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D5.14 Report on the implementation on new prototyping model products in the North Adriatic; and on new integrated data products for Good Environmental Status, Good Ecological Status, and Ecosystem Integrity assessment

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1. INTRODUCTION

This deliverable presents the content of the second year of activities 5.17 and 5.19. It provides the description of the ongoing work related to the delivery of integrated data products and integrated model products developed by the ITINERIS RIs. In the deliverable D5.7 "Report on the state of the art of integrated data products for Good Environmental Status, Good Ecological Status, and Ecosystem Integrity assessment; and modelled products provision" the focus was on three main aspects of integration: the merging and fusion of different sources of data for a given parameter, a collection and analyses of different variables to produce a derived information, or, particularly within ITINERIS, an effort to put in synergy the different RIs to complement a given information. Regarding modeling products, the integration could be described in terms of data assimilation or in concurring in a broader description of one parameter, being added to the in-situ and EO information.

The present deliverable aims to give an overview of integrated data products for the assessment of Good Environmental Status (GenS), Good Ecological Status (GeCs) and Ecosystem Integrity (EI) and model products already implementable starting from the dataset provided from the different Research Infrastructures (RIs) and which could also benefit from the new acquired parameters in ITINERIS. The procurement status, which is delayed compared to the original plan, currently allows for only a limited number of full exemplars. However, this deliverable discusses the complete methodology and how the newly acquired data could be integrated, when available. Therefore, the disclaimer indicated in D5.7 is here recalled: all the possible demonstrators on novel integrated data products and integrated model products are directly dependent on the timely acquisition of the new equipment, since before developing new products based on new data, there should be enough time to verify installation and proper data transfer.

Ideally, once the full installation and data flow will be guaranteed, the plan could be fulfilled. The pilots described here are planned in the Northern Adriatic, identified as the most relevant area where synergies among JERICO, DANUBIUS, eLTER RIs are still well established. Therefore, integrated data and model products are presented relying on the equipment belonging to the above mentioned RIs in the area. In particular, we will provide examples using available data and models and describe three different integration approaches:

1. Integration of the same variable from multiple RIs to inform Directive/EI framework-related indicators.
2. Connecting different variables to inform Directive/EI framework-related indicators.
3. Integrating data and models.

Activity 5.17, in this second year, has the aim to provide demonstrators of model improvements due to the inclusion of novel measurements in the North Adriatic. Preliminary work was done in identifying what are crucial variables to be included and to identify focused areas of applications. Given the absence of new data flows, here the robustness of the approach is proven making an effective use of already available data from different RIs. Once new equipment is installed, the needed effort will just be to include additional datasets in the procedure.

Activity 5.19 aims to implement an approach to integrate different conceptual schemes of variables such as the Ecosystem Integrity (EI) and the Essential Variables (EVs) frameworks, also to support and inform the main EU policies and strategies that deal with coastal and marine management (i.e. Marine Strategy Framework Directive – MSFD; Water Framework Directive – WFD). In particular, data products based on merged selected oceanographic and biological/ecological parameters from different RIs are used to provide a contribution useful for the assessment of the Good Environmental Status (GEnS; MSFD), Good Ecological Status (GEcS, WFD) and EI, in the Northern Adriatic.

Starting from the Deliverable D5.7, the general definition of a data product remains valid for this work. Data product refers to "a product that facilitates an end goal through the use of data," usually with a well-thought-out algorithm or approach. Data products tend to be structured and can be raw measurements or scientific products derived from raw measurements or other products. Products can also be statistical or numerical model outputs, including analyses, re-analyses, predictions, or projections. Earth Science data products may be further categorized based on their processing levels" (e.g EMODnet or COPERNICUS EO). Geospatial data products organize and provide physical, spatial, and temporal relevance to raw digital measurements or physical samples.

In the EU context, the EU Horizon 2020 funded ENVRI Plus project sought to develop a common, cross-Research Infrastructure approach within the environmental science domain. Central to this is a standard Reference Model, where a data product is defined as "an instance of persistent [meta]data which has been processed to be offered to external users." (Nieva et al., 2017). As a single definition this is adequate, however the range of potential data and data products required within the marine community requires a tiered approach to describing a data product. As cited before, EMODnet has developed a series of categories defining data and data products based on the amount of processing and/or analysis that has taken place to come to a particular level. These categorizations align with the suggestions for EBV data products as outlined in Kissling et al., 2018. In the case of EMODnet, each data category (from 0 to 4) implies an increased amount of processing and quality control with regards to the previous level(s), ranging from raw data to harmonized collections of thematic quality controlled (QC) data. Additionally, two categories of data products (from 5 to 6) are also defined according to the complexity of the processing needed. Data products of Level 5 (a,b and c) display the distribution of a single parameter (e.g. species occurrence or abundance, chlorophyll), built upon QC'd data from levels described previously. Data products of Level 6 are the result of multi-variate analysis that may include both data and data products as inputs (e.g. predicted seabed habitats) (Lear et al., 2020).
Also, in the framework of eLTER-RI there is an ongoing effort to define data products and the workflows necessary to build them. In general, data products are created through synthesis of different datasets and/or modelling of single observations. This will include spatial interpolation of different site data to form contiguous spatial coverages.

1.1 The Water Framework, Marine Strategy and Ecosystem Integrity frameworks

The Water Framework Directive (WFD; EC 2000) and the Marine Strategy Framework Directive (MSFD; EC 2008) are the two main legal frameworks, established by the EU policy, for the protection and management of our freshwater and marine resources with an ecosystem-based, holistic approach. The Ecosystem Integrity (EI) is a conceptual framework (Müller et al., 2000; Müller, 2005), that focuses on the ability to sustainable self-organization of ecosystem. EI has been adopted by the European node of eLTER and it has now been recommended for the entire (International)

ILTER network as the conceptual framework for indicator selection, data integration and upscaling for individual sites (Haase et al., 2018).
Central to the WFD is the achievement of the Good Ecological Status (GEcS) defined as "the values of the biological quality elements for the surface water body type which show low levels of distortion resulting from human activity but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions". In the WFD the Quality Status (QS) of a water body can be determined based on the evaluation of Biological Quality Elements (BQE), which are supported by chemical, physico-chemical quality elements (QE) (e.g., transparency, thermal and oxygen conditions, salinity and nutrients). The objective of the MSFD is to reach 'Good Environmental Status' (GEnS) of the EU's marine waters. GEnS is defined as "the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations". GEnS might be considered as an overall performance indicator, which can be valued as good or not good based on several biotic and abiotic parameters that must be included in the monitoring programs (Manea et al., 2021). The conceptual EI framework (Müller et al., 2000; Müller, 2005) focuses on the ability to sustainable self-organization of ecosystem. According to the framework, the main components to describe the pressures on, and state of, ecosystems are their structures and processes. Ecosystem structures are well characterized by biotic diversity (of flora and fauna) and abiotic heterogeneity (of soils, sediments, water, air) forming habitats. Ecosystem processes (cycling of energy, matter and water) are characterized by indicators of inputs, storages and outputs. The indicators of EI are represented by parameters accessible by conventional methods of ecosystem quantification ending up in a set of parameters recommended to be calculated or measured in many local instances.

2. The pathway toward ITINERIS Indicators based on integrated data products

The term ''indicator'' is used often in ecology and environmental planning, with many different meanings, definitions and purposes and in various contexts so that there is no one-fits-all definition (Heink et al 2010). Among the many definitions of indicators (see Organisation for Economic Co-operation and Development, OECD; European Environment Agency, EEA, and many others) one of the broadest and all-encompassing (Heink et al 2010) is: ''An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals". Indicators should be also considered as "boundary objects" (Star & Griesemer 1989) at the interface between science and policy, useful to communicate scientific information to policy makers and non-experts (Heink et al 2010). Indeed, by playing a crucial role for effective and coherent policymaking, they provide selected, aggregated and interpreted information with three major purposes (Stanners et al 2007): (i) deliver information on environmental problems, in order to support policymakers to evaluate their urgency (this is especially important for new and emerging issues); (ii) support policy development and priority-setting, by highlighting key factors in the cause-effect chain that affect environmental pressures and that policy can target; (iii) measure policy progress and evaluate the effectiveness of policy responses.

EEA (2002) divided the environmental indicators in four typologies depending on the target they should describe and the use for which they are selected:

• Type A: descriptive indicators of what is happening to the environment or human health, e.g. emissions and concentrations of pollutants.

• Type B: performance indicators linked to a reference value or policy target, illustrating how far the conditions are far from a desired level.

• Type C: efficiency indicators illustrating the efficiency of production and consumption processes, e.g. energy consumption per unit of output.

• Type D: total welfare indicators, which aggregate together economic, social and environmental dimensions to illustrate whether, overall, welfare is increasing.

As a starting point, we will focus our attention on descriptive indicators to describe the environmental state and its change in space and time. In particular, in this deliverable we will focus our attention on the indicators already defined in the WFD, MSFD and in the Ecosystem Integrity framework. The ITINERIS indicators produced will include:

- Quality Elements (QE): Used to assess the Quality Status (QS) of a water body under the WFD.
- Good Environmental Status (GEnS): an overall performance indicator for marine waters under the MSFD, assessed through biotic and abiotic parameters.
- Ecosystem Integrity (EI) Indicators: based on ecosystem structures (biotic diversity and abiotic heterogeneity) and processes (cycling of energy, matter, and water), measured through inputs, storages, and outputs.

In D5.7 we have already selected Essential Variables (EOVs, ECVs, and EBVs) which are most measured by all the Ris within ITINERIS context. In Table 1 and 2 we evidence the contribution and the connections between each EVs and the ITINERIS indicators and the datasets already available to deliver them. This table represents the foundation for the implementation and delivery of the integrated data products, according to the scheme in Fig. 1, already described in D5.7.

Specifically, we will illustrate examples using available data and models and present three different integration approaches:

- Single Variable Data products: combining the same variable from multiple RIs to derive indicators related to QE of the WFD (Table 1);

- Multiple Variable Data products: linking different variables to derive indicators related to the MSFD Descriptors and Criteria and EI frameworks (Table 2);

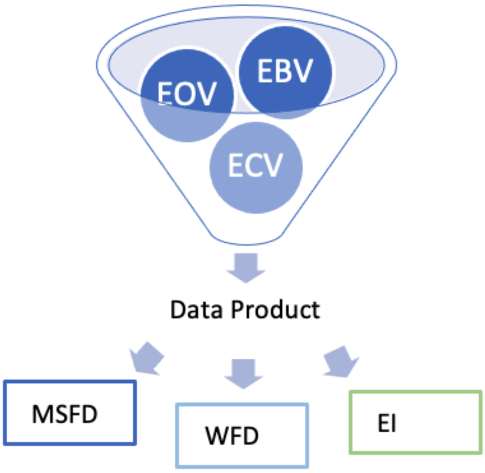

Figure 1: Scheme for the implementation of the integrated data products contributing to the MSFD, WFD and EI and based on EVs from the different RIs

Table 1: Connections between each EV (ECV, EOV and EBV), selected datasets and the WFD quality elements (QE).

ECVs	***EOVs***	***EBVs***	***WFD QE***	***Source***		
				Sensor based Dataset	***Model based Dataset***	***Sample based Dataset***
ECV - Ocean, Physical: Sea Surface Salinity			QE3-1-4 Salinity Conditions	DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE37_OCEAN_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT eLTER_E1_ISMARBASE_SBE37_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD15m_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD25m_OCEAN_NRT JERICO_S1-GB_ISMARBASE_SBE37_OCEAN_NRT	DANUBIUS_ISMAR_ADR_HINDCAST_PHYS_2018 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2017 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2022	
ECV - Ocean, Physical: Sea Surface Temperature			QE3-1-2 Thermal Conditions; Temperature	DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE37_OCEAN_NRT eLTER_AAOT_ISMARBASE_DavisVantagePRO_METEO_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT	DANUBIUS_ISMAR_ADR_HINDCAST_PHYS_2018 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2017 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2022	

				eLTER_S1-GB_ISMARBASE_SBE37_OCEAN_NRT eLTER_E1_ISMARBASE_SBE37_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD15m_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD25m_OCEAN_NRT JERICO_S1-GB_ISMARBASE_GillMaxiMetGMX500_ATM_NRT JERICO_S1-GB_ISMARBASE_SBE37_OCEAN_NRT		
ECV - Ocean, Biogeochemical: Oxygen			QE3-1-3 Oxygenation Conditions	DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE63_OCEAN_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT eLTER_S1-GB_ISMARBASE_SBE63_OCEAN_NRT eLTER_E1_ISMARBASE_SBE63_OCEAN_NRT JERICO_S1-GB_ISMARBASE_SBE63_OCEAN_NRT		
	EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity	EBV - Community composition: Functional diversity of marine phytoplankton (based on traits)	QE1-1 Phytoplankton	DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_N DANUBIUS-RI__PALOMA_ISMAR_TS_TRIPLET3m_OCEAN_NRT DANUBIUS-RI_PROBES_VeniceLagoon_ISMAR_bbase_water_quality_NRT		eLTER_Golfo di Venezia_Phytoplankton_OCEAN_DM eLTER_LagunadiVenezia_ISMARVE_Phytoplankton_OCEAN_DM

				eLTER_Golfo di Venezia_Phytoplankton_OCEAN_DM eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT eLTER_LagunadiVenezia_ISMARVE_ECOFLNTU_OCEAN_NRT eLTER_LagunadiVenezia_ISMARVE_Phytoplankton_OCEAN_DM		
	EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity	EBV - Ecosystem function: Phenology of marine spring phytoplankton bloom	QE1-1 Phytoplankton	DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_TRIPLET3m_OCEAN_NRT DANUBIUS-RI_PROBES_VeniceLagoon_ISMAR_bbase_water_quality_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT eLTER_LagunadiVenezia_ISMARVE_ECOFLNTU_OCEAN_NRT		eLTER_Golfo di Venezia_Phytoplankton_OCEAN_DM eLTER_LagunadiVenezia_ISMARVE_Phytoplankton_OCEAN_DM
		EBV - Ecosystem function: Marine primary productivity	QE3-1-3 Oxygenation Conditions	DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT		

ECV - Ocean, Biogeochemical: Inorganic Carbon			QE3-1-5 Acidification Status	ICOS-ISMAR_PALOMA_pCO2_3m_OCEAN_NRT ICOS-ISMAR_PALOMA_pH_3m_OCEAN_NRT ICOS-ISMAR_PALOMA_pCO2_25m_OCEAN_NRT		

As outlined in Table 1, the listed indicators are derived from the same EVs across different RIs and are associated with QEs defined by the WFD. These indicators play a crucial role in assessing the ecological status of water bodies by providing harmonized measurements across multiple data sources.

Specifically, they relate to the following QEs:

- QE3-1-4 Salinity Conditions, QE3-1-2 Thermal Conditions; Temperature, QE3-1-3 Oxygenation Conditions indicators: refer to the assessment of salinity levels, temperature and dissolved oxygen level in a given water body as a measure of its ecological quality. They evaluate deviations from natural conditions.
- The QE1-1 Phytoplankton indicator assesses the composition, abundance, and biomass of phytoplankton communities. Phytoplankton are key primary producers and play a crucial role in aquatic ecosystems. Changes in their diversity, biomass, or community structure can indicate environmental pressures such as nutrient enrichment (eutrophication), pollution, or climate change.
- The QE3-1-5 Acidification Status indicator assesses the pH levels of a water body to evaluate deviations from natural acid-base conditions. Acidification can result from atmospheric deposition, pollution, or other anthropogenic influences, affecting aquatic life and ecosystem stability.

As outlined in Table 2, the listed indicators are derived from different EVs across various RIs and are associated with the Descriptors and Criteria of the MSFD as well as the EI framework.

Specifically, they relate to the following MSFD DC:

- D1C6 - D1: Refers to Biological Diversity in marine ecosystems. This descriptor focuses on ensuring that marine ecosystems are healthy, functioning, and support a rich diversity of species and habitats. C6: Refers to Seafloor Integrity, which assesses the physical condition of the seabed. It evaluates the effects of human activities such as fishing, dredging, and coastal development on the structure and health of the seafloor, ensuring it supports diverse marine life. Together, D1C6 evaluates both biodiversity and the physical condition of the seafloor.
- D5C2 - D5: Refers to the Eutrophication descriptor, which addresses the condition where excessive nutrients (particularly nitrogen and phosphorus) lead to nutrient enrichment in marine waters, causing undesirable changes in the ecosystem. Eutrophication can result in algal blooms, oxygen depletion, and loss of biodiversity, impacting the health of marine ecosystems. C2: Refers to the Chlorophyll-a Concentration criterion, which focuses on the concentration of chlorophyll-a in marine waters. Chlorophyll-a is a key indicator of phytoplankton biomass, and its concentration can indicate the level of eutrophication. Elevated chlorophyll-a levels often signal excessive nutrient availability, leading to potential algal blooms and deterioration in water quality. Together, D5C2 assesses eutrophication levels through the concentration of chlorophyll-a.

- D5C5 - D5: see above. C5: Refers to the Nutrient Levels criterion, which focuses on assessing the concentration of nutrients (such as nitrogen and phosphorus) in marine waters. The aim is to ensure that nutrient levels do not cause eutrophication, thereby maintaining a healthy and balanced marine environment. Together, D5C5 evaluates the level of eutrophication and nutrient concentrations in marine waters.

They also relate to different EI indicators. The EI framework comprises two primary components, ecosystem structures and ecosystem processes, of the hierarchical EI structure, with five nested secondary components. Ecosystem structures comprise biotic diversity (e.g. number and identity of selected indicator taxa) and abiotic heterogeneity (e.g. soil type and water content), whereas ecosystem processes comprise energy, matter and water budgets. Budgets can be estimated based on system inputs, storages, outputs and additional state variables. The structural components of EI (biotic diversity and abiotic heterogeneity) essentially describe the state of the system, which can respond to pressures such as climate or land use change, whereas the process components directly reflect states, pressures and changes. This results in 23 basic EI indicators that comprise more specific variables, such as faunal diversity or water parameters (Haase et al., 2018).

Last three columns of Tables 1 and 2 list the datasets (sensor, model and sample based) that will be included in the initial version of the products described above for each indicator. As the IT-IOOS catalog is updated, these indicators may be revised to incorporate additional datasets.

Table 2: Connections between each EV (ECV, EOV and EBV), selected datasets and the MSFD DC and EI Components.

MS FD DC	***EI component***	***ECVs***	***EOVs***	***EBVs***	***Source***		
					Sensor based Dataset	***Model based Dataset***	***Sample based Dataset***
D1 C6	Ecosystem structure/abiotic heterogeneity/water	ECV - Ocean, Physical: Sea Surface Temperature			DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE37_OCEAN_NRT eLTER_AAOT_ISMARBASE_DavisVantagePRO_METEO_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT eLTER_S1-GB_ISMARBASE_SBE37_OCEAN_NRT eLTER_E1_ISMARBASE_SBE37_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD15m_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD25m_OCEAN_NRT JERICO_S1-GB_ISMARBASE_GillMaxiMetGMX500_ATM_NRT	DANUBIUS_ISMAR_ADR_HINDCAST_PHYS_2018 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2017 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2022	

					JERICO_S1-GB_ISMARBASE_SBE37_OCEAN_NRT		
		ECV - Ocean, Physical: Sea Surface Salinity			DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE37_OCEAN_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT eLTER_E1_ISMARBASE_SBE37_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD15m_OCEAN_NRT JERICO-ISMAR_PALOMA_CTD25m_OCEAN_NRT JERICO_S1-GB_ISMARBASE_SBE37_OCEAN_NRT	DANUBIUS_ISMAR_ADR_HINDCAST_PHYS_2018 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2017 DANUBIUS_ISMAR_PO_HINDCAST_PHYS_2022	
		ECV - Ocean, Biogeochemical: Oxygen			DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE63_OCEAN_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT		

					eLTER_S1-GB_ISMARBASE_SBE63_OCEAN_NRT eLTER_E1_ISMARBASE_SBE63_OCEAN_NRT JERICO_S1-GB_ISMARBASE_SBE63_OCEAN_NRT		
		ECV - Ocean, Biogeochemical: Inorganic Carbon			ICOS-ISMAR_PALOMA_pCO2_3m_OCEAN_NRT ICOS-ISMAR_PALOMA_pH_3m_OCEAN_NRT ICOS-ISMAR_PALOMA_pCO2_25m_OCEAN_NRT		
D5 C5	Ecosystem structure/abiotic heterogeneity/water; Ecosystem processes/matter budget	ECV - Ocean, Biogeochemical: Oxygen			DANUBIUS-RI_AAOT_ISMAR_BASE_SeaBird_Ocean_NRT DANUBIUS-RI__PALOMA_ISMAR_TS_CTD3m_OCEAN_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_SBE63_OCEAN_NRT eLTER_AAOT_ISMARBASE_SBE37_OCEAN_NRT eLTER_S1-GB_ISMARBASE_SBE63_OCEAN_NRT eLTER_E1_ISMARBASE_SBE63_OCEAN_NRT JERICO_S1-GB_ISMARBASE_SBE63_OCEAN_NRT		

				EBV - Ecosystem function: Marine primary productivity	DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT		
D5C2	Ecosystem structure/Biotic diversity/flora diversity		EOV - Biology and Ecosystems: Phytoplankton Biomass and Diversity	EBV - Community composition: Functional diversity of marine phytoplankton (based on traits)	DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT		
	Ecosystem processes/energy and matter budget			EBV - Ecosystem function:	eLTER_E1_ECOTriplet-w_OCEAN_NRT		

				Phenology of marine spring phytoplankton bloom	DANUBIUS-RI__PALOMA_ISMAR_TS_TRIPLET3m_OCEAN_NRT DANUBIUS-RI_PROBES_VeniceLagoon_ISMAR_bbase_water_quality_NRT DANUBIUS-RI_S1-GB_ISMAR_BASE_ECOTriplet-w_OCEAN_NRT		eLTER_Golfo di Venezia_Phytoplankton_OCEAN_DM eLTER_LagunadiVenezia_ISMARVE_Phytoplankton_OCEAN_DM
				EBV - Ecosystem function: Marine primary productivity	eLTER_S1-GB_ISMARBASE_ECOTriplet-w_OCEAN_NRT eLTER_E1_ECOTriplet-w_OCEAN_NRT eLTER_LagunadiVenezia_ISMARVE_ECOFLNTU_OCEAN_NRT		eLTER_Golfo di Venezia_Phytoplankton_OCEAN_DM eLTER_LagunadiVenezia_ISMARVE_Phytoplankton_OCEAN_DM

3. Modelling implementation framework to provide demonstrators' exercises in the North Adriatic region

In addition to the integrated data products for GEnS, GEcS and EI, which now also include modelled product for a limited number of EOV and come from the previous state of the art evaluation of model products in the North Adriatic, performed in Activity 5.17 for D5.7, a second line of action was developed in the second year of activity. This activity identifies three different approaches to increase the observational capability improving the offer of modelled products in the coastal environments and transitional zones:

- the first identifies available modelled data covering relevant EOV and ECV, which can be integrated with in situ and EO measurements, increasing the temporal and spatial coverage, possibly including also the vertical dimension, where missing from other data sources (e.g. EO satellite products in the surface, models along the water column);
- the second identifies derived new variables/indices, which complement the information from a modeling point of view; except the identified relevant EOV, ECV, to increase the knowledge in the coastal and transitional environments, a few additional variables/indices are considered relevant. Some examples are, e.g. the concentration of marine litter, the identification of sources of pollution or the typology and amount of sediment loads from rivers, the quantification of residence time in a lagoon.
- the third, also considered the most complex one, applies data assimilation techniques, making full use of the available in-situ measurements, to improve modeling products in specific areas; in the North Adriatic it is already state of the art the data assimilation effort performed on water level modelled data from storm surge models (e.g. ISSOS model, based on SHYFEM code) through tide gauges; additional opportunities can be found in assimilating temperature and salinity measured data, particularly in the transitional environments.

In this section we give an overview of these three different approaches and on the present status for the demonstrators in the North Adriatic for the physical component.

Among the list of the modelling initiatives/applications presented in D5.7, the activities are developing around the followings:

- 3D Modeling outputs for sea temperature and sea salinity, water levels and currents for year 2018 (planned to perform 2015-2022) from an application of the SHYFEM model over the whole Adriatic Sea.
- 3D Modeling outputs for sea temperature and sea salinity, water levels and currents for years 2017 and 2022 from a high resolution application of the SHYFEM model over the Po River Delta and approaching coastal area.

- Oceanographic model ensemble for the Adriatic Sea, 3D, spatial resolution 2-8 km, 15 layers, 3 hourly, Forcing from SMHI-RCA4 (CMIP5) driven by different GCM, 6 historical+rcp8.5 1987-2099 simulations, 2 control simulations 1987-2010. Subset monthly averages for currents, water levels, potential temperature, salinity.
- Marine litter Model product – langrangian application in the Adriatic Sea; the implementation was developed under the Maelstrom Project, while the model outputs are made available through the DANUBIUS-RI to guarantee long lasting access to the data, beyond the end of the project.
- Modelling outputs, with temperature and salinity data assimilation, for the Venice Lagoon, performed through an implementation of the SHYFEM model; the application was developed within the Venezia2021 project, and can be further improved including the ITINERIS fixed stations from DANUBIUS-RI within the Venice Lagoon.

Model Data integration

As described in the previous section, the North Adriatic results as a well monitored area, but with a limited coordination among the observing systems, given the large number of actors and authorities in charge. Thanks to the organization of EOVs and ECVs data acquired by the ITINERIS ESFRI RIs within the IOOS, we can simply combine different sources of data for a given variable. Given the new availability that is being built in this period of the project, to give full access in the IOOS to the modeling products distributed through DANUBIUS, for some variables the integrated products can be enriched with modelled dataset. As a demonstrator, the plan is to include 3D temperature data from SHYMEM model implementation in the North Adriatic with available temperature data from in situ fixed stations, merging the contribution of DANUBIUS-RI, JERICO-RI and eLTER RI. This effort, here defined as an approach, will be completed with the availability of the data measured by the new ITINERIS equipment (e.g. the water quality stations for the Venice Lagoon) which will be installed in the coming months and with transmit data by the end of the project, if the procurement, authorization and installation process will not be affected by further delays.

Production of derived variables/indices from model implementations

Except EOVs and ECVs recognized as relevant to describe the status of the environment, particularly for the land-sea interface, the coastal and transitional areas, there is additional information to assess the status of the environment. Some variables, not recognized as EOV or ECV are relevant particularly to quantify the influence of land to sea (e.g. the amount and concentration of marine litter) or the dynamicity of semi enclosed or restricted environments, such as the residence time on the coastal lagoons. Despite some of these variables can be measured or computed from measurements (e.g. the quantity of litter sampled), models can fill the gap providing a derived variable over a given area. As a demonstrator, for the North Adriatic, within ITINERIS maps of marine litter distribution will be provided. The concentration of parcels in the North Adriatic is the described variable and the output can integrate the information coming from punctual sampling of field campaigns limited in time.

Data Assimilation

Regarding the data assimilation approach, the demonstrator can be provided for the Venice Lagoon, and will include, once installed and with assured data flow, also the new ITINERIS DANUBIUS stations.

Below, the description of the procedure adopted, clarifying the benefit for modeling products. This is, so far, the demonstrator of the potentiality of the method. The inclusion of new stations, which are presented in Fig. 2, will further improve the results, given the ratio of choice of the location of new stations. This procurement process was agreed with ISPRA within the PNRR Marine Ecosystem Restoration (MER) – funded by NextGenerationEU, Comune di Venezia, ARPA Veneto, Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trentino Alto Adige e Friuli Venezia Giulia (Ex Magistrato alle Acque - Venezia), since the new stations will integrate monitoring networks already in place enhancing the overall observative capability for the Venice Lagoon.

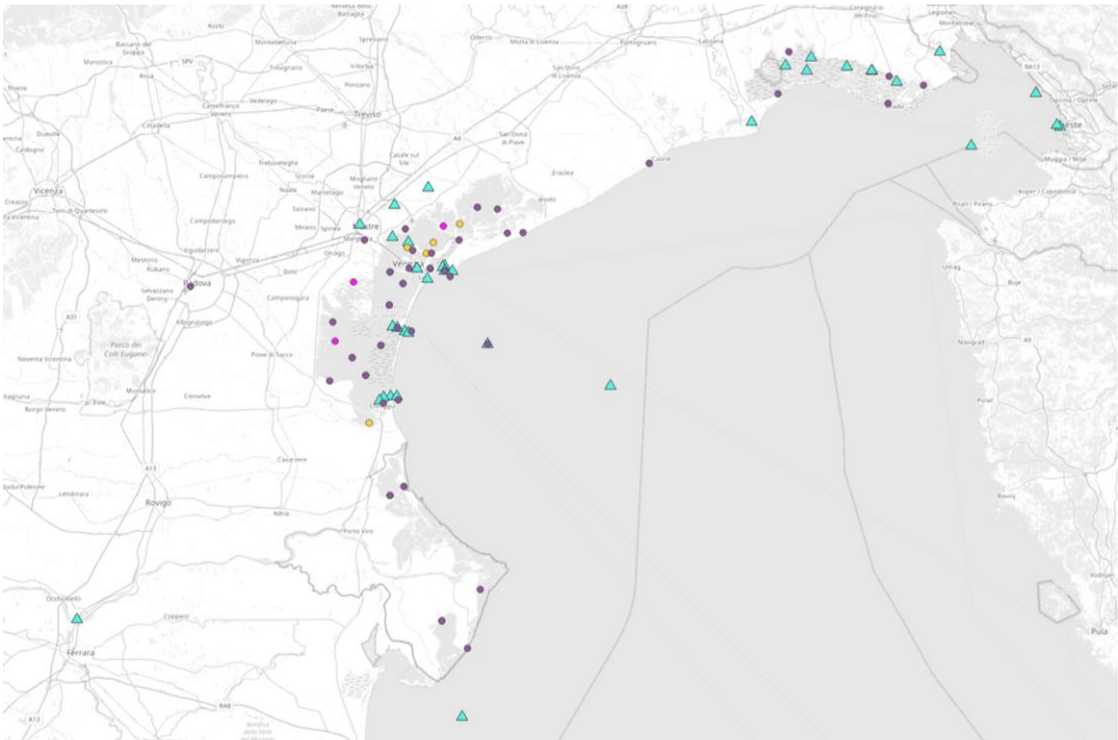

Figure 2: cyan triangles, DANUBIUS-RI Stations; purple dots, ISPRA stations PNRR MER B29; yellow dots, ISPRA buoys PNRR MER B30; magenta dots, ISPRA fixed stations PNRR MER B30

The data assimilation procedure relates to in-situ water temperature and salinity measurements. These variables are assimilated in the SHYFEM 3D hydrodynamic model implementation for the Venice Lagoon domain. A preliminary test was performed for the month April 2019 within the Venezia2021 project.

In the test period 6 SAMAnet stations (Fig. 3) were used: Ve1 – Fusina, Ve2 – Campalto, Ve3 – S. Piero in Volta, Ve7 – Palude Cona, Ve8 – Palude Maggiore, Ve9 – Valle Millecampi. Added to these stations there is also the long-term Punta della Salute station, outside the SAMAnet network.

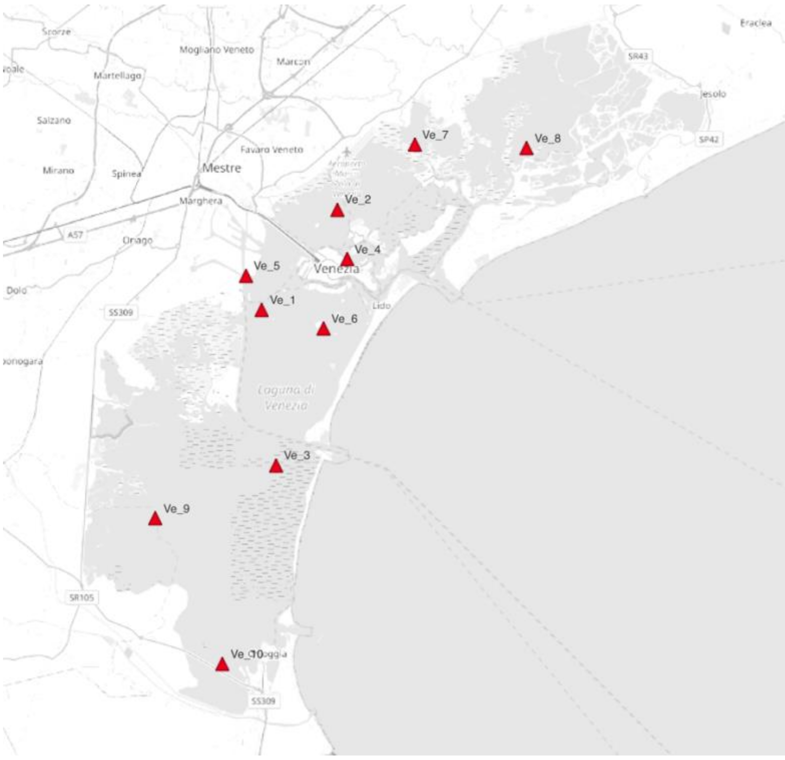

Figure 3: SAMAnet Network of fixed stations owned by Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trentino Alto Adige e Friuli Venezia Giulia (Ex Magistrato alle Acque - Venezia)

Their locations are sparse over the domain, allowing a good, despite not complete, coverage of the Lagoon.
The new ITINERIS DANUBIUS stations complement this picture, covering also the inlets and some freshwater inputs within the lagoon (Fig. 2).
Assimilation tests were performed on a 31863 finite element grid and the applied methos is called Ensemble Squared Root filter (EnSRF), fully described in Ferrarin et al. (2021) and applied for the first time in the described test to assimilate temperature and salinity.
The method uses an ensemble of model runs to compute a covariance matrix. The test evaluated the uncertainty performing ensemble runs, with perturbations of the status, for each boundary condition (lateral: rivers; inlets: salinity, temperature water level; and surface: wind, air temperature, solar radiation, rain, cloud cover, relative humidity). This allowed to produce a gaussian distribution of each repetition, having the mean centered on the unperturbed condition, with standard deviation equal to the estimated error. Data for in-situ stations were checked and filtered to exclude spikes and were assimilated every hour, with a phase lag (at minute 0 for salinity and at minte 30 for temperature).
The tests quantified the improvement for the reproduction of temperature and salinity: considering the ensemble mean results, compared to deterministic results, the correlation of temperature, in the

considered stations increase from 0.95 to 0.98. The correlation for salinity, increases from 0.79 to 0.93 compared with results not including data assimilation.
Once the ITINERIS DANUBIUS station will provide a regular water temperature and salinity flow for 7 additional locations, this will allow a better reproduction of the lateral sources of freshwater, where salinity gradients are more evident and a more realistic thermohaline lateral fluxes at the lagoon inlets.

In D5.7 two more possible demonstrators were mentioned, directly linked to some of the planned acquisitions of new equipment: Oxygen, turbidity, Chl-A from new CTDs located at the inlets of Venice Lagoon aimed at determining the exchange flows between lagoons and the sea, to establish boundary conditions for the biogeochemical model; coastal webcams aimed at supporting and integrating the information from models for flooding characterization. The webcam was installed along the Lido coastline in January 2024 and preliminary tests are going on. But the full data flow is not completed for all equipment, therefore, given the project timing, some additional demonstrators previously planned are not confirmed. However, all data will be stored in the IOOS to be fully available for future tests.

4. Technical integration of data products in the IT-IOOS and future perspectives

Given the overview of the creation of integrated products and additional modelled products, a crucial step forward involves embedding this plan into the IT-IOOS. This will enhance the usability of the extensive pool of data catalogued by ITINERIS and facilitate the generation of novel information that addresses the directives and EI framework needs.

In practice, for selected examples (refer to tables 1 and 2), a collaborative effort involving Activities 5.1, 5.17, and 5.19 is underway. By the end of the project, specific IT-IOOS queries will be developed to search, retrieve, and make available collections of datasets connected with the indicators in a single operation.

Technically, the three types of data products described in section 2 will be accessible through the ITINERIS Marine Hub Portal, IT-IOOS. As detailed in Deliverable D5.20, IT-IOOS will enable the display of the metadata catalogue via a webGIS interface, differentiating between variable type, research infrastructure, or production unit.

Users can explore the metadata further by selecting the acquisition site or using various keywords and filters, such as:

- Variables reported according to the code assigned by the reference vocabulary through a drop-down menu,
- time interval (by selecting Time),
- entity that published the data (by selecting Publisher),
- geographical location (drop-down menu activated by selecting Map).

For each dataset identified with the set search parameters, users will be able to display the results on the main page map and download both the metadata and the associated data. It will be possible to search for multiple variables simultaneously, even if they belong to different datasets, or to use specific keywords that define sets of specific variables (indicators). The search results will be compiled into one or more files, depending on the number and type of datasets involved.

In the next and final deliverable, examples from the North Adriatic will be provided, along with a discussion on the potential list of new integrated products, which may continue to be refined even beyond the end of the project. The full potential of these integrated and modeled products will be realized once the complete set of equipment is installed and a sufficiently large dataset is available, enabling not only basic examples but also more structured research activities.

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