EVs considered in deliverable D5.3 is 57. The bio-eco EOVs and EBVs considered in this deliverable are instead detailed in the first columns of Table 1 and sum up to a total of 25, 7 bio-eco EOVs and 18 EBVs. Bio-eco EOVs are selected from the full list of EOVs which can be found at the following link: https://www.goosocean.org/index.php?option=com_content&view=article&id=14&Itemid=114 , together with the full set of EBVs for the marine domain listed in this other link: https://github.com/EuropaBON/EBV-Descriptions/wiki .

Table 1 - Number of sensors measuring bio-eco EOVs and EBVs for the RIs considered in this deliverable.

Category	Subcategory	Bio-eco EOV/EBV full name	eLTER	EMSO	EuroArgo	JERICO
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity	16	1	9	4
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Zooplankton Biomass and Diversity	4	0	6	1
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Fish Abundance and Distribution	2	1	0	0
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Seagrass Cover and Composition	0	0	0	0
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Macroalgal Canopy Cover and Composition	1	0	0	0
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Microbe Biomass and Diversity (*emerging)	1	0	0	0
EOV	Ocean Biology and Ecosystems	EOV - Biology and Ecosystems: Invertebrate Abundance and Distribution (*emerging)	1	0	0	0
EBV	Community composition	EBV - Community composition: Functional diversity of marine phyto/zooplankton (based on traits)	5	0	2	1
EBV	Ecosystem Function	EBV - Ecosystem function: Degree of seabed disturbance	0	0	0	0
EBV	Ecosystem Function	EBV - Ecosystem function: Harmful marine algal blooms	5	0	0	0
EBV	Ecosystem Function	EBV - Ecosystem function: Phenology of marine spring phytoplankton bloom	3	0	2	1
EBV	Ecosystem Function	EBV - Ecosystem function: Marine primary productivity	8	1	6	4

EBV	Ecosystem Structure	EBV - Ecosystem structure: Ecosystem distribution of hard corals habitats	0	0	0	0
EBV	Ecosystem Structure	EBV - Ecosystem structure: Ecosystem distribution of marine macroalgae canopy cover	1	0	0	0
EBV	Ecosystem Structure	EBV - Ecosystem structure: Ecosystem distribution of marine seagrass habitats	0	0	0	0
EBV	Ecosystem Structure	EBV - Ecosystem structure: Ecosystem distribution of oyster reef habitats	0	0	0	0
EBV	Genetic composition	EBV - Genetic composition: Genetic diversity of selected marine taxa	0	0	0	0
EBV	Specie Traits	EBV - Species traits: Phenology of migration of marine birds and mammals	0	0	0	0
EBV	Species Population	EBV - Species populations: Species distributions of marine fishes	2	0	0	0
EBV	Species Population	EBV - Species populations: Species abundance. of marine commercial fish species and long-distance migratory fish	0	0	0	0
EBV	Species Population	EBV - Species populations: Species distributions of marine birds	0	0	0	0
EBV	Species Population	EBV - Species populations: Species distributions of marine mammals	0	0	0	0
EBV	Species Population	EBV - Species populations: Distributions of marine turtle species nesting grounds	0	0	0	0
EBV	Species Population	EBV - Species populations: Species distributions of benthic marine invertebrates	3	0	0	0
EBV	Species Population	EBV - Species populations: Species distributions of invasive alien marine taxa of European concern	6	0	0	0

Considering only the four RIs of this deliverable, just 22 facilities, i.e. about 17%, are reported to measure bio-eco EOVs and EBVs out of the 128 declared in deliverable D5.3 and involved in the WP5. In the following paragraph of this document, an analysis of the information coming from these facilities is presented in terms of number and typology of bio-eco EOVs and EBVs measured and relative contribution of each RI in measuring bio-eco EOVs and EBVs. The information collected is discussed to identify gaps of biological and ecosystem observations together with a brief description of the new equipment planned in ITINERIS for each RI to increase national measurements of bio-eco EOVs and EBVs.

Figure 1 shows the percentage of bio-eco EOVs (in blue) and EBVs (in green) measured by each RI considered in this deliverable with respect to the total number of 57 possible EVs. A bio-eco EOV or EBV is counted in this percentage if at least one sensor in any facility belonging to that RI is measuring it. Due to the specific focus on ecosystems, eLTER is the only RI currently approaching the percentage of 25% with a predominance of EBVs (14%) with respect to bio-eco EOVs (10.5%). The percentages for the remaining RIs are lower: EuroArgo and JERICO get close to the 10% value, with a total of 8.8% (EBVs at 5.3% and bio-eco EOVs at 3.5%). EMSO total percentage is instead at about 5% (EBVs at 1.8% and bio-eco EOVs at 3.5%).

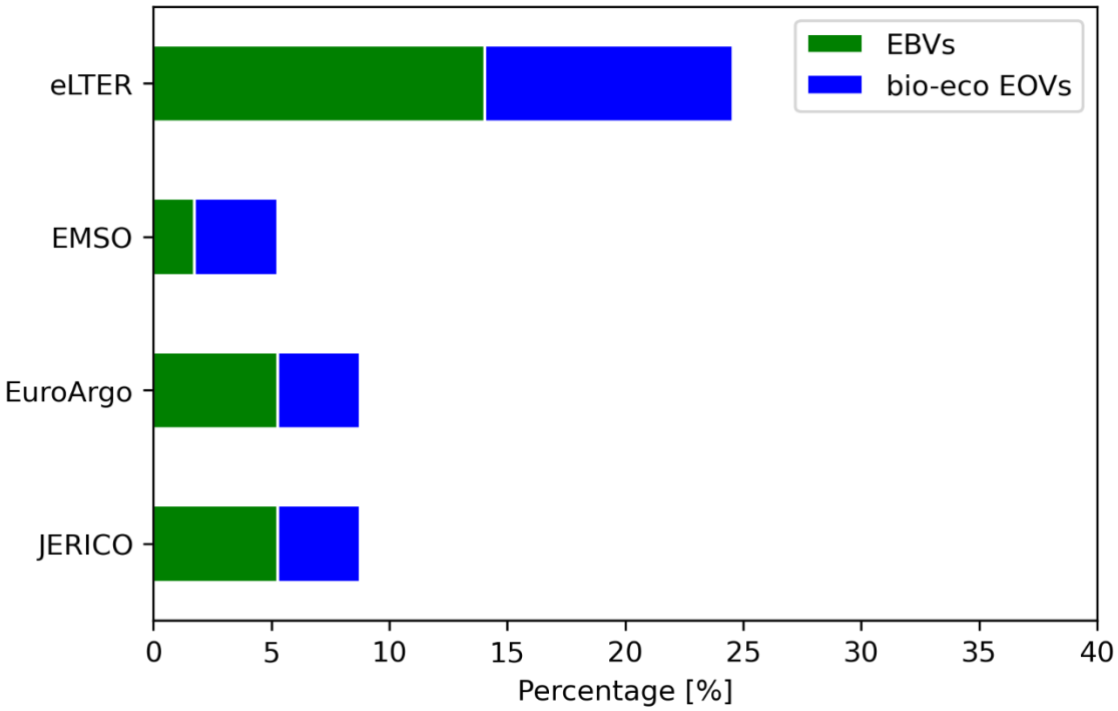

Figure 1: Percentage of bio-eco EOVs and EBVs measured by each RI considered in this deliverable with respect to the total number of 57 possible EVs.

Figure 2 shows the total number of RIs measuring each specific bio-eco EOV and EBV. As above, a bio-eco EOV or EBV is counted if at least one sensor in any facility belonging to that RI is measuring it. Only two variables, namely the "EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity" and the "EBV - Ecosystem function: Marine primary productivity", are measured by all 4 RIs considered in this deliverable. It must be noted that the two variables are related as some measures of primary productivity may rely on phytoplankton biomass estimates.

Figure 2 – Total number of RIs measuring specific bio-eco EOVs and EBVs.

Only three EVs are measured by three RIs while the "EOV - Biology and Ecosystems: Fish abundance and Distribution" is the only variable measured by two RIs. There is only one RI (i.e., eLTER) measuring 8 other different bio-eco EOVs and EBVs.

eLTER contribution is also the largest in terms of both total number of samplings/sensors (about 60) and samplings/sensors for each specific bio-eco EOV and EBV (Figure 3). The maximum value of 16 sensors is for the "EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity" variable. Deliverable 5.3 has indeed highlighted eLTER peculiarity in covering bio-eco EOVs. This Deliverable 5.5 also shows that eLTER is the RI with the largest coverage of EBVs (see also Figure 7 below).

As shown in Deliverable D5.3, EMSO covers a large range of variables spanning from ocean, physical to biogeochemical and atmosphere. Nevertheless, EMSO contribution to measure bio-eco EOVs and EBVs is limited to only three samplings/sensors (Figure 4).

EuroArgo mainly covers ocean and physical variables but its contribution to measure bio-eco EOVs and EBVs is largely increasing thanks to the use of BioGeoChemical (BGC) Argo floats as these facilities are equipped with about 25 optical and biogeochemical sensors (Figure **5**).

JERICO general coverage is mainly related to ECV ocean physical, atmosphere and surface categories. Nevertheless, JERICO contributes with about ten samplings/sensors to the measures of bio-eco EOVs and EBVs (see Figure **6**).

Figure 7 shows the distribution of the EBV measurements among the RIs considered in this deliverable. The largest percentage is for eLTER that makes up for two-thirds of the total number of sensors dedicated to EBVs. EuroArgo and JERICO follow with 20% and 12% respectively, while only EMSO EBV measurement counts for 2%.

Figure 3 - eLTER contribution for the measurements of specific bio-eco EOVs and EBVs.

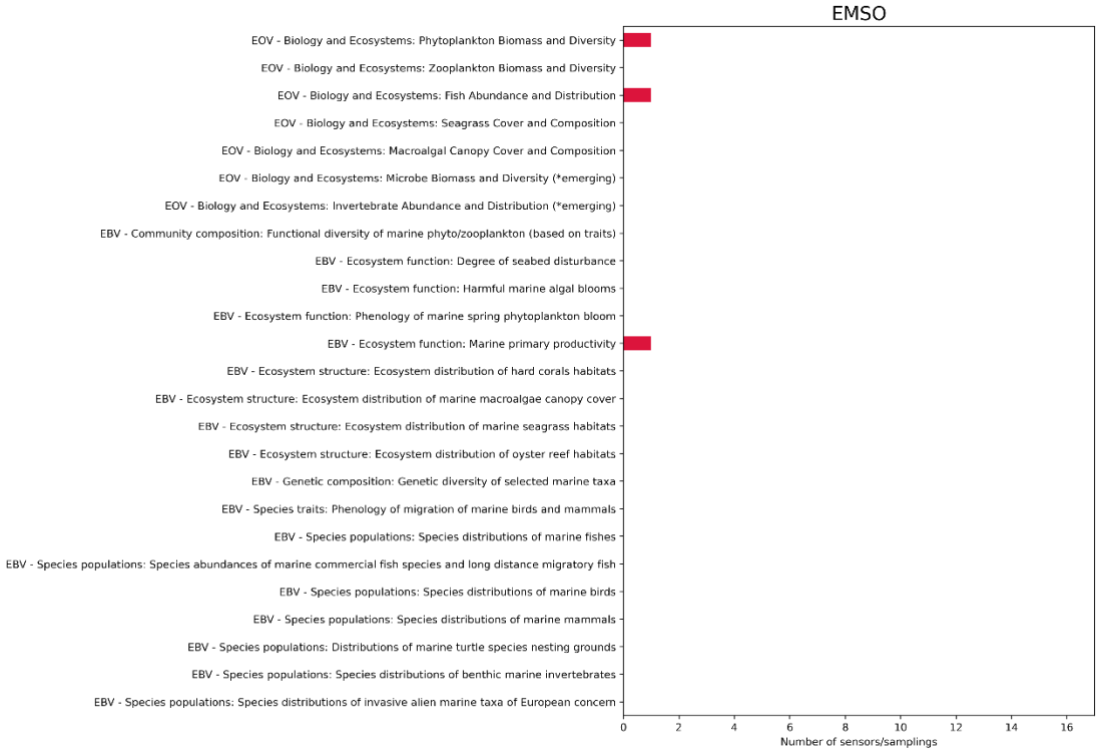

Figure 4 - EMSO contribution for the measurements of specific bio-eco EOVs and EBVs.

Figure 5 – EuroArgo contribution for the measurements of specific bio-eco EOVs and EBVs.

Figure 6 - JERICO contribution for the measurements of specific bio-eco EOVs and EBVs.

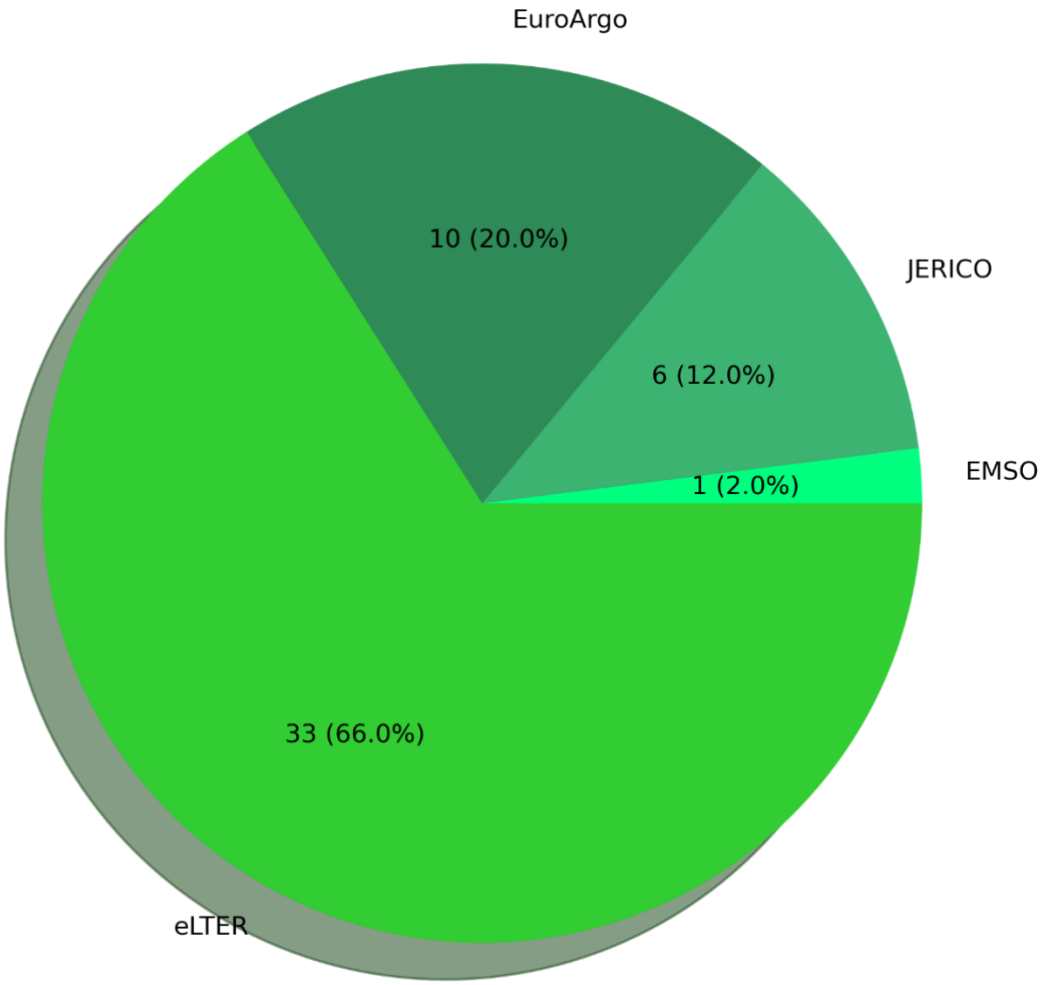

Figure 7 - Distribution for the measurements of EBVs among the RIs considered in this deliverable. Numbers indicate the number of EBV measurements for each RI while the percentages with respect the total number are in parentheses.

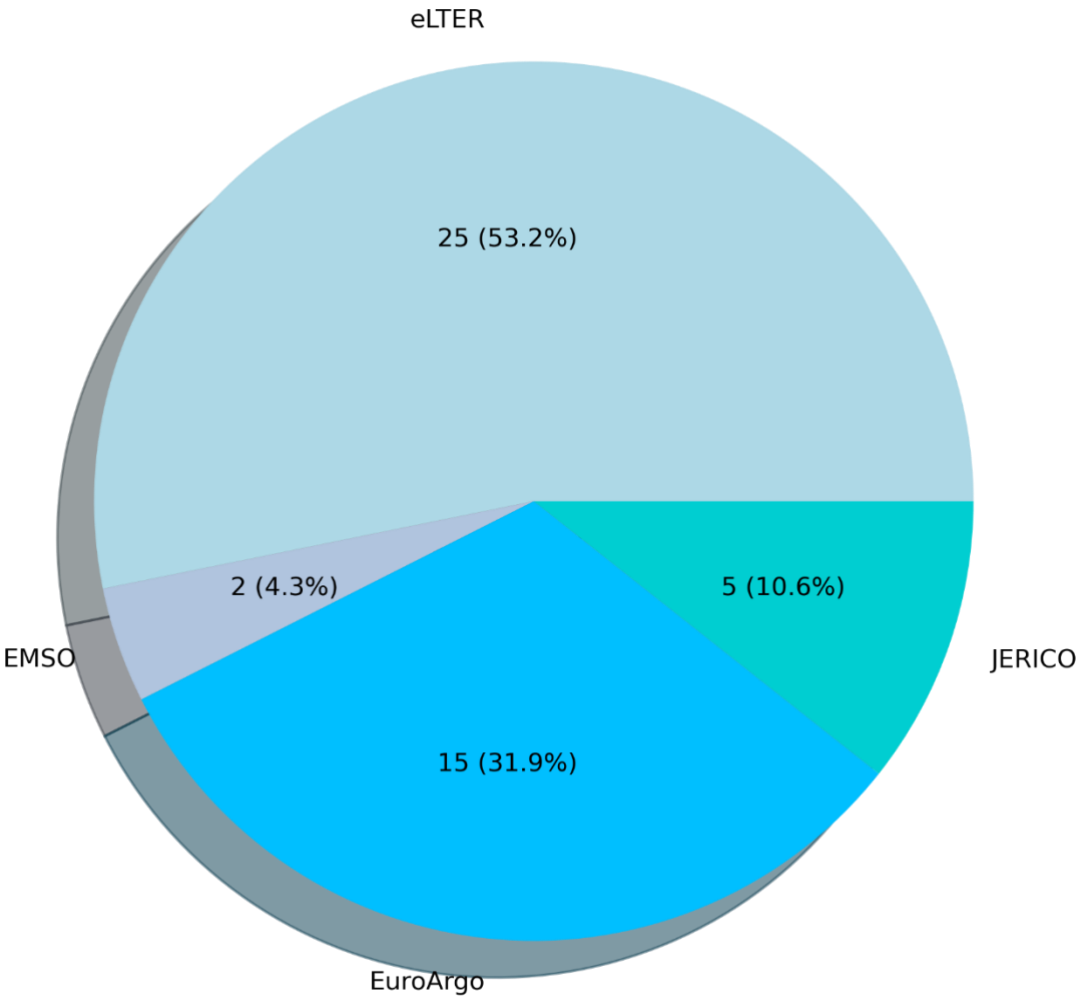

Figure 8 - Distribution for the measurements of bio-eco EOVs among the RIs considered in this deliverable. Numbers indicate the number of bio-eco EOV measurements for each RI while the percentages with respect the total number are in parentheses.

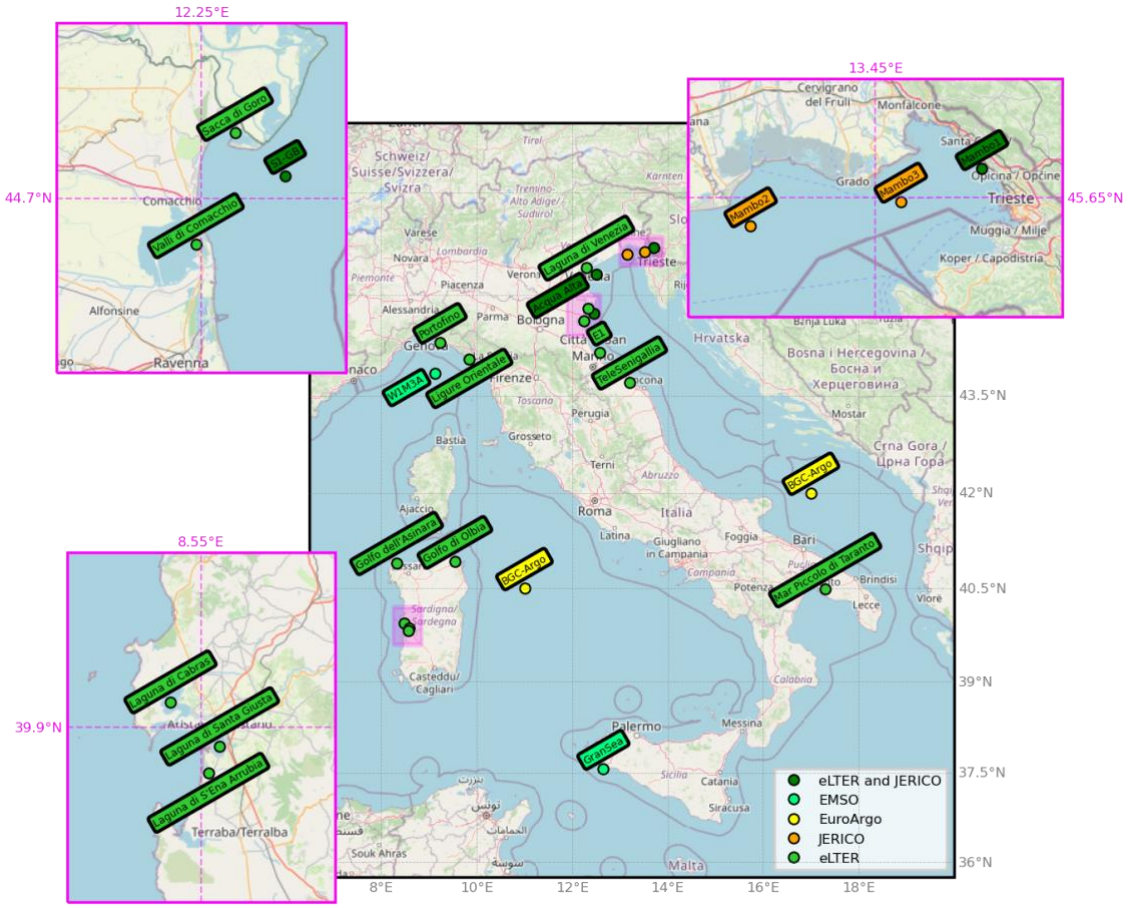

Figure 9 - Locations and names of the facilities measuring bio-eco EOVs and/or EBVs related to the four RIs considered in this deliverable. Locations of BGC-Argo floats are indicative as they are mobile devices. Insets show closeups of facility locations in the Gulf of Trieste (upper right panel), south of the Po River mouth (upper left panel) and in the Gulf of Oristano (lower left panel). Please note that RI indications are limited to those considered in this deliverable: for example, only eLTER and JERICO are indicated for the Acqua Alta platform while it is shared also with DANUBIUS.

Figure 8 shows the distribution of the bio-eco EOV measurements among the RIs considered in this deliverable. The contribution by eLTER to bio-eco EOVs is less than for EBVs but still larger than 50%. As above, EuroArgo and JERICO follow with percentages slightly larger than 30% and 10%, respectively. The EMSO percentage for bio-eco EOVs is about 4%.

Figure 9 shows the national geographical distribution of the 22 facilities measuring bio-eco EOVs and EBVs. Most of them are eLTER coastal stations covering the North Adriatic, the Ligurian Sea and the North-western Sardinian region. The only station in the Ionian Sea is also eLTER. JERICO bio-eco EOV and EBV measurements take place only in the North Adriatic where three facilities are also shared with eLTER, namely the Mambo observatory, the Acqua Alta platform and the S1-GB elastic beacon. EMSO measurements take place in two locations, in the Ligurian and Sicilian regions while the positions of the BGC Argo floats are only indicative as they can be relocated to other positions.

The following different gaps can be identified based on the above figures and relative analysis:

- In general, at the national level, the coverage of bio-eco EOVs and EBVs is limited and low-resilient since it is dominated by the eLTER RI: there is a need for increasing the number of sensors for bio-eco EOVs and EBVs. With the exception of eLTER, this is especially true for all other RIs;
- Most of EBVs (i.e. 10 on the total number of 18) and one bio-eco EOV, namely the "EOV - Biology and Ecosystems: Seagrass Coverage and Composition", are currently not observed by any RI participating in the ITINERIS project: there is a need to provide a clear mandate to the RIs that are currently most mature in observing bio-eco EOVs and EBVs, to start measuring these variables;
- Most bio-eco EOV and EBV measurements are located either in small gulfs and embayments or in wetlands and lagoons: there is a clear geographical gap towards the shelf and offshore areas;
- Looking at the specific needs for each RI of this deliverable, the current bio-eco EOV and EBV measurements for both EMSO and EuroArgo rely only on a few facilities each: there is a clear need to increase the number of facilities for both these RIs;
- The number of JERICO facilities for the bio-eco EOV and EBV measurements is also low and currently concentrated on the North Adriatic: there is a need to increase the number of JERICO facilities in different areas of the country;
- The observation of a number of EVs (e.g. the ones on phytoplankton and zooplankton distribution and abundance within eLTER) is still sample based: there is a need to enhance automated acquisition of these variables.

3. ACTIONS IN THE ITINERIS PROJECT TO FILL THE GAPS

The following paragraphs describe the specific actions taken by each RI to address some of the gaps identified by the above analysis on the present state of RI facilities measuring bio-eco EOVs and EBVs.

eLTER

As emerged from this deliverable, currently, the observations at the marine and transitional Italian eLTER sites, considered in the project, are mainly focused on the planktonic component both phytoplankton and zooplankton (biomass and diversity, functional diversity, phenology of algal blooms, presence of alien species).

The main implementations foreseen during the project are aimed at filling crucial gaps in the EV observation framework and at enhancing the automated acquisition. Moreover, a proper integration between oceanographic and biological/ecological research and monitoring is always essential to broaden the spectrum of observing actions, holding the ecological connectivity concept as one of the main driving forces of marine ecosystems' functioning. Thus, both the understanding of the marine ecosystems and the assessment of their state and changes over time and space could be effectively enhanced.

In this context, the main activities and the corresponding planned increase in equipment will be:

- Implementation of the number of biological variables measured (innovative instrumentation will allow to map and monitor, e.g., fish and gelatinous macroplankton with RT imaging and an Automatic Identification System or AIS);
- Enhance the automated acquisition of biological variables (e.g., phytoplankton/cytometer - innovative instrumentation will allow to acquire near-real time data with an unprecedented time resolution (1 h) and to facilitate the broad taxonomic classification, Zooscan for the automatic acquisition of zooplankton images);
- Implementation of synergies between eLTER sites, enabling comparability between areas/basins (instrumentation will be acquired for covering observations at multiple sites, e.g., cytometers, Guard-1, Underwater Video Profiler-UVP);
- Implementation and/or integration of instrumentation for acquisition of physical-chemical variables in the marine environment (e.g., Photosynthetically active radiation-PAR, solar net radiation, Turbidity) to guarantee a better integration between oceanographic and biological/ecological research.

EMSO

The spatial distribution of the Italian observational facilities in EMSO, in spite Italy provides a larger number of facilities compared to other Countries, is not able to illuminate many crucial areas around our peninsula (e.g., Tyrrhenian Basin). It is worth outlining that EMSO peculiarity respect to other RIs, is the focus on the deep and open marine environment and that the deep-sea observations are rarely used in the computation of deep circulation models. The actions which address gaps mainly relates the EOV and ECV spatial coverage expansion, the reduction of the 'data latency' for the user (implementation of near-real and real-time data communication), the increment of the collection of ancillary data related to the functioning of the ecosystem as well as the operational acquisition of in-direct measurements of EOVs.

One of the next EMSO objectives is the improvement of the monitoring capability offshore of the Ligurian Sea and in the Sicily channel, expanding the horizontal and vertical spatial coverage of EOVs and ECVs with near real-time data transmission. In the Ligurian Sea, the reduction of the existing gap of near real time EOVs and ECVs measurements in deep water will be filled through the implementation of a data link that will allow the transmission of data from the instruments deployed in deep sea on the W1M3A observatory. Specifically, two acoustic modems coupled with CTDs will be installed on the W1M3A facility and the data transfer will be enhanced by installing servers and land stations onshore using both a satellite system and a radio link. The updated land stations will also expand the computing power and storage capacity of W1M3A 's dedicated servers and, in turn, the capability to provide external users with new observations EOVs related. The servers will be further enhanced with professional software that will support the researcher in the analysis of backscatter acoustic data provided by the ADCP, already part of the scientific equipment of the W1M3A observatory.

In the Sicilian Channel the number of shallow water acoustic measurements will be increased to spatially (both vertically than horizontally) extend and the development of a web-portal section will favor sharing and managing data of the marine shallow water observatory.

Offshore eastern Sicily, the EMSO Western Ionian Sea facility will be enhanced with a new electro-optical cable about 30 km long with junction boxes for hosting a wide range of sensor equipment's from a wider range of disciplines than presently. The purpose is to extend the range of the observables and the depth range of measurements (i.e., including water-column observation), provide

hosting service to other disciplines (i.e., marine biology) and access (physical and virtual) to unprecedented deep-sea experiments , increase the real time data transfer from deep sea site to shore station and extend the operation of the facility for the next 20 years

The Southern Adriatic Regional Facility will enhance the observational capacity of the Southern Adriatic by implementing and improving a more stable and continuous real-time data transmission of physical and biochemical variables using an inductive cable and sensor-coupled inductive data links. This action, and the harmonization with data from Argo floats and gliders, should increase Italy's capacity for deep-sea and open-sea observations.

In addition, the deployment of new sensors at the site aims to complement the observational capacity for biogeochemical and biological parameters (partial bottom CO2, ocean sounding, and photosynthetically active radiation - PAR) at the ecosystem level and to fill gaps in EOV measurements, especially at the bottom and surface levels. The development and installation of a land station will enhance communication and real-time data transmission of observations of nearly the entire open ocean water column through satellite transmission. This upgraded land station will also expand the computational power and storage capacity of the E2M3A system, and thus the capability to provide external users with new observations related to EOVs.

EuroArgo

The Italian Euro Argo ERIC scientific strategy has been primarily designed to observe, in Near-Real-Time (NRT), the physical state of the upper 2000 m of the oceans to assess and understand Earth's climate. This has yielded to a critical gap in NRT observation of marine biota and biogeochemistry in the upper 2000 m of open seas. Since marine biodiversity and related ecosystem functions occur over a continuum of spatial and temporal scales, a fit-for-purpose sampling is mandatory. The necessary observational breakthrough can be achieved through the deployment of Biogeochemical (BGC)-Argo profiling floats. Each subsurface profiling float repeats cycles of descent, submerged drift, ascent, and satellite data transmission, collecting measurements of several parameters from the equipped sensors. These autonomous robots are the most flexible and cost-effective platforms to measure a wide range of EOVs, ECVs and EBVs. In ITINERIS, cutting-edge multi-sensor/multi-process Argo robots will fill the gap of biological and biogeochemical observations in open seas over a continuum of spatial-temporal scales. The main activities to increase number, distribution and usage of biological and biogeochemical EVs will be:

- Increase the number of floats hosting optical sensors (chlorophyll, fluorometry, scattering, radiometry). Some floats will focus on hyperspectral radiometry to help increasing and refining the observations of EOVs and EBVs related to phytoplankton biomass and diversity, and on imaging cameras to characterize the diversity of marine microfauna (i.e., zooplankton). Floats will also be complemented with sensors to resolve oxygen dynamics, the carbon and nitrate cycles, being all these variables essential to understand marine ecosystem and biota health. Some floats will be equipped with additional battery to extend the lifetime of the platform and thus to increase the number of measurements that can be collected and transferred to land via satellite communication. All floats thus must have GPS and antenna for Real-Time transmission data via satellite communication, positioning and remote control of the float mission. A few floats will house sensors from different manufacturers to compare the quality of sensors to incentivize future cost reduction.
- Prepare, test and deploy several floats from vessels and increase the spatial and temporal coverage of bio-eco EV observations in undersampled open seas

- Implement international Argo accepted quality-control (QC) procedures, and algorithms, to guarantee open access distribution of the portfolio of biological EOVs, ECVs and EBVs.
- Investigate synergies between EuroArgo/BGC-Argo, the other RIs and satellite optical measurements (such those from operationally available EU Copernicus services) to strengthen assessment of marine ecosystem health over multiple spatial and temporal scales.

JERICO

As described in deliverable D5.3, the JERICO scientific strategy is based on three Key Scientific Challenges (KSCs):

- Assessing and predicting changes of coastal marine systems under the combined influence of global and local drivers (KSC#1);
- Assessing the impact of extreme events on those changes (KSC#2);
- Unravelling the impacts of natural and anthropogenic drivers of climate change (KSC#3).

Bio-eco EOV and EBV measurements played, play and will play a fundamental role in addressing all the three JERICO KSCs, especially considering the JERICO regional implementation strategy at the national level. This strategy is currently declined both in the North-Western Mediterranean Pilot Super Site (PSS) and in the North-Adriatic Integrated Regional Site (IRS). Its main objective is aimed at increasing, via a multiplatform approach, the national monitoring level of the complex interplays between biogeochemical and physical processes taking place in the coastal environment.

Following this direction, in the ITINERIS project, JERICO will increase the number of its autonomous vehicles and smart devices able to measure bio-eco EOVs and EBVs. The new gliders, drifters, profilers, smart observatories and cameras acquired during the project will have specific sensors to measure above all three variables, namely the “EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity”, “EBV - Ecosystem function: Marine primary productivity” and “EOV - Biology and Ecosystems: Fish abundance and Distribution”. The new facilities will be mainly located in shelf and coastal areas of the North-Western Mediterranean PSS, thus filling some of the geographical gaps identified above.