Long-term strategic plan for site-specific operating of monitoring and observation system at Pilot Sites

Final Version of 30/11/2021

Deliverable Number D.4.4.1

Project Acronym	CHANGE WE CARE
Project ID Number	10043385
Project Title	Climate cHallenges on coAstal and traNsitional chanGing arEas: WEaving a Cross-Adriatic REsponse
Priority Axis	2
Specific objective	2.1
Work Package Number	4
Work Package Title	Evolution dynamics in Pilot Sites and Northern/Central Adriatic under climate change
Activity Number	4.4
Activity Title	Definition of common monitoring and observation system on identified significant parameters
Partner in Charge	PP8 (IZOR)
Partners involved	LP (CNR-ISMAR), PP2 (POPARK), PP4(AR RAVG), PP7 (PIDNIC), PP10 (VRANLAKE)
Status	Final
Distribution	Public

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1. Foreword

This document has been produced in the framework of the INTERREG Italy – Croatia CHANGE WE CARE Project. CHANGE WE CARE fosters concerted and coordinated climate adaptation actions at transboundary level, tested in specific and representative pilot sites, exploring climate risks faced by coastal and transitional areas contributing to a better understanding of the impact of climate variability and change on water regimes, salt intrusion, tourism, biodiversity and agro-ecosystems affecting the cooperation area. The main goal of the Project is to deliver integrated, ecosystem-based and shared planning options for different problems related to climate change (CC), together with adaptation measures for vulnerable areas, to decision makers and coastal communities. Additional information and updates on the CHANGE WE CARE can be found at https://www.italy-croatia.eu/web/changewecare.

Within the activities defined by the work plan of the Interreg Italy-Croatia project "Climate cHallenges on coAstal and traNsitional chanGing arEas: WEaving a Cross-Project Adriatic REsponse" (CHANGE WE CARE), this deliverable aims to define long-term strategic plan for site-specific operating of monitoring and observation system at Pilot Sites, as a set of activities that would maintain the monitoring activities at the satisfactorily level.

The report is a companion report of D4.4.2 (Guidelines for climate change monitoring in the cooperation area), which is providing the recommendations specifically targeting the key activities that would assure the sustainability of the climate monitoring on the long term, related to the monitoring programmes itself, tools for more efficient management, securing long-term finances, opening the data and the data products to all potential users and products, fostering collaborations between scientists, managers and policy-makers, and on educational activities. This deliverable overview first the common climate monitoring approaches, including the list of essential climate variables that are a standard of monitoring systems. Then, the sampling strategy is developed for all five Pilot Sites, and include an overview of a site, present-level sampling strategy and plans for the future. Finally, an overview of sustainability instruments is provided.

2. Essential climate variables

An Essential Climate Variable (ECV) is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate (WMO, 2021). ECV datasets provide the empirical evidence needed to understand and predict the evolution of climate, to guide mitigation and adaptation measures, to assess risks and enable attribution of climate events to underlying causes, and to underpin climate services.

ECVs are identified based on the following criteria (Bojinski et al., 2014):

- *Relevance*: The variable is critical for characterizing the climate system and its changes.
- *Feasibility*: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
- *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.

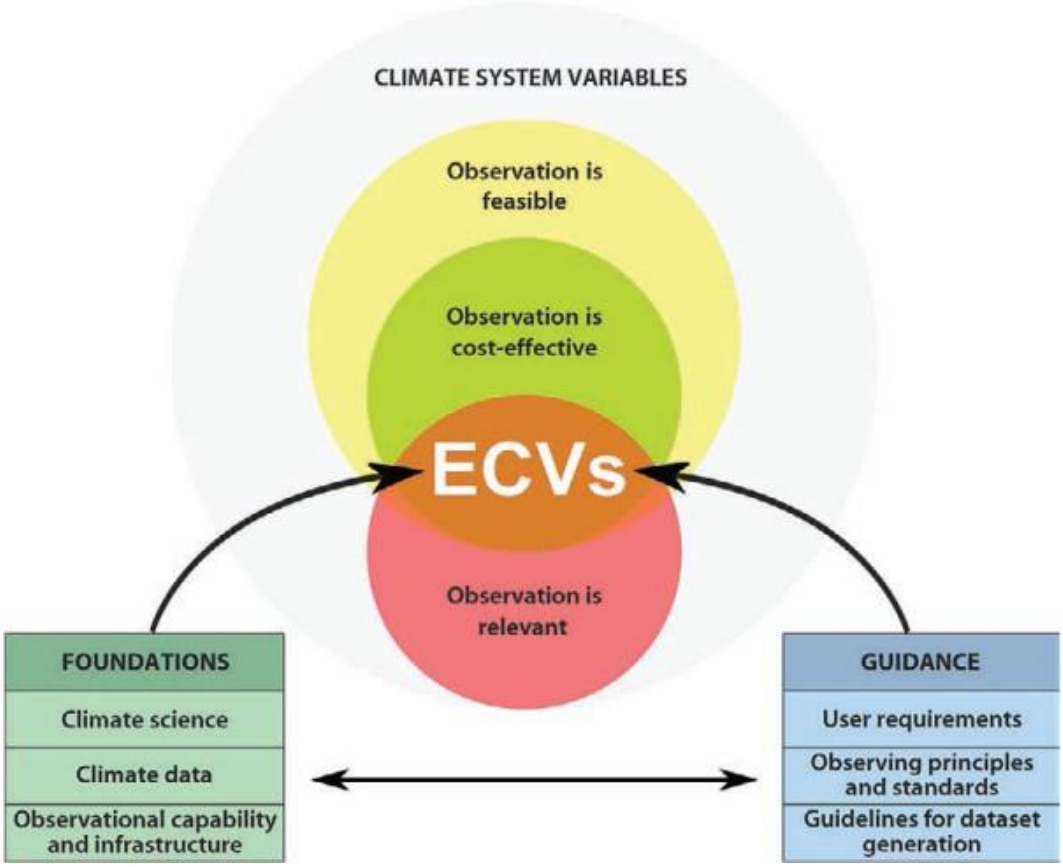
ECVs are observed according to the Global Climate Observing System (GCOS) Climate Monitoring Principles (GCOS, 2021), which define a framework for establishing climate monitoring activities:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically-uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.

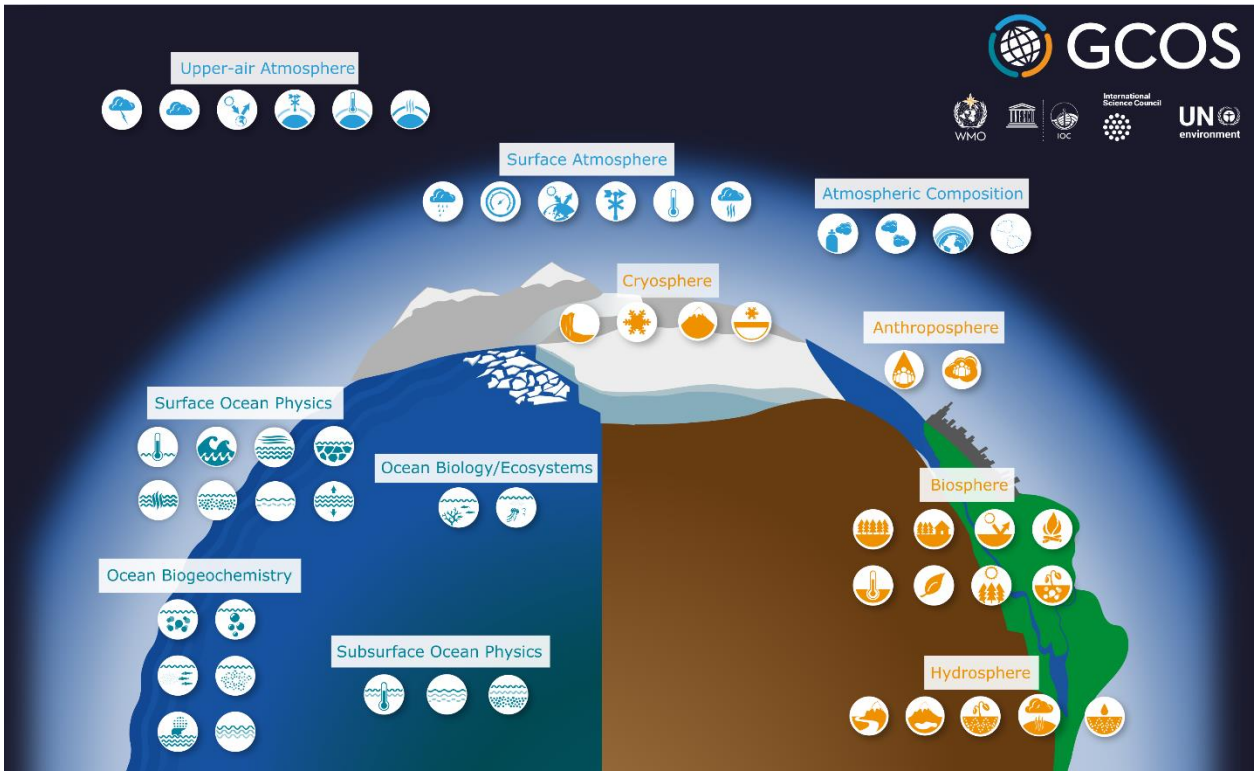
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.

9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.

10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.



Schematic of the ECV concept: knowing existing climate-relevant observing capabilities, climate datasets, and the level of scientific understanding of the climate system are the foundations (lower-left box) necessary for selecting the ECVs from a pool of climate system variables (after Bojinski et al. 2014).

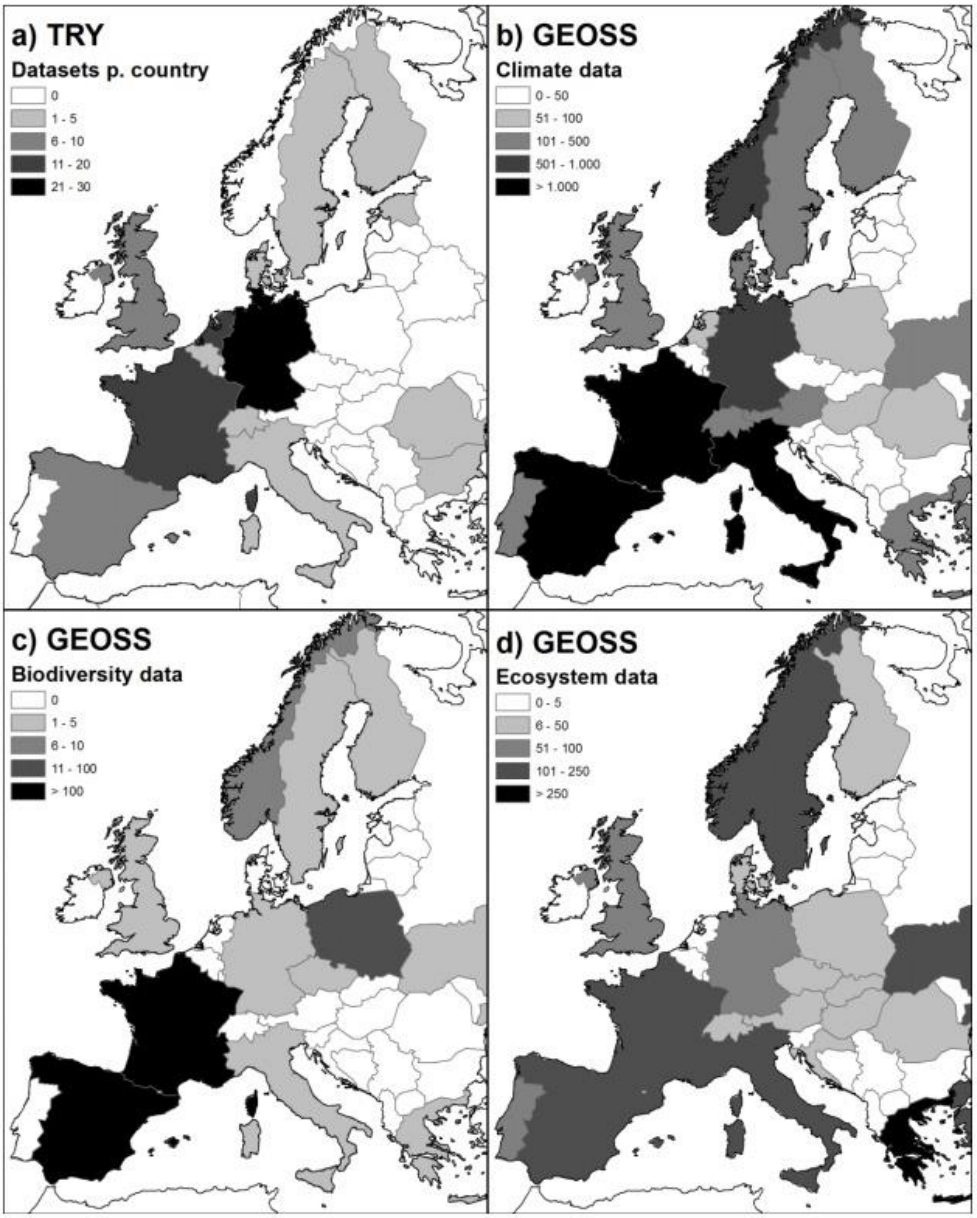


The schematic view of Essential Climate Variables (after GCOS, 2021).

For each ECV there are a number of relevant key datasets, separated for observation domains, which aim to meet the following criteria:

- Worldwide in coverage
- Free and open access
- Quality controlled with documentation
- Include metadata
- Considered by the appropriate GCOS Science Panel Experts

In Europe, including the Adriatic region, the data coverage is not uniform, and it can vary a lot between different countries, e.g. between Italy and Croatia:



Information density in data bases for Europe. a) Number of datasets contributed to TRY per country, b) Number of entries per country in GEOSS (Global Earth Observation System of Systems) with theme "Climate", c) Number of entries per country in GEOSS with theme "Biodiversity", d) Number of entries per country in GEOSS with theme "Ecosystems". Note that entries in GEOSS can include datasets, monitoring and observation systems, computational models, initiatives, websites and documents, analysis and visualizations, catalogues, inventories and metadata collections as well as software and applications (after Guerra et al. 2017).

2.1. Essential atmospheric variables (EAVs)

The list of EAV and the derived climate products in the atmosphere, at its surface, being relevant for the Adriatic Sea is including:

ECV	Product
Precipitation	Estimates of liquid and solid precipitation
Pressure (surface)	Pressure
Surface Radiation Budget	Surface ERB longwave
	Surface ERB shortwave
Surface Wind Speed and direction	Surface wind speed and direction
Temperature (surface)	Temperature
	Daily maximum and minimum temperature
Water Vapour (surface)	Water vapour

The details on each Essential Atmospheric Variable is provided on the Global Observing Systems Information Center (GOSIC) web site (GOSIC, 2021), while here providing just a few examples of their description:

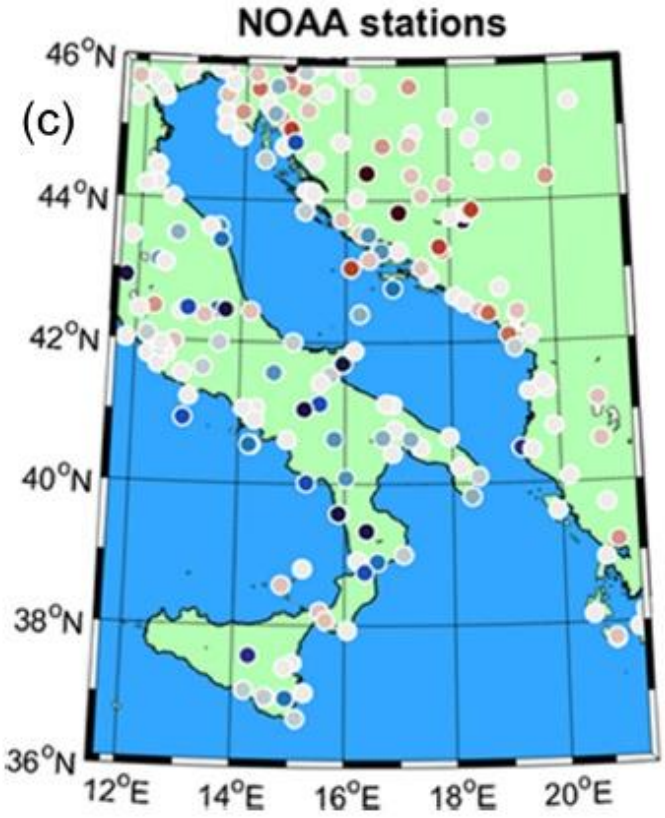
- Surface air temperature has profound and widespread impacts on human lives and activities, affecting health, agriculture, energy demand and much more. It also has impacts on natural systems. It affects the fluxes of heat, momentum, water vapour and trace species between land and atmosphere and between ocean and atmosphere. Its monitoring provides a key indicator of climate change. Observations of it contribute to estimates of what is commonly known as "global-mean surface temperature" and to a number of indices of extreme conditions.

- Precipitation, either liquid or solid, is the most important climate variable directly affecting humans. Through either its duration, intensity and frequency or its lack of occurrence, it influences the supply of water for personal consumption and use in agriculture, manufacturing industries and power generation, causes risks to life and the functioning of society when associated with floods, landslides and droughts, and affects infrastructure planning, leisure activities and more. Precipitation is closely related to cloud properties, a number of terrestrial ECVs and to ocean-surface salinity. It is indicative of the release of latent heat within the energy cycle, as well as being at the heart of the hydrological cycle.

- The surface radiation budget is a fundamental component of the surface energy budget that is crucial to nearly all aspects of climate, and needs to be monitored systematically.

In the Adriatic region these variables are measured – aside from satellite measurements – at regular meteorological stations that are managed by national meteorological agencies. The data is normally

available for the research, while being also accessible at the NOAA (National Atmospheric and Oceanic Administration) website at https://gis.ncdc.noaa.gov/maps/ncei/cdo/hourly. It includes more than 250 ground stations in the Adriatic region (Denamiel et al., 2021):



Meteorological stations listed in the NOAA database with the ECV data available for the public (after Denamiel et al., 2021).

2.2. Essential land variables (ELVs)

The list of ELV and the derived climate products on the land surface, being relevant for the Adriatic Sea, is including:

ECV	Product
Above-ground biomass	Maps of AGB
Albedo	Maps of DHR albedo for adaptation
	Maps of BHR albedo for adaptation

	Maps of DHR albedo for modelling
	Maps of BHR albedo for modelling
Anthropogenic Greenhouse Gas Fluxes	Emissions from fossil fuel use, industry, agriculture and waste sectors.
	Emissions/ removals by IPCC land categories
	Estimated fluxes by inversions of observed atmospheric composition - continental
	Estimated fluxes by inversions of observed atmospheric composition - national
	Hi-res CO2 column concentrations to monitor point sources
Anthropogenic Water Use	Volume of water per year
Fire	Burnt Areas
	Active fire maps
	Fire radiative power
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	maps of FAPAR for modelling
	maps of FAPAR for adaptation
Groundwater	Groundwater volume change
	Groundwater level
	Groundwater recharge
	Groundwater discharge
	Wellhead level
	Water quality
Lakes	Lake water level
	Water Extent
	Lake surface water temperature
	Lake ice thickness
	Lake Ice Cover
	Lake Colour (Lake Water Leaving Reflectance)
Land cover	Maps of land cover
	Maps of high resolution land cover
	Maps of key IPCC land use, related changes and land management types
Land Surface Temperature	Maps of land surface temperature
Latent and Sensible Heat fluxes	

Leaf Area Index (LAI)	maps of LAI for modelling
	maps of LAI for adaptation
River Discharge	River discharge
	Water Level
	Flow Velocity
	Cross-section
Snow	Area covered by snow
	snow depth
	snow water equivalent
Soil Carbon	%Carbon in soil
	Mineral soil bulk density to 30 cms and 1m
	Peatlands total depth of profile, area and location
Soil Moisture	Surface soil moisture
	Freeze/thaw
	Surface inundation
	Root-zone soil moisture

The details on each Essential Land Variable is provided on the Global Observing Systems Information Center (GOSIC) web site (GOSIC, 2021), while here providing just a few examples of their description:

- The albedo of a land surface is the non-dimensional ratio of the radiation flux reflected by a (typically horizontal) surface in all directions and the incoming irradiance, which is the radiation flux from the upper hemisphere. This is technically known as the bihemispherical reflectance factor, and both fluxes must be relative to the same spectral range. For bare soils and other solid, convex objects, the material interface between the ground and the atmosphere constitutes the reference surface. In the case of vegetation, a reference surface is typically defined at or near the top of the canopy and must be specified explicitly. This "generic" albedo is highly variable in space and time as a result of changes in surface properties (snow deposition and melting, changes in soil moisture and vegetation cover and so on), as a function of fluctuations in the illumination conditions (solar angular position, atmospheric effects, cloud properties and so on) and with human activities (for example, clearing and planting forests, sowing and harvesting crops, burning rangeland and so on). Albedo is thus not an intrinsic surface property, but a joint property of the surface and the overlying atmosphere, since the latter's composition (gases, clouds and aerosols) significantly affects the spectral and directional distribution of the irradiance.

- River-discharge measurements have essential direct applications for water management and related services, including flood protection. They are needed in the longer term to help identify and adapt to some of the most significant potential effects of climate change. The flow of freshwater from rivers into the oceans also needs to be monitored because it reduces ocean salinity, and changes in flow may thereby influence the thermohaline circulation.

- Soil moisture is an important variable in land–atmosphere feedbacks at both weather and climate timescales. It plays a major role in determining how the energy flux into the land from incoming radiation is partitioned into fluxes of latent and sensible heat from the land to the atmosphere, and in the allocation of precipitation into runoff, subsurface flow and infiltration. Soil moisture is intimately involved in the feedback between climate and vegetation, as both local climate and vegetation influence soil moisture through evapotranspiration, while soil moisture is a determinant of the type and condition of vegetation in a region. Changes in soil moisture can accordingly have substantial impacts on agricultural productivity, forestry and ecosystem health.

2.3 Essential ocean variables (EOVs)

The ocean environment is vast, remote, and harsh, and the cost involved in its observation are high. There is a need to avoid duplication of efforts, across observing platforms and networks, and to adopt common standards for data collection and dissemination to maximize the utility of data. To address these concerns, the Framework is designed to approach ocean observations with a focus on Essential Ocean Variables, ensuring assessments that cut across platforms and recommend the best, most cost effective plan to provide an optimal global view for each EOV.

Table 1. Essential Ocean Variables as listed by the Global Ocean Observing System (GOOS, 2021).

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover and composition
Surface currents	Stable carbon isotopes	Macroalgal canopy cover and composition
Subsurface currents	Dissolved organic carbon	Mangrove cover and composition
Sea surface salinity		Microbe biomass and diversity (*emerging)
Subsurface salinity		Invertebrate abundance and distribution (*emerging)
Ocean surface heat flux		
CROSS-DISCIPLINARY		
Ocean colour	Ocean Sound	

Essential Ocean Variables are identified by the Global Ocean Observing System (GOOS) Expert Panels, based on the following criteria (GOOS, 2021):

- *Relevance*: The variable is effective in addressing the overall GOOS Themes – Climate, Operational Ocean Services, and Ocean Health.
- *Feasibility*: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
- *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.

The details on each Essential Ocean Variable is provided on the GOOS web site, while here providing just a few examples of their description:

- Sea State is the characterization of wave and swell, typically in terms of height, wavelength, period, and directional wave energy flux. Waves generated by ocean surface stress evolve from wind waves to swell through nonlinear dynamical processes. Wave characteristics are modified by bathymetry when the depth of the water is comparable to the wavelength, and by surface currents.

  Sea state is most well-known for its impacts on marine safety, marine transport and damage to structures. It is also a substantial modifier of air-sea exchanges of momentum, moisture and CO_2. Waves also impact beach erosion, storm-related water damage (wave set-up contributes to storm surge), surface albedo, and transport of larva and contaminants such as oil. Waves can also modify the growth or decay of sea ice.

  The primary aspects of sea state that are measured are the wave height (usually significant wave height (SWH), but sometimes maximum wave height), wave period and wave direction. Wavelength might be observed, but is more often inferred from period and wave phase speed. Parameters of interest that are not measured by existing systems include crest height (usually parameterized from wave spectra or SWH), wave breaking, whitecap coverage (derived from some satellite estimates, and numerical models), rogue waves, and tangentially, Stokes drift.

  Sea State is typically observed from moored buoys and satellite altimeters, although some wave information can be inferred from coastal radar and specialized drifting buoys, and observations are provided from some Voluntary Observing Ships and oil platforms. Most moored buoys measuring waves are located in the coastal margins of North America, Europe and Australia; other than the Australian coast, there are virtually no wave measurements in the southern hemisphere. Waves are recorded on only two of the buoys measuring eddy covariance fluxes. Current in situ reports are not standardized resulting in impaired utility.

- Sea Surface salinity observations contribute to monitoring the global water cycle (evaporation, precipitation and glacier and river runoff). On large scales, surface salinity can be used to infer long-term changes of the global hydrological cycle. Surface salinity, together with surface temperature, is indicative of the surface expression of ocean frontal features and eddies. Sea

Surface Salinity is observed principally in situ from flow-through water intake systems on research and commercial ships, or conductivity sensors deployed on autonomous floats, drifters, and unmanned surface vehicles. More recently, the advent of satellite sea surface salinity sensors has provided less precise but global coverage including marginal seas and better spatiotemporal sampling than the in situ observation network. In situ surface observations will remain an important validation and calibration complement to satellite observing.

Ocean surface salinity observations provide an important input for data assimilation ocean models that are being used to provide gridded global estimates of ocean circulation at varying spatial and temporal scales. The complementarity of satellite and in-situ SSS observations is needed to resolve sea surface salinity features important to ocean circulation and marine biogeochemistry, and linkages with weather forecasts, and seasonal to multi-decadal variability and predictability of the global water cycle.

- The availability of inorganic macronutrients (nitrate (NO3), phosphate (PO4), silicic acid (Si(OH)4), ammonium (NH4), nitrite (NO2)) in the upper ocean frequently limits and regulates the amount of organic carbon fixed by phytoplankton, thereby constituting a key control mechanism of carbon and biogeochemical cycling. There is a number of biogeographic regions in the open ocean characterized by different macronutrient regimes, either permanently or seasonally limiting the growth of phytoplankton. Measuring changes in macronutrient concentrations is essential to constraining net biological production and export fluxes, detecting shifts in biogeographic regimes, but also monitoring eutrophication phenomena.

- Seagrasses are vascular plants that that can reproduce by flowering (sexually) and also spread asexually through rhizome extension. They can form dense, submerged meadows in coastal and estuarine waters. There are approximately 72 seagrass species that belong to four major groups. Seagrasses are often highly productive and provide essential habitat and nursery areas for many finfish, shellfish, charismatic megafauna, and species of concern, including sea turtles, dugongs and manatees. Seagrasses also help stabilize and protect coasts by binding underlying sediments. They contribute to good water quality by trapping sediment and absorbing nutrient runoff. Seagrasses are recognized as a “blue” carbon storage system, by fixing inorganic carbon via photosynthesis and storing and sequestering it in seagrass rhizomes and associated sediments. Although coastal vegetated habitats comprise only 0.2% of the world ocean they contribute >10% of all carbon buried annually in the sea. Vigorous photosynthesis by seagrasses can also reduce the acidity of surrounding water by removing dissolved carbon dioxide. Seagrasses are declining worldwide as a result of coastal development, nutrient loading that leads to poor light conditions on the sea floor, climate change, and cascading impacts of fishing. Loss of resources, including biological habitats such as seagrass meadows, is a major concern for governments worldwide and emerges as a major societal pressure motivating international conventions and bodies focused on ocean environment and resources.

  Regular monitoring of seagrass cover and ecosystem structure will be useful to modelling coastal and reef fishery production, the global carbon cycle, and tracking impacts of climate change and coastal eutrophication.

Process used to identify biology and ecosystems essential ocean variables (EOVs) (external circle). Each of the external bubbles describes steps in the process. The inner circle represents the DPSIR model (drivers-pressures-state-impact-response), with the bubbles providing the details on each of the five components (after Miloslavich et al., 2018).

3. The sampling strategy

3.1 Po River delta

3.1.1 Site description

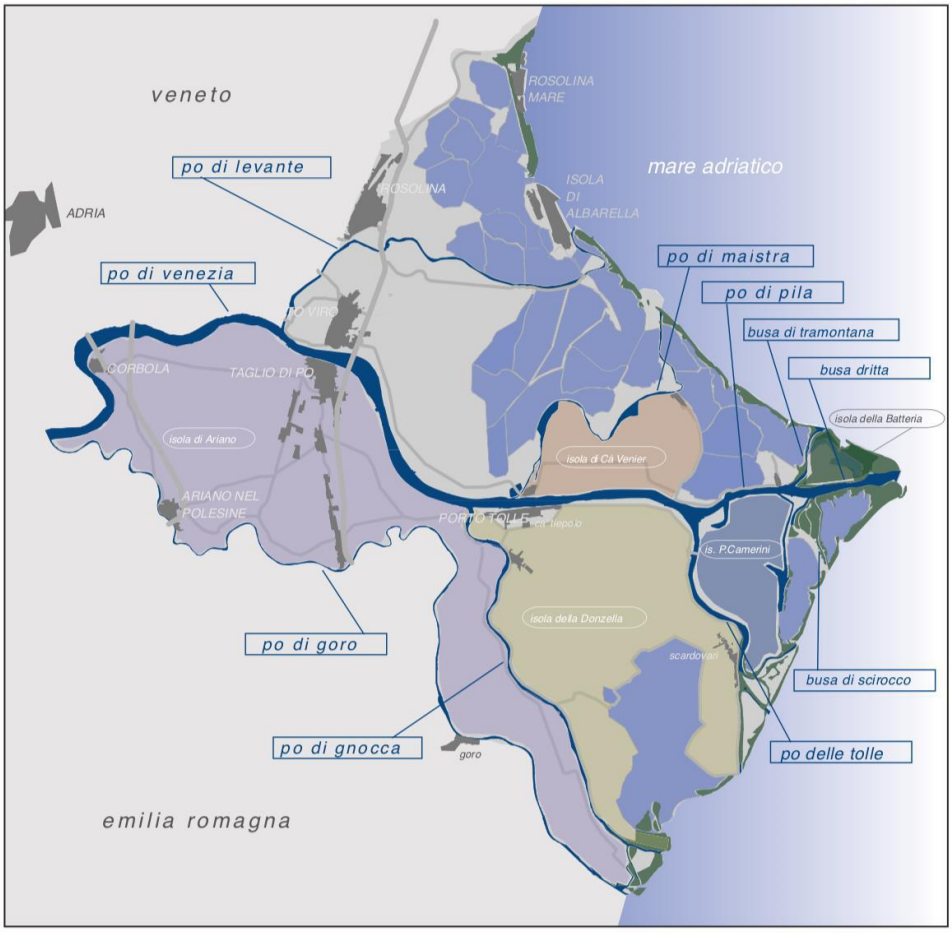
The Po Delta represents the final sub-basin subtending the entire Po catchment, and it develops as a flat region with a surface of 472.55 km2 (1.6 % of the total Po catchment), which is almost completely below the sea level (Piano di gestione del distretto idrografico del Fiume Po, Stato delle risorse idriche, 2016). In this region the Po River is divided into different branches: Po di Levante, Po di Maistra, Po di Pila (with the mouths of Scirocco and Tramontana), Po di Tolle, Po di Gnocca, Po di Goro.

The Po delta is made up of all its river branches and it also includes the territory between them. Consequently, its surface is approximately 18,000 hectares. According to this definition, the Po Delta falls entirely in the province of Rovigo, or Polesine, and occupies a vast portion in the eastern part of the Po River (from the branch of Po di Goro to the sea) representing an example of "active delta".

In a broader sense, it encompasses the largest area of the historical delta, the one included among the ancient delta branches of the Po River and this allows us to consider the part of the province of Ferrara forming a cusp shape between the vertices of Stellata, Sacca di Goro and Comacchio Valleys.

The Po delta includes protected natural areas established in the geographical area of reference:

- Veneto Regional Park of the Po Delta - operating since 1997, it includes practically the entire geographical delta of the Po, as defined above.
- Po Delta Regional Park of Emilia-Romagna - established in 1988, operating since 1996, it also includes territories that are part of the reservoir of other rivers (including the Reno). It includes the southern part of the historic Po delta, and a small part of the current delta (the “active delta”).



Po Delta region with its branches and lagoons (Atlante Delta del Parco).

The main Pila mouth of the Po River and the inlet to Sacca del Canarin. On the background the Enel power station is visible (not working anymore). https://emiliaromagna.cia.it/agrinsieme-ferrara-parco-nazionale-del-delta-del-po-idea-da-rivedere/.

With exception of embankments and dunes, most of the delta plain is completely below the mean sea level, with maximum depths of -4 m in some points. The territories between the river branches and the sea are defined “island” while the marsh areas close to the coast are lagoons, such as Caleri, Marinetta-Vallona, Barbamarco, Burcio, Basson, and the two focus areas of Canarin and Scardovari.

Here fresh and brackish waters coexist, generating an ephemeral landscape that changes with the variation of the inflows from the watercourses or from the sea. Salinity usually reflects this dynamic environment, showing a high spatial and temporal variability.

Particular hydrodynamic conditions characterize the entire area, in which the morphology is controlled by the interaction between sediments and water, as well as among depositional processes, stabilizing action of the vegetation and destructive power of the flood surges. As a result, the Po delta shows distinctive morphological features, like velme, barene and scanni, and it hosts an extensive range of

habitats ideal for the life of numerous species of migratory species and plants, representing an area with high level of biodiversity.

Most of the coastline is characterized by sandy beaches and mouth bars (scanni), except for some rigid hydraulic works along the coastline that are built to regulate some of the lagoon and fluvial mouths. Some reaches of the coast (e.g. Scanno del Palo and Bonello Bacucco) are defended through a series of wood groynes, others through a system of levees.

The economy of the Po Delta has historically developed in the traditional sectors of agriculture and craftsmanship, and activities typically related to fishing, aquaculture, and tourism have occupied a prominent role in the development of the area. Sugar production and sugar refinement represented an important source of income for local populations, with the sugar refineries developed thanks to the agricultural production and cultivation of sugar beet.

The morphological and environmental features of the lagoons represent a peculiar aspect in the management objectives of these areas. In this respect, some crucial features can be highlighted:

1. Low depth (1-2 m)
2. Connection to the sea through one or more mouths, which regulate the exchange of marine water.
3. Important annual temperature variation.
4. Large salinity variation.

The main problems of the lagoons are connected to the intrinsic and highly variability of their environmental and morphological conditions (as explained more deeply further in the chapter), which tend to change quickly in response to the external factors.

In particular: i) the salinity levels are extremely mutable and depend on the water exchanges with the sea and Po River (through floods); ii) the oxygen content in the shallowest areas has a large impact on the production activities; iii) the water quality is threatened by algae blooming and nutrients (phosphates and nitrates) coming from the fluvial waters; iv) the infilling of the lagoons, due to sediment deposition, influence the internal circulation and consequently the fishing and shell-farming production; finally v) the continuous erosion of the external spits that usually protect the lagoons from the open sea threaten the same existence of the lagoon areas.

One of the main challenges is the stabilization of the lagoon environment for the economic and development purposes, without deteriorating their value, especially considering the mutable conditions that the Climate Change will bring.

The phenomenon of the salt intrusion consists in the movement of saline water into aquifers. The salt wedge often develops at the river mouth, propagating at the bottom of the riverbed, since it has a higher salt concentration and is consequently denser than the fluvial fresh water. In the case of the Po River,

whose riverbed near the mouth is below the sea level, this process is almost always present and is pronounced throughout the year.

In recent decades, salt intrusion has assumed increasingly worrying proportions with a progressive intrusion almost in all the water bodies of the Po Delta, which has showed a tendency to increasing salinity. The phenomenon, which in the 1930s was observed only for two or three kilometers from the river mouth, increased later extending to about twenty kilometers.

The effects of the salt intrusion can be summarized as follows: 1. modification of the biological characteristics with changes in the trophic chain and consequent effects on the fish population with impacts on fishing activities; 2. interruption of withdrawals for irrigation, with serious damages on agricultural activities; 3. interruption of the water supply in the easternmost part of Polesine. The drinking water plants are not, in fact, able to desalinate the water; 4. salinisation of the aquifers. 5. drying up of coastal areas and micro desertification processes.

On the other hand, the intrusion of the saline water along the river mouths of the Po River, by modifying the environmental and trophic conditions of the delta branches, often leads to favorable situations for the settlement of juveniles of marine / brackish species, some of which of considerable interest for the local economy. Recently, the final part of Po della Pila has started to host large settlements of clam juveniles Tapes philippinarum, becoming an area of economic interest, as it represents an exploitable natural fishing area.

3.1.2 Present-day data collection

As regards the analysis of the current climatic condition, reference is made first to the National Plan for Adaptation to Climate Change (PNACC). The PNACC identifies homogeneous climatic macro-regions and national homogeneous climatic areas, starting from the analysis of the current and future climatic conditions. These areas have been characterized in terms of risk propensity and for specific sectors relevant to climate change in Italy within the National Strategy for Adaptation to Climate Change (SNAC).

The climatic analysis was conducted separately for the terrestrial areas and for the marine/coastal areas.

The parameters taken into consideration for the zoning of the terrestrial macro-regions on the reference climatic period (1981-2010) are the following:

Indicator	Abbreviation	Description	Unit of measure
Average annual temperature	Tmean	Annual average of the average daily temperature	(°C)
Days of heavy rainfall	R20	Annual average of the days with daily precipitation above 20 mm	(days/year)

Frost days	FD	Annual average of the days with minimum temperature below 0 °C	(days/year)
Summer days	SU95p	Annual average of the days with a maximum temperature above 29.2 °C (95th percentile average value of the maximum temperature distribution, observed via E-OBS)	(days/year)
Cumulative winter precipitation	WP	Total rainfall in the winter months (December, January, February)	(mm)
Cumulative summer rainfall	SP	Total rainfall in the summer months (June, July, August)	(mm)
Snow cover	SC	Annual average of the days in which the snow layer exceeds 1 cm	(days/year)
Evaporation	Evap	Cumulative annual evaporation	(mm/year)
Consecutive dry days	CDD	Annual average of the maximum of consecutive days with rain less than 1 mm/day	(days/year)
95th percentile of precipitation	R95p	95th percentile of precipitation	(mm)

The identification of "homogeneous climatic macro-regions", for which the data show similar climatic conditions in the last thirty years (1981-2010), was made by applying the cluster analysis methodology to a set of climate indicators (identified following Schmidt-Thomé and Greiving 2013) and using the E-OBS dataset (Haylock et al. 2008).

The Po delta area belongs to the following category:

MACROREGION 2	Average annual temperature (C°)	Days of heavy rainfall	Frost days	Summer days	Cumulative winter precipitation	Cumulative summer rainfall	95th percentile of precipitation	Consecutive dry days
	14,6 (±0,7)	4 (+1)	25 (±9)	50 (±13)	148 (±55)	85 (±30)	20	40(±8)

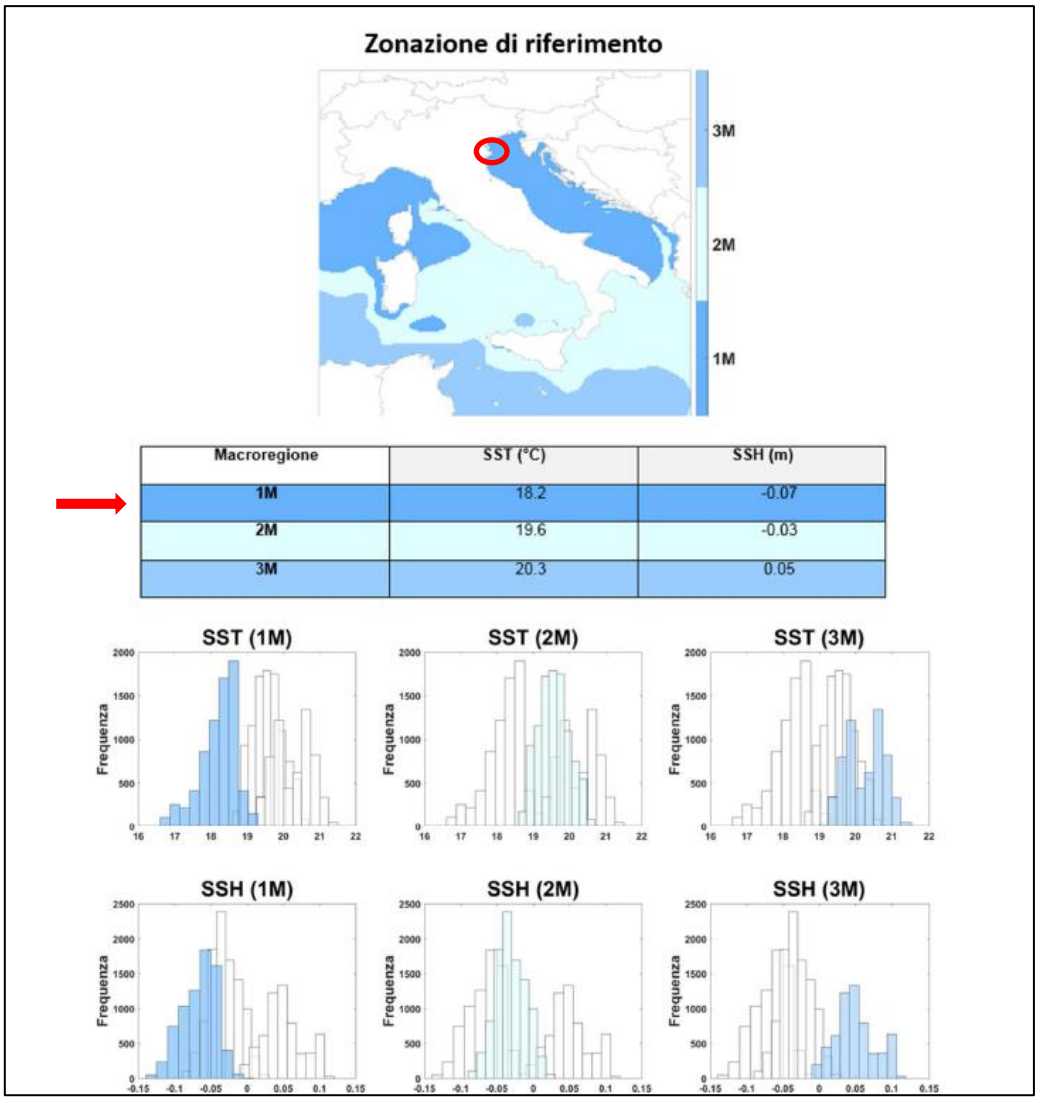
For the identification of homogeneous marine and coastal areas in the national territory it was not possible to use a proper methodology, unlike what was done for the climatic zoning of terrestrial areas.

Therefore, the considerations were made in relation to the physical variables available for marine areas, namely:

- Sea Surface Temperature (SST);
- Sea Level (Sea Surface Heights - SSH).

The figure below shows the marine climatic zoning over the available reference period (1987-2010). Furthermore, the distributions relating to each macro-region identified for the central Mediterranean are indicated for the SST (Sea Surface Temperature) and SSH (Sea Surface Heights) indicators.

The area of the PO delta is part of the "1M" homogeneous marine climate macro-region. This macro-region is characterized by the lowest values of surface temperature and sea level:



The National Climate Change Adaptation Plan has divided the territory into terrestrial climate macro-regions and marine climate macro-regions.

Furthermore, in order to know the future climatic conditions and the main impacts associated with them, it has identified the relative climatic anomalies with respect to two future scenarios, namely the intermediate scenario RCP4.5 and the extreme scenario RCP8.5.

Through the superimposition of macro-regions and climatic anomalies, it identified the areas characterized by the same current climatic condition and the same projection of future anomaly and identified “homogeneous climatic areas”.

For the terrestrial macro-regions, the climatic anomalies were calculated as the difference between the average values of the indicators in the future period 2021-2050 and the reference period 1981-2010.

These are based on the difference between two periods, both lasting 30 years. This length was considered adequate for the characterization of both the average values and the extremes of the atmospheric variables of interest (IPCC 2013a).

Therefore, as part of the PNACC, the climatic framework was assessed based on seasonal climate projections of anomaly of the average temperature and average cumulated precipitation. Subsequently, the selected indicators for the analysis of the future climatic condition were calculated, based on the data simulated by the COSMO-CLM Regional Climate Model, for the period (1981-2010) and for the period (2021-2050) with the scenarios RCP4.5 and RCP8.5.

The climatic anomalies are expressed partly in absolute values (average annual temperature, days of intense precipitation, frost days, summer days, snow cover) and partly in relative values (accumulated winter precipitation, accumulated summer precipitation, cumulative annual evaporation, 95th percentile of precipitation).

Compared to the analysis of the current climate, the Evap (Evaporation) indicator was considered instead of the CDD (Consecutive dry days) indicator.

For the marine macro-regions, in order to study the climatic anomalies expected during the mid-21st century, as regards the temperature and the sea level, the data of the climatic simulations for the period 1981-2050 were considered (Madec, 2008). They were obtained through the NEMO oceanic model applied to the Mediterranean Sea (7 km resolution) and forced with the atmospheric and hydrological data of the CMCC-CM climate model at ~ 80 Km of horizontal resolution (Scoccimarro et al., 2011).

The model configuration used in these simulations, identified as MEDSEA, was developed by the CMCC Foundation and describes the evolution of the system for the RCP8.5 climate scenario (Lovato et al. 2013).

In a previous Paragraph, the **Essential Atmospheric Variables** were listed:

ECV	Product
Precipitation	Estimates of liquid and solid precipitation
Pressure (surface)	Pressure
Surface Radiation Budget	Surface ERB longwave
	Surface ERB shortwave
Surface Wind Speed and direction	Surface wind speed and direction

Temperature (surface)	Temperature
	Daily maximum and minimum temperature
Water Vapour (surface)	Water vapour

In the Veneto Region, the analysis of meteorological variables is carried out through the satellite, meteorological radar and numerous meteorological stations (Regional network of meteorological parameters).

The network of telemetry stations for Meteorology and Agro-meteorology is currently managed by the Regional Environment Agency (ARPAV) and consists of 203 stations divided into meteorological, agro-meteorological and hydrometric stations.

These are distributed throughout the entire territory of the Veneto Region and continuously measure the main meteorological, agro-meteorological and hydrological parameters, transmitting them to an acquisition station.

The network consists of:

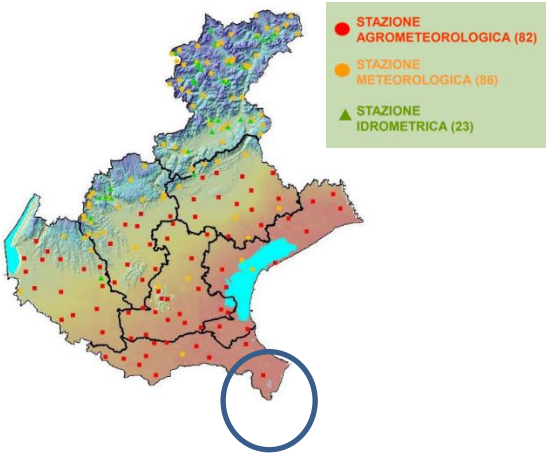
n. 78 agrometeorological stations;

n. 85 weather stations;

n. 24 hydrometric stations;

n. 16 repeaters (to guarantee the connection);

2 data centers.



In the Po Delta there are 2 monitoring stations (agrometeorological stations):

1. Porto Tolle (RO) – Pradon.
2. Rosolina - Po di Tramontana.

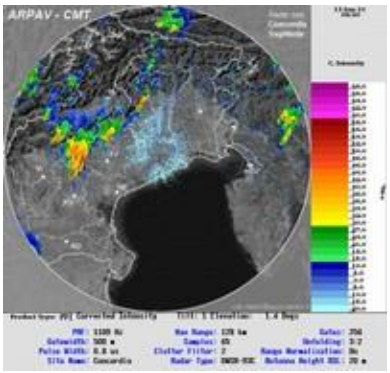
The data are acquired according to the indications of the World Meteorological Organization (https://www.arpa.veneto.it/temi-ambientali/meteo/monitoraggio/rete-di-telemisura-1):

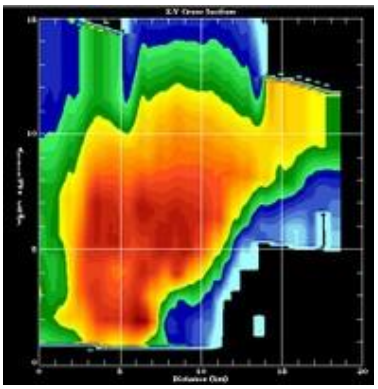
Type of data	Acquisition interval	Special measures
Wind direction	Average of the values acquired every 10 minutes	
Wind intensity	Average of the values acquired every 10 minutes	Time and value (in m/s) of the maximum wind gust
Air temperature	Every 15 minutes	Time and value (° C) of the minimum and maximum temperature
Relative air humidity	Every 15 minutes	Time and value (in%) of the absolute minimum and maximum humidity
Leaf wetness	Average of the values acquired every 15 minutes	
Soil temperature	Every 60 minutes	
Atmospheric pressure	Every 30 minutes	Time and value (in hPa) of the absolute minimum and maximum pressure
Incident solar radiation	Average of the values acquired every 15 minutes	Heliophane (hh.mm); K index (value between 0.00 and 0.80)
Reflected solar radiation	Average of the values acquired every 15 minutes	Heliophane (hh.mm); K index (value between 0.00 and 0.80)
Rainfall	Cumulative value every 5 minutes	
Evaporation	Cumulative value every 60 minutes	
Hydrometric level	Every 15 minutes	Time and value (in m) of the minimum and maximum level

The Civil Protection of Veneto has equipped itself with a web platform for the control and processing of the data acquired automatically by the hydro-meteorological detection stations. The system indicates in real time the alert levels useful for preventing flood phenomena. In reality, the flood control system involves a larger area, and makes use of manual monitoring, especially in the secondary and reclamation-irrigation network, which, however, are not automatically recorded. The management of water flows involves a vast interregional territory, in which, in relation to the phenomena in progress, the flows are diverted in order to avoid flood events.

The use of radar has significantly expanded and improved the ability to monitor rainfall in real time, with high spatial resolution. This is also true for phenomena with a marked local character. In fact, this tool allows to locate, within a certain area, the precipitation in progress and to estimate its intensity. Finally, it allows, through appropriate data processing techniques, to follow in detail its movement and evolution and foresee its displacement after a few hours.

In the Veneto region there are three meteorological radars. One in the province of Padua, in Teolo, on the top of Monte Grande (Euganean Hills), at an altitude of 472 meters above sea level; one in the province of Venice, in Concordia Sagittaria in the locality of Loncon, at an altitude of 20 meters above sea level; one in the province of Verona, in Valeggio sul Mincio.





ARPAV has been continuously measuring temperature, wind and humidity in the Planetary Boundary Layer (PBL) since 2005 - up to over 1,000 m on the vertical of the measurement point - through automatic control units with a maximum detection frequency of 15 minutes. Measurements are made through SODAR and MWR Passive Radiometers (Micro Wave Radiometer). The content of the graphs is updated every 1-3 hours as soon as the non-validated value detected by the profiler becomes available.

As regards the measurements of UV radiation, the Veneto Region has two monitoring stations (managed by ARPAV). One of these has been located in Vicenza since 2012 at the headquarters of the ARPAV Provincial Department, the other was activated in March 2017, and is located at Passo Valles, on the border between the provinces of Belluno and Trento, at an altitude of 2032m a.s.l.

In both cases, a pair of broadband radiometers was installed in order to evaluate the UV-index and measure the UV-A irradiance.

The measurement carried out at the Vicenza station may be representative of the situation that can be found in the flat areas of Veneto, starting from the coastal area to reach the slopes of the pre-Alpine area.

Concerning the **Essential Land Variables (ELV),** the list is very extensive and includes very different parameters. The Veneto Region has monitoring networks for some categories of parameters, in accordance with national and EU legislation.

ECV	Product
Above-ground biomass	Maps of AGB
Albedo	Maps of DHR albedo for adaptation
	Maps of BHR albedo for adaptation
	Maps of DHR albedo for modelling
	Maps of BHR albedo for modelling
Anthropogenic Greenhouse Gas Fluxes	Emissions from fossil fuel use, industry, agriculture and waste sectors.
	Emissions/ removals by IPCC land categories
	Estimated fluxes by inversions of observed atmospheric composition - continental
	Estimated fluxes by inversions of observed atmospheric composition - national
	Hi-res CO2 column concentrations to monitor point sources
Anthropogenic Water Use	Volume of water per year
Fire	Burnt Areas
	Active fire maps
	Fire radiative power
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	maps of FAPAR for modelling
	maps of FAPAR for adaptation
Groundwater	Groundwater volume change
	Groundwater level

	Groundwater recharge
	Groundwater discharge
	Wellhead level
	Water quality
Lakes	Lake water level
	Water Extent
	Lake surface water temperature
	Lake ice thickness
	Lake Ice Cover
	Lake Colour (Lake Water Leaving Reflectance)
Land cover	Maps of land cover
	Maps of high resolution land cover
	Maps of key IPCC land use, related changes and land management types
Land Surface Temperature	Maps of land surface temperature
Latent and Sensible Heat fluxes	
Leaf Area Index (LAI)	maps of LAI for modelling
	maps of LAI for adaptation
River Discharge	River discharge
	Water Level
	Flow Velocity
	Cross-section
Snow	Area covered by snow
	snow depth

	snow water equivalent
Soil Carbon	%Carbon in soil
	Mineral soil bulk density to 30 cms and 1m
	Peatlands total depth of profile, area and location
Soil Moisture	Surface soil moisture
	Freeze/thaw
	Surface inundation
	Root-zone soil moisture

The Veneto Region has monitoring networks for some categories of parameters, in accordance with national and EU legislation.

The main among these is the regional network for the qualitative and quantitative monitoring of water (rivers, lakes, groundwater, transitional waters and lagoons), in accordance with the water framework directive (Dir 2000/60/EC) and Legislative Decree 152/2006. The monitoring activities of the regional network are carried out by ARPAV.

Through these networks, data relating to the sections **highlighted in light blue** are collected.

- Groundwater

As for the regional groundwater bodies, they are controlled through two specific monitoring networks:

- a network for chemical monitoring;
- a network for quantitative monitoring.

The annual monitoring program includes:

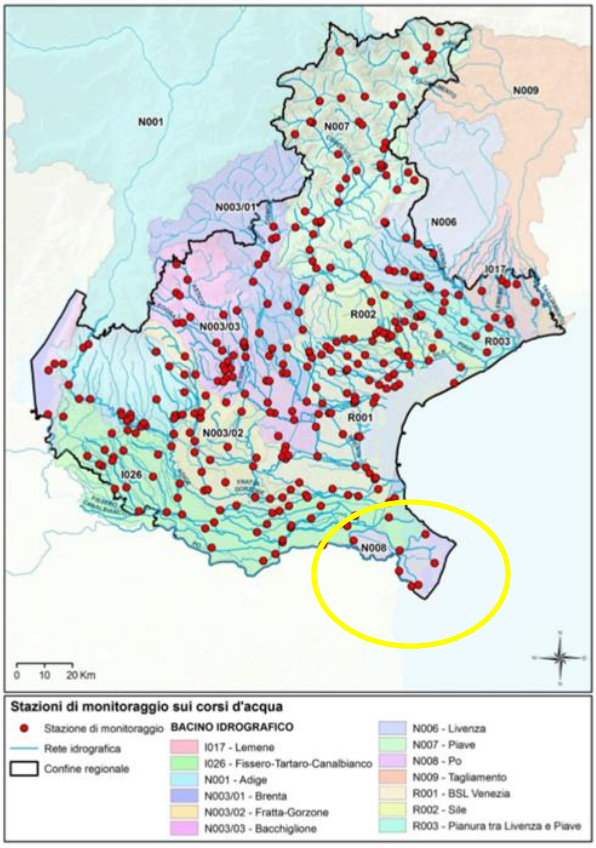
- chemical analyzes on about 300 monitoring points every six months, in spring (April-May) and autumn (October-November);
- piezometric level measurements on over 210 wells / piezometers on a quarterly basis (late January, late April, late July and early November);
- flow measurements on over 40 sources twice a year in correspondence with the sampling.

- Lakes (there are no lakes in the pilot site).
- Anthropogenic Water Use:

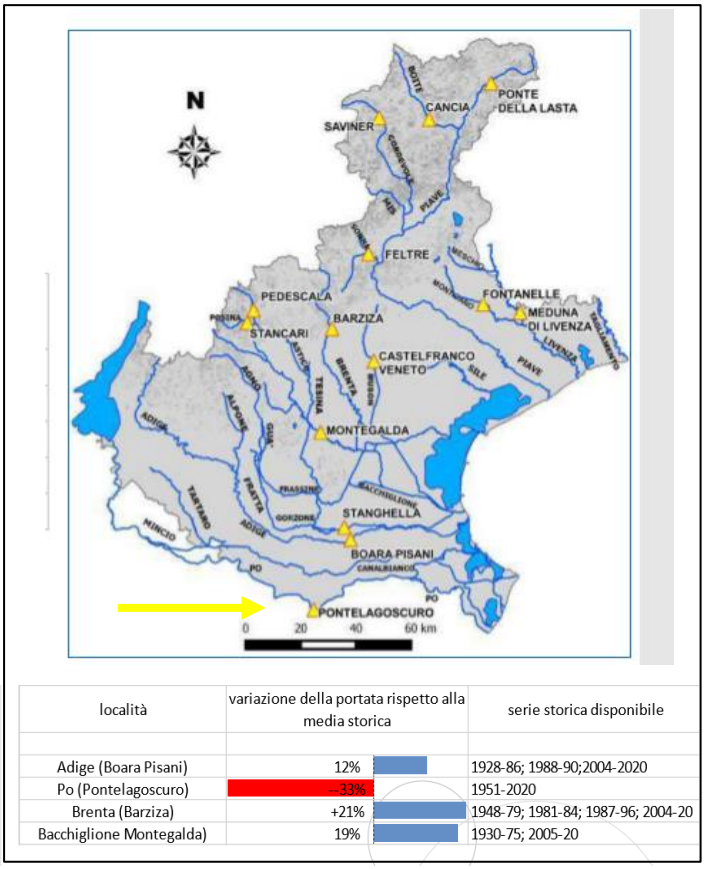
The matter is regulated by the decree 1775/33. The practices relating to the use of public water are managed by the Region (Departments of Civil Engineering). They are accompanied by the projects of the works, as well as by a series of data relating to the use, the quantities requested, etc. The data is collected in a specific database called ALICE.

- River Discharge:

The Veneto river monitoring network includes the stations for the definition of the chemical and ecological status. The monitored stations are in total 320. It also includes the monitoring network of the flow rates of the major Venetian rivers (for the Po Delta area there is a continuous monitoring station located in Pontelagoscuro). In addition, flow measurements are carried out in the context of specific study projects.



Watercourse monitoring stations (monitoring network pursuant to Legislative Decree 152/06)



località	variazione della portata rispetto alla media storica	serie storica disponibile
Adige (Boara Pisani)	12%	1928-86; 1988-90;2004-2020
Po (Pontelagoscuro)	-33%	1951-2020
Brenta (Barziza)	+21%	1948-79; 1981-84; 1987-96; 2004-20
Bacchiglione Montegalda)	19%	1930-75; 2005-20

Flows of water courses (May 2021)

Measurement sections located on the branches of the delta (2002-2011 monitoring campaign)

As for the other topics, they are briefly described below.

- Above-ground biomass.

There are numerous thematic maps, such as: "Regional Forest Map" (2006), scale 1:10,000; "Map of types and landscape units", scale 1: 250,000; "Habitat Map" and "Map of Protected areas (Natura 2000)", scale 1: 50,000, provided for by the CORINE Biotopes Classification system, as determined by the Council of the European Commission.

- Anthropogenic Greenhouse Gas Fluxes

Air quality monitoring is defined by Legislative Decree no. 155/2010, in transposition and implementation of Directive 2008/50/EC. In the province of Rovigo there are 4 measuring stations, managed by ARPAV. There is also 1 station dedicated to monitoring air quality, in relation to the regasification plant built off Porto Levante. This is also the only station located within the study area. Sampling frequency: daily / hourly. Among the parameters detected are: fine dust (PM10 and PM2.5), nitrogen oxides (NOx), nitrogen oxide (NO), nitrogen dioxide (NO2), ozone (O3), carbon monoxide (CO), benzene (BTX), hydrocarbons (PAHs) and Metals.

- Land cover

The Veneto Region has created thematic maps in various scales including the Land Cover Map, CORINE Landcover of 2000 at a scale of 1: 25,000; the Map of the inhabited centers 1: 25.000 (ISTAT); Geological and geomorphological maps.

A list of the collected data was reported in the report WP3.2.3 RDV_ANNEX 3-DATA SET OF GEOMORPHOLOGICAL PARAMETERS. An excerpt is reported.

WP3 - AVAILABLE DATA - GEOMORPHOLOGICAL PARAMETERS		
YEARS / REFERENCE PERIOD	**DATA DESCRIPTION (reference area, scale, typology)**	**OWNER DATA**
2018	Topo-bathymetric survey, lagoons of Po Delta, (Scardovari, Caleri, Canarin, Barbamarco); dwg, xyz	Veneto Region - Soil Defense Directorate
2005, 2008	57 cross-sections every 1 km along the Po Delta coast (Rovigo district), between the Adige mouth and Po di Gnocca; dwg, x,y,z more frequent near costal works	Veneto Region - Soil Defense Directorate
2012	Cross-sections every 200 m along the shoreline of Rosolina from Adige to Po di Levante; dwg, x,y,z	Veneto Region - Soil Defense Directorate
2014	Cross-sections every 1 km from Po di Levante and Po di Goro; dwg, x,y,z	Genio Civile di Rovigo Veneto Region - Soil Defense Directorate
	Micro-survey of the Veneto plain	Veneto Region
	Contour map of the Veneto Region	Veneto Region
Different years untill 2005	Regional technical maps (CTR), available for each Municipality of Veneto Region, urban plan, 1:5.000 - 1:10.000; tiff, dxf, shp	Veneto Region
1978, 1983, 1990, 19999, 2008, 2009	Reven flights, Po Delta area, index map, "Regione del Veneto – L.R. n. 28/76 Formazione della Carta Tecnica Regionale"; jpg	Veneto Region
2007, 2012, 2015	Ortophoto, Veneto Region	Veneto Region
2006; 2009; 2012 - (grid 0,5 m)	DTM high resolution from Lidar, Entire coast of Rovigo district; xyz, asc	Veneto Region
2018- (grid 0,5 m)	DTM high resolution from Lidar, Entire coast of Rovigo district including lagoons; xyz, asc	Veneto Region
2015	DTM 2015 of the river Po and of the Delta reaches; grid	Interregional Agency for the Po River (AiPo)
	Flood hazard map in the Fissero-Tartaro-Canalbianco catchment	Veneto Region
	Alert areas for the hydrological and hydraulic risks; shp	Veneto Region
	Number of "rigid" defense works along the coastline; c0402020_NumDifesaLitoralR; shp	Veneto Region
	Coastal area with "soft" defense works; c0402010_SupSpiaggeDifesaM; shp	Veneto Region
	Area with mechanical drainage, Veneto Region; shp	Veneto Region
2014-2018	Topographic survey of the levees elevation (both along the river Po and the coast); shp	Interregional Agency for the Po River (AIPO)
2018	Coastal areas with a retreat trend, Veneto Region; shp	Veneto Region
2018	Coastal areas with a progradation trend, Veneto Region; shp	Veneto Region

2018	Coastal areas subject to subsidence, Veneto Region; shp	Veneto Region
2006-2009, 2009-2012, 2012-2018	Po Delta, Rovigo district, shoreline variation from Lidar, Contours (0,25 m), n. 57 crossing land-sea; shp	Veneto Region
2012	Land use Veneto Region (Corine Land Cover)	Veneto Region
2005-2019	RETE NATURA 2000 of Veneto Region	Veneto Region
	Map of the texture and skeleton of the soil in the first 100 m, Veneto, 1:50.000, 1:250.000; shp	Veneto Region
	Soil Map of the hydrological group "Gruppo Idrologico USDA", 1:50.000; shp	Veneto Region
	Map of the texture and skeleton of the soil in the first 50 cm, Veneto, 1:50.000, 1:250.000 ; shp	Veneto Region
	Map of the depth of the first aquifer in the soil; shp	Veneto Region
	Database with different classes of lithology composing the Veneto Region, 1:250.000, c0501 – Litologia; shp	Veneto Region
	Lithology of the Rovigo Province; shp	Veneto Region – Rovigo Province
	Width of the shoreline, c0402030_AmpiezzaSpiagge; shp	Veneto Region
	Veneto Region, maps of Soil and Subsoil; shp: ARPAV_suoli50k_unitacartografiche ARPAV_suoli50k_distretti ARPAV_tessuoli50k50cm ARPAV_idrosuoli50k ARPAV_suoli50k_unitaPaesaggio ARPAV_tessuoliven50cm ARPAV_suoli250k_unitacartografiche ARPAV_metmetalloidi ARPAV_suoli50k_sovraUnitaPaesaggio ARPAV_suoli250k_sistemiSuoli ARPAV_idrosuoliveneto ARPAV_tessuoli50k100cm ARPAV_permsuoli50k ARPAV_suoli250k_regioniSuoli ARPAV_permsuoliveneto ARPAV_suoli250k_provinceSuoli	ARPAV
2009	Lithological map of Rovigo Province (from PTCP: Provincial territorial Coordination Plan); shp	Veneto Region, Rovigo Province
1988	Geological map of Veneto region, 1:250.000; paper	Veneto Region
1954-2003	Geomorphological map of Po River Delta derived from aerial photo surveys (Flights GAI 1954-55 and TerraItaly NR 2003), 1:60,000; pdf	Veneto Region
2009	Geomorphological map of Rovigo Province, from PTCP; shp	Veneto Region, Rovigo Province
1987	Geomorphological map of Veneto region, 1:250.000; paper	Veneto Region
	Coastal area, PTRC in force, Veneto Region; shp	Veneto Region
	Coastal flood areas (for storm surges), PTRC in force, Veneto Region; shp	Veneto Region
2007	Erosion processes, analysis and technical proposals - Trieste University-DiSGAM. Anno 2007 and new revision (Rosolina shoreline); pdf	Veneto Region - Soil Defence Directorate
2007	Evolution trend of Po di Maistra mouth and nearest area - Ferrara University-Dipartimento Scienze della Terra. (Po di Maistra mouth area); pdf	Veneto Region - Soil Defence Directorate
2008	Sacca di Scardovari sand bar morphological evolution - Ferrara University- Dip. Scienze della Terra (from Po di Tolle to Po di Goro); pdf	Veneto Region - Soil Defence Directorate

2013	Rosolina e Scardovari litoral morphological evolution. Ipros- Ingegneria Ambientale srl. (Rosolina shoreline end from Po di Tolle to Po di Gnocca); pdf	Veneto Region - Soil Defence Directorate
2013	Operation strategy for the Po river delta litorals. Hydrosoil srl. (Rosolina shoreline end from Po di Tolle to Po di Gnocca), pdf	Veneto Region - Soil Defence Directorate
2014	Delta Po geodatabase - Universita' di Trieste - Dipartimento di Matematica e di Geoscienze – (Entire coast of Rovigo district), pdf	Veneto Region - Soil Defence Directorate

- Snow

ARPA Veneto has a network of automatic snow and weather stations, it is a subset of stations belonging to the integrated regional network of meteo-hydro-nivo-meteorological monitoring.

It consists of 17 automatic stations located in the Dolomites and Venetian Pre-Alps in areas of medium or high altitude which are significant from a snow point of view. The distinctive character of these stations is that, together with the normal meteorological sensor equipment, they are equipped with one or more snow sensors (snow gauge, snow thermometers, surface temperature thermometer). The stations are powered by solar cells with buffer batteries and are governed by a control unit that manages the various sensors installed and the data transmission system.

The data collected by the control units are transmitted to the acquisition centers of Arabba and Marghera, which send them to the national Civil Protection network and to SIRAV, the database to which the main regional authorities have access.

Each snow weather station measures the following parameters:

- Air temperature and humidity
- Wind direction and speed
- Incident and reflected solar radiation • Height of the snow cover
- Surface temperature of the snowpack
- Temperature inside the snowpack (on 12 levels).

In the delta area, obviously there is no snow and weather station.

- Soil Carbon

The data were collected in numerous sampling campaigns and are contained in the reports accompanying the regional soil map and the soil map of the province of Rovigo.

The **Essential Ocean Variables** (EOVs) are listed above.

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover and composition
Surface currents	Stable carbon isotopes	Macroalgal canopy cover and composition
Subsurface currents	Dissolved organic carbon	Mangrove cover and composition
Sea surface salinity		Microbe biomass and diversity (*emerging)
Subsurface salinity		Invertebrate abundance and distribution (*emerging)
Ocean surface heat flux		
CROSS-DISCIPLINARY		
Ocean colour	Ocean Sound	

As regards the monitoring points of the lagoons and the coast (dir. 2000/60), the Region, through ARPAV, has been monitoring the environmental conditions of the lagoon and transition areas since 2008. The activity is carried out in accordance with the provisions of the Legislative Decree 156/2006.

The monitoring activities are carried out by means of 9 multi-parameter probes.

The analyzed parameters are water temperature, dissolved oxygen, pH, salinity, conductivity, chlorophyll.

Measurements are performed at all sites every 30 minutes.

The reference values are indicated in Legislative Decree 152/06 (third part, annex 2 section C tab / C) which identifies the general criteria and methodologies for measuring the qualitative characteristics of the water intended for the life of mollusks.

Through continuous monitoring, the trend towards environmental disturbance situations, such as anoxia and dystrophy, is detected in real time.

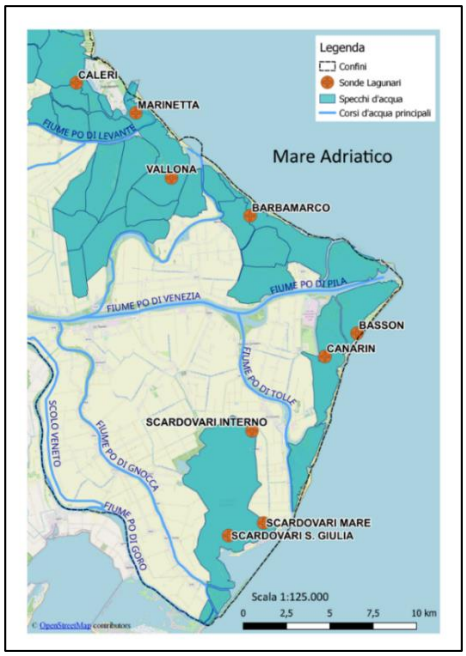
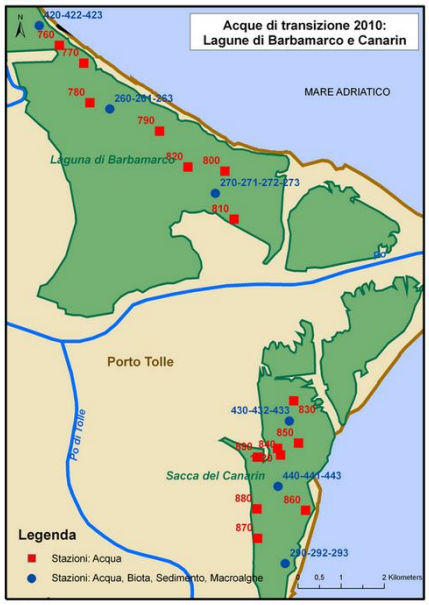


Fig. 17.1.4 - Acque di transizione: Lagune di Barbamarco e Canarin – Anno 2010



Fonte: ARPAV

Location of the probes and monitoring stations

The results of this monitoring are integrated by a monitoring network by detecting, as already reported in the "Report on existing data and relative gaps" Activity 3.4, Task 3.4.1, the following parameters:

- Physical-chemical parameters. Water: temperature, pH, salinity, Dissolved Oxygen concentration (DO), Total Suspended Solids (TSS), Dissolved Inorganic Nitrogen (DIN), Orthophosphate (PO_4).
- Biological parameters: Chlorophyll-a, Multivariate-AZTI's Marine Biotic Index (*MAMBI*) for Macrozoobenthonic communities, Macrophyte quality index (MaQI) for macrophytic communities, Manila clam (*Ruditapes philippinarum*), Natura 2000 habitats, reedbeds mappinig.

In addition, pursuant to Legislative Decree 152/06, marine-coastal water bodies are monitored. The current Regional Monitoring Network has been active since January 2010 and consists of nine transects, perpendicular to the coastline. Each consisting of several sampling stations, located near the main sources of pressure.

In the two marine water bodies, a station for the water matrix and one for the sediment and benthos matrix are identified respectively.

The monitoring network for the assessment of the environmental status includes a series of points that are also monitored for the control of the compliance of the water with the life of the mollusks.

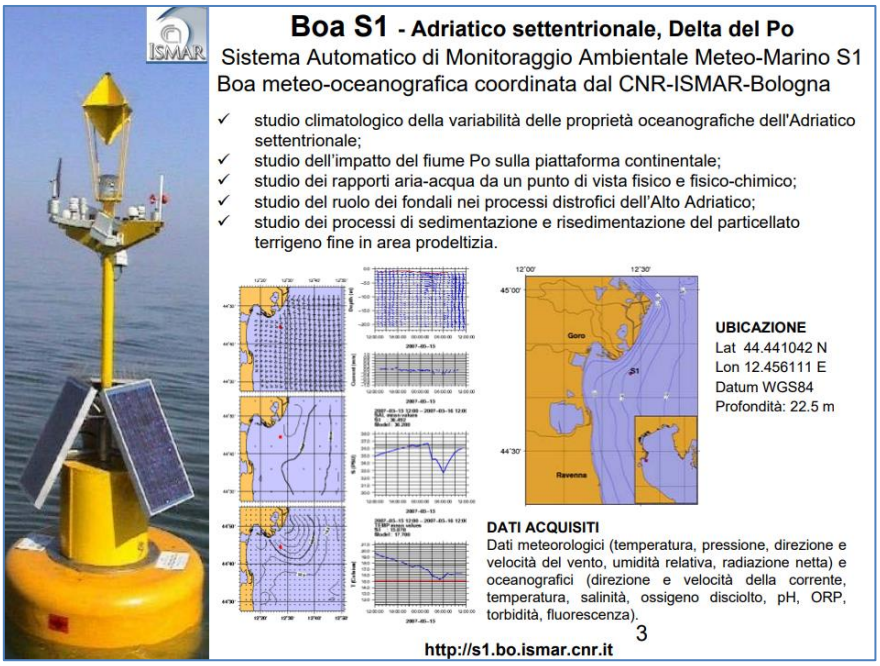
The main Physics and Biogeochemistry parameters are monitored as well as Biology and Ecosystems, as part of the monitoring required by Directive Directive 2008/56/EC (Marine Strategy).

The parameters relating to the qualitative descriptors are monitored for the determination of the good environmental status (as established by Legislative Decree No. 190/2010) 1. Biodiversity. 2. Non-indigenous species. 3. Fish and shellfish exploited for commercial purposes. 4. Marine trophic network. 5. Eutrophication. 6. Integrity of the seabed. 7. Hydrographic conditions (marine ecosystems). 8. Presence of contaminants. 9. Contaminants found in fish and other seafood intended for human consumption. 10. Marine litter. 11. Submarine sound sources.

Furthermore, the Institute of Marine Sciences of the National Research Council manages a multi-parametric observing system for the North Adriatic, which includes:

- "Acqua Alta" oceanographic platform, 15 km offshore in front of Venice, bottom depth 16 m. Meteorological data: wind speed and direction, air temperature, humidity, solar radiation, precipitation. Oceanographic data: sea temperature, sea level, ADCP currents, waves. Surface and scuba web cams Wide band intranet connection allowing real time data transmission.
- S1 Station, delta Po area, bottom depth 22.5 m. Multi-parametric buoy. Oceanographic data: temperature, salinity, dissolved oxygen, pH, ADCP currents, waves. Meteorological data: air temperature, atmospheric pressure, relative humidity, net radiation, wind speed and direction.

Real time data transmission. The station is part of the LTER Northern Adriatic Site. The Boa S1 has been in place since 2004.



Finally, the ISPRA Tides and Lagoons Area, which has acquired the competences of the Hydrographic and Mareographic Office of Venice, now has a network of 26 meteo-tidegraphic stations distributed along the Adriatic coast.

At the Delta there is only one littoral tide station (Porto Caleri) and one wind station (Po mouth, near Scardovari). The data are collected in real time.

3.1.3 Sampling strategy for the future

A network dedicated to climate change must consist of a set of stations belonging to various measurement networks (meteorological, agro-meteorological, hydro-meteorological, etc.).

It must also:

- include measurement stations for which long and continuous time series of data are available;

- guarantee the homogeneity of the spatial distribution and the density adequate to the representation of the climatic variables in the territory;
- ensure the development and constant updating of climate change data and trend indicators,
- ensure the adequacy and uniformity of the methods for calculating climate statistics;
- provide series of data, albeit from different sources, such as possibly to allow the calculation and use of climate indicators with semi-automatic procedures.

A monitoring system, specific for the Po Delta, will have to respect these principles. Furthermore, it must be integrated into the National System.

Furthermore, climate monitoring must allow:

1. immediately (hours or a few days), to alert the population in the event of catastrophic events, such as floods, storm surges, storms, etc .;
2. to plan the projects in the medium term (10-20 years) on the basis of the trends of selected climatic and environmental indicators;
3. to improve the performance of simulation models used to predict long-term climatic and environmental scenarios;
4. to control over time the consequences of the interventions implemented to counter the effect of climate change (planning).

The expansion of the existing monitoring network is expected / hoped for, with reference to the Delta area both inland and lagoon areas, in addition to the coastal strip and the overlooking marine area.

In this regard, the Regional Council, with resolution no. 1529 of 17/11/2020, adopted the Regional Plan for Recovery and Resilience (PRRR) of Veneto, which includes numerous project proposals including the "Strengthening, development and innovation of environmental monitoring and controls" project, in thematic area "Investments aimed at achieving European Green Deal objectives".

The priorities of the European Green Deal include:

- Protect our biodiversity and ecosystems;
- Reduce air, water and soil pollution;
- Actions for a circular economy;
- Improve waste management;
- Ensure the sustainability of our blue economy and the fisheries sectors.

The proposal provides for the development, enhancement and innovation of environmental monitoring and controls, performed by ARPAV, with particular reference to ongoing emergencies including climatic ones. The project plans to develop a permanent monitoring system for species and habitats, in line with the envisaged objectives, aimed at obtaining “clean air and water, healthy soil and biodiversity”. This represents one of the challenges of the Green Deal. Implementation time 48 months, total financial requirement 21 million euros.

3.2 Banco di Mula di Muggia

3.2.1 Site description

The Banco Mula di Muggia is located in Friuli Venezia Giulia Autonomous region. It is entirely included in the Municipality of Grado (province of Gorizia GO, Italy), on the northern coast of the Adriatic Sea, located between the Grado inlet and the mouth of the Isonzo River. The coordinates are between 13°24’36” and 13°28’15” East and between 45°21’17” and 45°39’30” North.

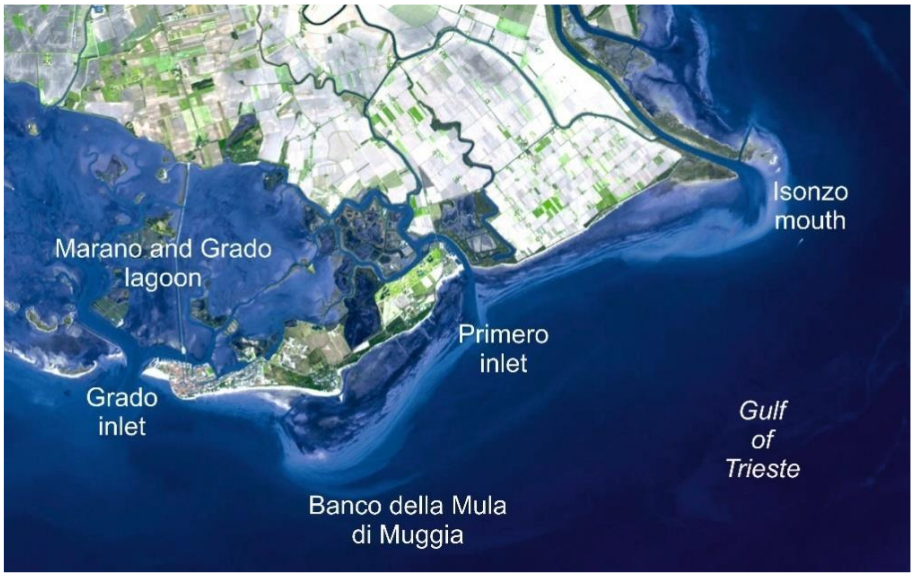
It is part of the system of low sandy beaches of the Friuli Venezia Giulia, limited to the west by the mouth of the Tagliamento, and to the east by that of the Timavo, where the high rocky coast begins. The coastline has undergone significant changes in historical times due to natural processes but also to anthropic actions i.e. land reclamation and tourism development.

The system is very sensitive to sea-level rise and storm patterns, thus providing clues to process changes through time. The tidal magnitude is unusual for the Mediterranean Sea, with semidiurnal mean and spring tidal ranges of 65 and 105 cm respectively. The passage of atmospheric low pressure systems is able to amplify tidal water levels up to 160 cm: the so called “acqua alta”. Climate is temperate, influenced by ENE (Bora) and SE (Sirocco) winds.

External sandy bars tend to migrate toward south-west, following the littoral drift generated by waves. On the western terminus, the bathymetric contours curve abruptly, thus inducing bars to shift landward toward the touristic beaches. Therein, sediment tends to accumulate over time, and the area is currently a sediment sink for the whole up-drift sector.

The area of Banco Mula di Muggia is recognized for its outstanding biodiversity: it is a geosite and it is part of the Special Area of Conservation IT 3330006. Habitat 1110, Sandbanks, which are slightly covered by sea water all the time and Habitat 1140, Mudflats and sandflats, not covered by seawater at low tide, are its features.

On the edge of the protected area, many touristic activities are present; they are mainly seasonal activities, linked to seaside tourism. Four big camping-resorts with fully equipped beaches are located in the eastern part. Grado Pineta is a touristic district of Grado having several hotels, restaurants and second houses; a small marina is present too. The territory of the municipality of Grado has a touristic offer of 23,791 beds (2016). Most of the beaches are equipped, with services for tourists such as bars, and beach equipment, while the Banco Mula di Muggia area, thanks to its environmental peculiarities, has low anthropic pressures because shallow waters and silty sediments are not a tourist attraction.



Overview of the study area.

Arial view of the Banco Mula di Muggia

The management of the camping and touristic villages ask for sandy beaches for their guests, but actually their businesses look onto the wide muddy intertidal zone partially covered by seagrass protected by the succession of sandy bars. This is the result of a wrong urban planning of the sixties of the last century, when seaside tourist activities were setup in a paleo lagoon area.

The other problem is the external sandy bars that tend to migrate toward south-west causing the loss of quality of the main touristic beach of Grado, the seabed becomes lower and the muddy component prevails.

On the other side, the system of banco Mula di Muggia is very sensitive to sea-level rise and storm patterns, as well as the entire urbanized part of the city of Grado.

Therefore, a solution must be driven by natural trends, as a fundamental guideline for a correct human use, thus forcing us to a responsible and sustainable development. This permits to limit possible impacts of definitive choices, as those following hard engineering philosophy. Configuration regimes aimed at beach nourishment or morphological reshaping could be possible options.

3.2.2 Present-day data collection

Data collection project has targeted the institutional information made available by Regional Environmental Protection Agency of Friuli Venezia Giulia (ARPAFVG) (sampling station). The timeframe considered for the ARPAFVG dataset collection covers the period 2009-2019. This activity was focused on the acquisition of following parameters:

Physical-chemical parameters: Water temperature, salinity, pH, Dissolved Inorganic Nitrogen (DIN), Orthophospates, Turbidity, Oxygenation.

Biological parameters: Chlorophyll-*a*, Natura 2000 habitats map (2011), Habitats map according to the Regional classification system (2008).

Moreover, four orthophotos of the study area were used to map the seagrass meadow over time: 1978: aerial photos CGR; 2006, 2014 and 2018: aerial photos AgEA. Further data collected within the same timeframe but not considered in this study, but included in Annex III and in D3.4.2, include:

- Macrozoobenthos
- Phytoplankton
- Macrophytes
- Other physical – chemical variables

Physical-chemical and biological parameters. Banco Mula di Muggia stations sampled (red dot) in the period 2009-2019.

A description of the parameters collected and considered for the assessment of the status and trend of physical chemical parameters in the Banco Mula di Muggia is resumed in the following table:

Tabular synthesis of the physical-chemical parameters considered for Banco Mula di Muggia

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD (and, if known, indicate the monitoring frequency)	AVAILABILITY of the data (institution/web-site, …)
Water temperature	.xls	CTD probe	CE131 ME111 (WFD)	sea water measurements	2009 – 2019 / monthly measurements	ARPA FVG
pH	.xls	CTD probe	CE131 ME111 (WFD)	sea water measurements	2009 – 2019 / monthly measurements	ARPA FVG
Water salinity	.xls	CTD probe	CE131 ME111 (WFD)	sea water measurements	2009 - 2019 / monthly measurements	ARPA FVG
DIN, PO4 ccontent in water	.xls	P and N total from water samples	CE131 ME111 (WFD)	sea water measurements	2010 - 2019 / monthly measurements	ARPA FVG
Turbidity	.xls	CTD probe	CE131 ME111 (WFD)	sea water measurements	2014 - 2019 / monthly measurements	ARPA FVG
Oxygenation	.xls	Dissolved Oxygen in column water using CTD probe	CE131 ME111 (WFD)	sea water measurements	2009 - 2019 / monthly measurements	ARPA FVG

A resume of the biological data collected and considered for the assessment of the status and trend of biological parameters in the Banco Mula di Muggia is resumed in the following table.

Biological investigations considered for the Banco Mula di Muggia include the ecological quality elements chlorophyll-*a* (as proxy of phytoplankton biomass) and seagrass (study on the temporal evolution of seagrass meadows in the Banco della Mula di Muggio during the period 1978-2018).

Four orthophotos of the study area were used to map the seagrass meadow over time: 1978: aerial photos CGR; 2006, 2014 and 2018: aerial photos AgEA. All the orthophotos were taken in spring or summer. The photointerpretation was carried out after a preliminary field campaign carried out in October 2019 to characterize the meadow. The study area (5.55 km^2) was defined considering the shallow part of the bank (depth < 2m) overlapped from the available orthophotos.

Further information collected include: Natura 2000 habitats map (2011) and Habitats map according to the Regional classification system (2008).

Tabular synthesis of the biological parameters considered for the Banco Mula di Muggia

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD (and, if known, indicate the monitoring frequency)	AVAILABILITY of the data (institution/web-site, ...)
Phytoplankton biomass (chlorpohyll a)	**.xls**		**CE131 (WFD)**	**sea water measurements**	**2009 - 2019 / monthly measurements**	**ARPA FVG**
Phanerogams	**.shp**	**Digitalization from: 1978 aerial photos CGR; 2006, 2014 and 2018 aerial photos AgEA.**	**Pilot site**	**Orthophotos analysis**	1978 2006 2014 2018	**Change we care**

According to the report of the management plan SCI/SPA (Regione Autonoma Friuli Venezia Giulia, 2012), the following habitats are indicated in this area as they are identified by the habitat classification of Friuli Venezia Giulia Region (Poldini et al., 2006), some of which coincide with the Natura 2000 habitats:

- **MI5 biocoenosis of fine sands at low depth**

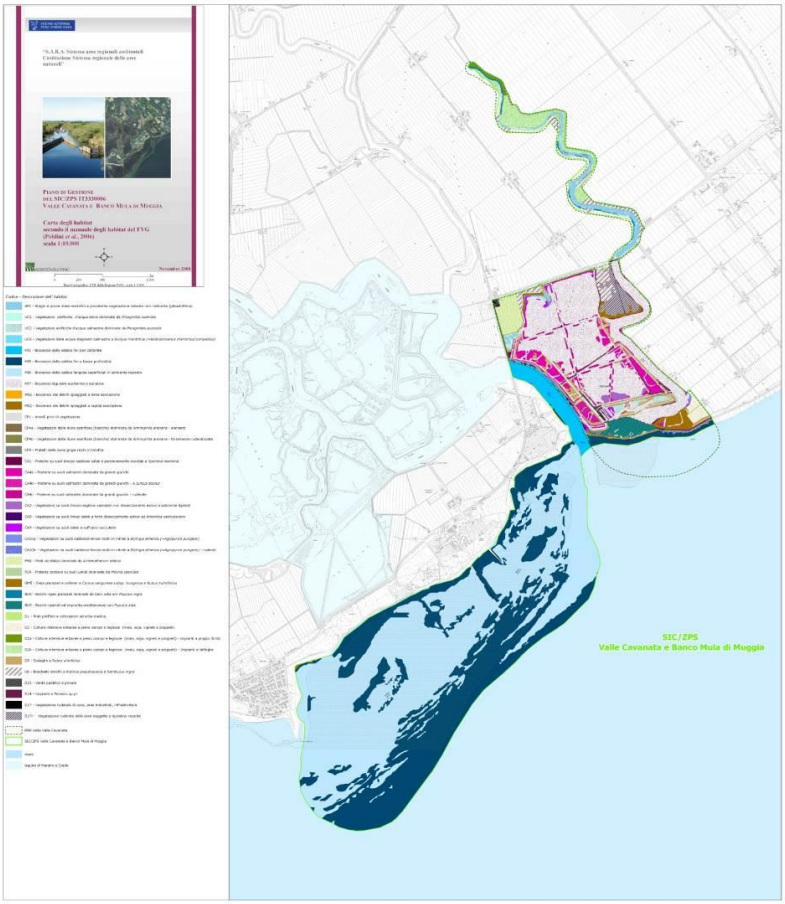
  This habitat borders onshore that characterized by fine, well calibrated sands and shares with it many preferential species. In calm conditions sand is enriched by finer materials and the habitat

overlaps the one corresponding to MI6

- **MI6 biocoenosis of superficial muddy sands in a sheltered environment**

  The substrate consists of muddy sand sometimes rich of shell debris. It is present in an environment sheltered from waves, covered at intervals by *Zostera noltei* in the shallower part and *Cymodocea nodosa* (in deeper areas) replaced by *Zostera marina* in the presence of fresh water. Variability is remarkable in relation to the consistency of the muddy component and the presence of marine phanerogams.

These habitats identified within the classification performed by the Friuli Venezia Giulia Region are both classified with the same code into the Nature 2000 habitat.



Habitats map (2008) according to the Regional classification system (from: Regione Autonoma Friuli Venezia Giulia, 2012)

3.2.3 Sampling strategy for the future

The Regional Environmental Protection Agency of Friuli Venezia Giulia (ARPAFVG) will continue gathering and analysing data on all measuring stations for physical-chemical and biological data with in situ measurements and remote sensing methods.

3.3 Vransko Lake

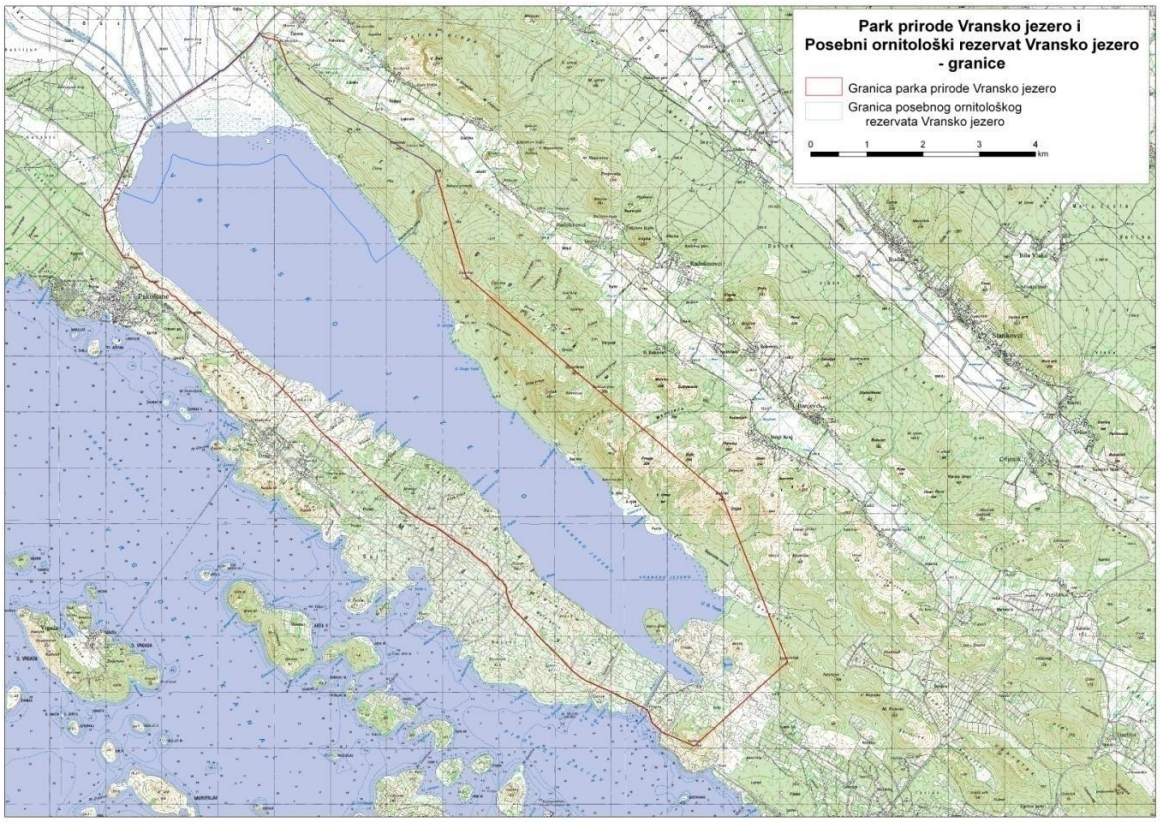
3.3.1 Site description

Vransko Lake Nature Park is located on the east longitude 15 30 '53 "to 15 39' 36", and in the northern latitude 43 50 '52 "to 43 56' 18" is within two Croatian counties, with 42 km² (74%) in the area of Zadar County and 15 km² (26%) of the area in Šibenik-Knin County. The entire surface of the Vransko Lake water belongs administratively to Zadar County. The distance from the city of Zadar is 30 km and from the town of Šibenik is 24 km.

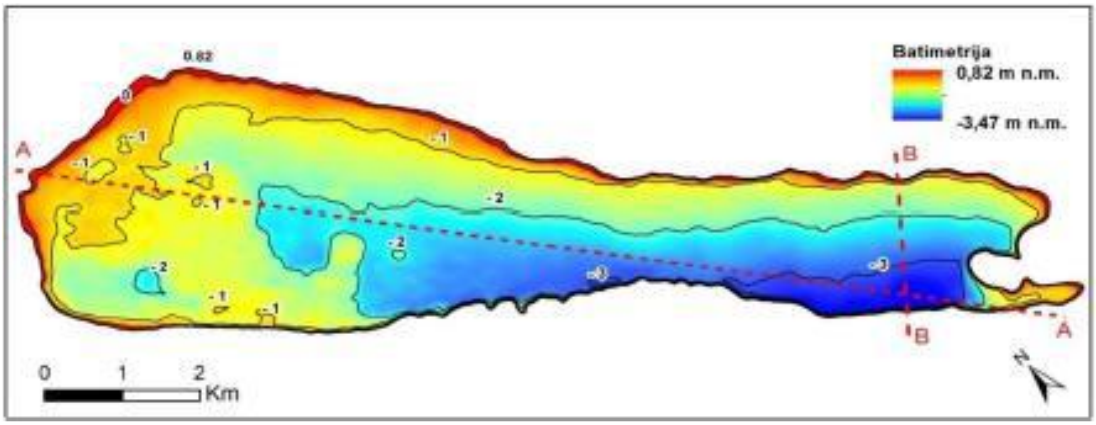
At the local government level, the area is mostly located within the municipality of Pakoštane, and includes parts of the municipalities of Stankovci, Pirovac and Tisno and the town of Benkovac. At the administrative level of the settlement, parts of the settlements of Pakoštane, Draga, Vrana, Radašinovci, Banjevci, Kašić, Betina and Murter are included, although most of the populated areas are 1-3 km outside the boundaries of the Nature Park. Several smaller parts of the inhabited areas are located within the boundaries of the Park: part of Vrana (Majdan), part of Betina (Prosika) and part of Pakoštane (southern lake shore).

Vransko Lake is the largest lake in Croatia and one of only two large wetlands in the Mediterranean part of Croatia. The area of the Vrana Lake Nature Park, together with the adjacent Jasen floodplain, is a unique natural and hydrogeological phenomenon. Due to its unique natural values, Vransko Lake with its surrounding area, total area of 57 km², was declared a Nature park on July 8, 1999. Due to wildlife biodiversity, especially birds, an 8.65 km2 area in the northwestern part of Lake Vrana, was declared an Ornithological Reserve by the Municipality of Biograd na Moru on February 22, 1983. This area is one of the most ornithologically significant in Croatia and is included in the list of important ornithological areas in Europe (Important Bird Areas in Europe). Extreme geological activity in the past has created a diversity of terrestrial forms and geochemical composition of rocks in a small area, resulting in different soil types that support numerous habitats and species.

The lake is situated in a shallow karst bed and separated from the Adriatic Sea by a narrow karst ridge. Significant seasonal variations in water level and changes in salinity due to intrusion of sea water through permeable karst, create conditions for development of very specific habitats. The shallowest northwest part of the Ramsar site proclaimed in 2013 is characterized by reedbeds, floodplain and seasonally flooded arable land; the hills lining the eastern coast are covered by typical Mediterranean macchia and garrigue, while the lower western coast gives a more rocky appearance. Vransko lake marsh habitats is a remaining of what used to be a much larger Vrana swamp, drained by melioration canals in 18th century.



Area of Nature Park Vransko lake, Nature park borders-red line. Special ornithological reserve -blue line.



Bathymetric survey of the bottom of Vrana Lake: situational imaging (Rubinić, 2014, according to data measured by Teodolit 2012)

The Nature Park, the Ornithological Reserve, and the areas of the ecological network within the boundaries of the Nature Park are managed by the Public Institution Vransko jezero Nature Park. The activity of a public institution includes the protection, maintenance and promotion of an area with the aim of protecting and preserving the authenticity of nature and ensuring the smooth running of natural processes and the sustainable use of natural resources, as well as monitoring the implementation of conditions and measures of nature protection. Most of the total area of the Nature Park, and the entire area of Jasen, are owned by the Republic of Croatia.

Vransko Lake is the biggest reservoir of fresh water in this region of Croatia. In 1970s there have been plans for building accumulation of fresh water in Vransko Jezero Lake and its usage for water supply, but the idea was abandoned due to problem of salinization. Springs from Vransko jezero's catchment (Kakma, Biba, Škorobić, Turanjskojezero, Kutijin stan) are, however, regularly exploited for water supply, and Begovača seasonally. Springs Tinj, Mali Stabanj, VelikiStabanj, Pećina are used for irrigation of arable land. During rainy season, Vransko jezero's marsh prevents high waters from destroying the dikes and intruding the fields outside of the flood zone. The reedbeds are excellent in purifying waters that enter the lake through melioration canals, carrying fertilizers that could enhance lake eutrophication. The land in the catchment area is mostly used for intensive agriculture on medium-size plots. As the land is not very fertile due to salinization, it is not cultivated regularly, which is in favour of maintaining good water quality of the lake.

Combination of limnic and karst relief in areas of highly productive agricultural area in combination of ornithological reserve and Nature Park - many conflicts present in all directions. Particular attention should be paid to monitoring the communication of Vransko Lake and sea water at the locations of coastal springs and hot springs in the lake and the sea. In order to find their location, classical methods of hydrological measurements and sampling, it is necessary to supplement the methods of remote sensing, using infrared satellite or aerial images.

3.3.2 Present-day data collection

Water quality is being measured with Libelium smart water sensors (Libelium Waspmote Plug & Sense!). Data acquisition equipment based on autonomous devices equipped with sensors for measuring conductivity, salinity, dissolved oxygen, water temperature, and temperature, humidity and air pressure available for 3 different measuring stations in the lake. A solution based on the products of the Spanish company Libelium (www.libelium.com), buoys manufactured by Ocean Origo AB (https://www.oceanorigo.com/) from Sweden, Microsoft Power BI data analysis tools and software upgrades.

The data interface displays data for parameters: https://app.powerbi.com/view?r=eyJrIjoiZTM1MWUwMjAtYTczNS00N2FjLWIzM2QtNWQ4M2E4Mjk0NzNlIiwidCI6IjczMWFhNzVkLWE1NjctNDI2MC1iMDYyLWFiY2RiYTAxMjM5ZSIsImMiOjI9

- water temperature
- oxygen level (Mg/l)
- oxygen saturation (%)
- water salinity (ppm)

The interface shows graphs for the period starting from June 2020. Different displays are available: Separate graphs for measurement parameters, a table with latest measurement (last day), and table with average values, detailed view and min and max values. Raw data is available via contact to Public institution Vransko lake Nature Park strucna.sluzba@pp-vransko-jezero.hr. Public institution also analyses water samples on three locations measuring different parameters of water quality (the locations are the same as the bouys with Libelium sensors) on a monthly basis: Temperature (°C), Turbidity, pH, O_2 mg/l, O_2 %, salinity ‰ (surface and bottom); Conductivity mS/cm (surface and bottom), Ammonium, Nitrates, Nitrites, Chlorides, Phosphates, Silicates, total hardness, Mg-hardness, Ca-hardness, Phosphorus Alkalinity, Chlorophyll. Water level is available on http://vodostaji.voda.hr/ for two measuring stations on the lake.

The Public institution is financing the research with monitoring of biological diversity of phyto and zooplankton, macroscopic algae Characea, Natura 2000 Habitats monitoring (Eastern sub-Mediterranean dry grasslands of Scorzoneretalia vilosae, sub-Mediterranean grasslands of Molinio-Hordeion secalini grasslands, Mediterranean high wet grasslands of Molinio-Holoschoenion, Mediterranean Thero-Brachy meadows), Ichthyofauna monitoring, Bird species monitoring (wintering and breeding), amphibian and reptile species.

3.3.3 Sampling strategy for the future

The Public institution will continue gathering and analysing data on all measuring stations for water quality and as well as biodiversity components with in situ measurements and remote sensing methods. In cooperation with Institute for Oceanography and Fisheries the additional data will be collected on the Prosika harbour measuring station (water level, meteorological data, water temperature and salinity) http://faust.izor.hr/autodatapub/postaja_prikaz_r?p_pos_id=10&jezik=eng.

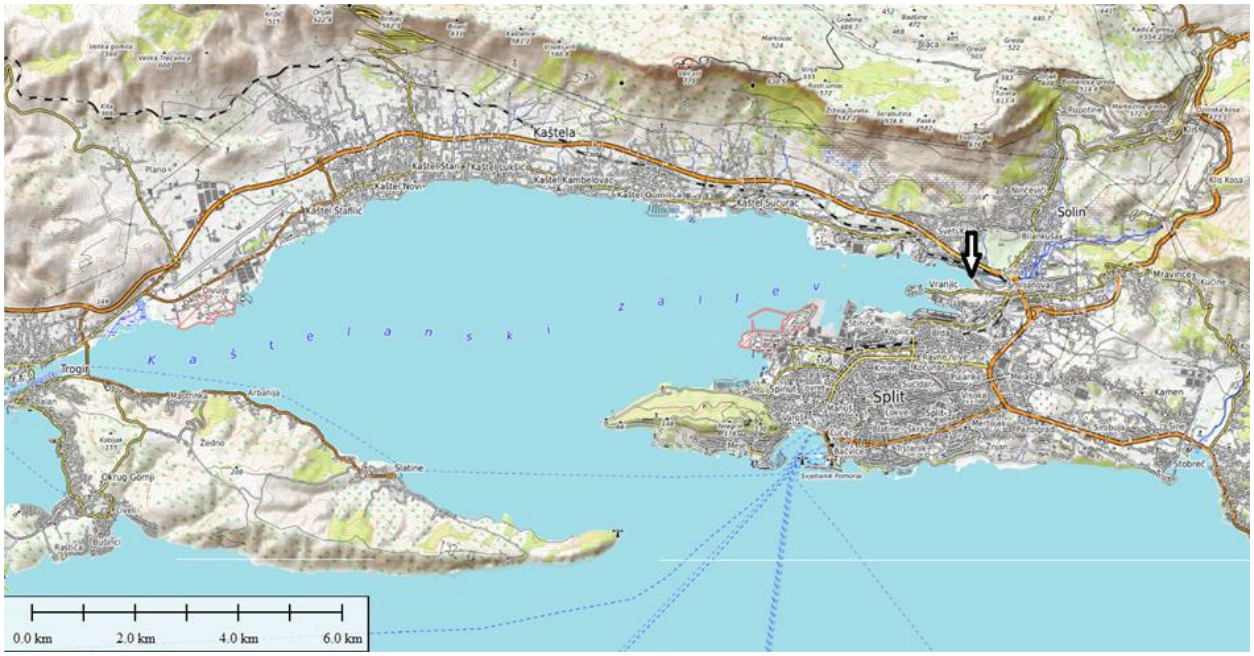
3.4 Jadro River

3.4.1 Site description

Jadro River is located in the central Dalmatia (Croatia), in the central part of the eastern Adriatic coast.

The area is situated in the close hinterland of the regional capital - city of Split. Most of the short River and the mouth itself are administratively situated within the town of Solin.

The mouth is situated in Vranjic Bay - the easternmost tip of the larger Kaštela Bay. The Kaštela Bay is a semi-enclosed oval-shaped embayment of the Adriatic Sea, bordered by the Kozjak Mountain from the north, by Split peninsula from the southeast, and the island of Čiovo from the southwest. The northern part of Kaštela Bay belongs to the town of Kaštela, while the town of Trogir is situated on the western tip.



Location map of Jadro River (mouth is marked by arrow) at the easternmost tip of Kaštela Bay (Kaštelanski zaljev) in the town of Solin - ancient Roman Salona (Source: Open Topo Map)

Geomorphologically, Jadro River is situated on the easternmost part of a lowland area called Split-Kaštela basin. The basin is elongated east-west and bordered by Dinaric mountain range from the north, and partly covered by shallow Adriatic Sea in the present-day Kaštela Bay (Kaštelanski zaljev) that is characterized by maximal depth of 43 m in the central part of the Bay.

Geologically, the Split-Kaštela basin is predominantly built of highly deformed and eroded Eocene flysch deposits (marls and sandstones), while the underlying and surrounding karstified and highly fractured Cretaceous to Eocene carbonate rocks (mostly limestones and dolomites) outcrop on the mountains and the islands (Marinčić et al., 1971). The wider area is referred to the typical Dinaric karst or the External Dinarides, developed in the latest stage of the Alpine orogenesis in the region (Korbar, 2009). The basin is situated between the High Karst Zone in the northern hinterland and the Adriatic Zone on the south, both charaterized mainly by carbonate rocks (http://webgis.hgi-cgs.hr/gk300/default.aspx).

The catchment area of Jadro spring is more than 400 km^2 that is characterized predominantly by karstified carbonate rocks (Mesozoic limestone and dolomites) in the wider hinterland. Thus, Jadro River spring is part of the largest aquifer systems in Dalmatia (Fritz and Kapelj, 1998).

The area of the Kaštela Bay was known as one of the most polluted areas of the eastern coast of the Adriatic. The environmental pollution was a consequence of fast industrialisation and urbanisation without development of appropriate urban infrastructure, in particular of a wastewater collection and disposal system. The main conflicts because of that are between industry and tourism, industry and housing, and wastewater discharge and tourism (Margeta, 2002).

After the Croatian War of Independence that ended in 1995, the activities on infrastructure development have been clearly indicated as the first area for the project's implementation. The Croatian Government, as well as the local governments of the Bay's surrounding municipalities has given the approval for the action to be taken with development banks. The World Bank and EBRD have approved large loans for the construction of sewage systems (Margeta and Barić, 1996).

In 2004, the sewage system was completed, comprising a network of pipelines, pumping stations, a tunnel, treatment plants and offshore submarine outfalls. Consequently, sewage discharge into Vranjic Basin suddenly stopped (Buljac et al., 2016 and references therein). The monitoring program of sanitary quality of sea in Kaštela Bay (October 2008 - May 2009) indicates a significant improvement in the sanitary quality of sea Vranjic after years of extremely high concentrations of faecal pollution indicators in this area (The Integral Project of Kaštela Bay Protection - ECO Kaštela Project).

The length of the watercourse is 4.3 km. The topographic catchment of the Jadro is relatively small and covers about 22 km^2. The upper stream is under the influence of a substantial discharge and relatively high topographical gradient, while the lower stream is characterized by estuarine circulation. Several smaller streams and two larger tributaries contribute to the flowing discharge. However, the tributaries have in general a torrential character and, hence, feed the Jadro occasionally, during the rainy season, bringing significant amounts of sediment. In the summer period the streams are mostly dry.

3.4.2 Present-day data collection

Public Institution for the Management of Protected Areas in the County of Split and Dalmatia "Sea and Karst" is responsible for management of the Special Ichytiological Reserve Jadro. Data available for Jadro are scarce.

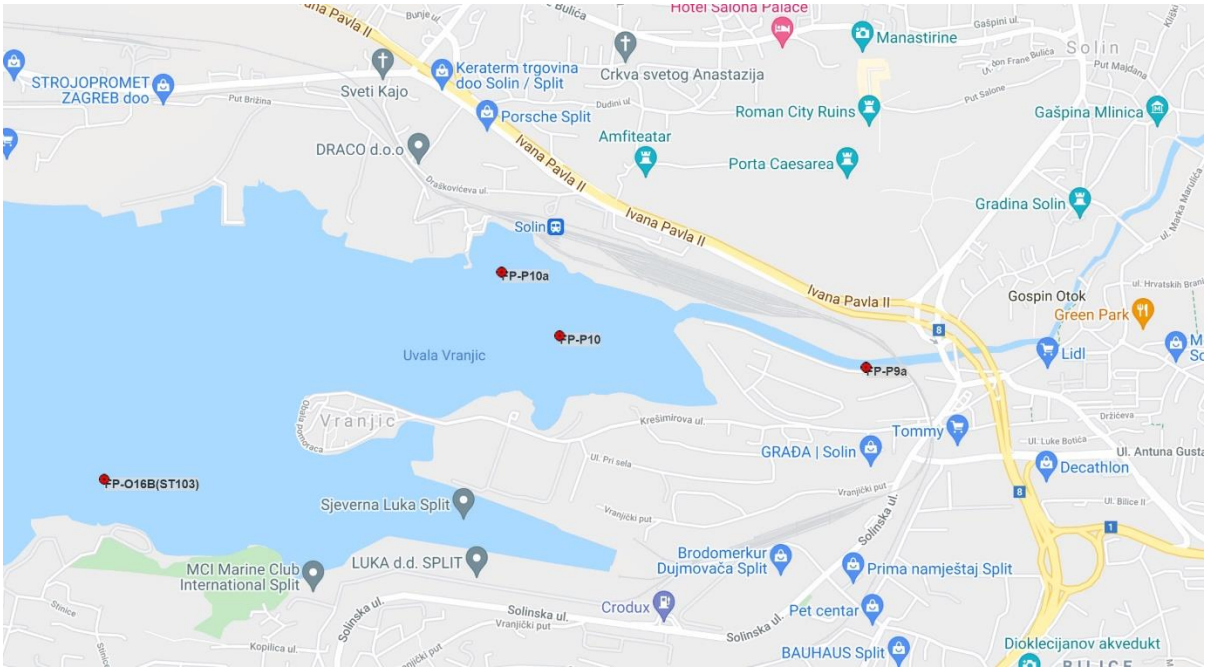
Croatian Meteorological and Hydrological Service regularly collects data on water level and flow. As Jadro is an important source of drinking water for wider urban area, company Vodovod i kanalizacija Split (eng. Water System and Sewage Split) collected data on drinking water quality in cooperation with Nastavni zavod za javno zdravstvo Splitsko-dalmatinske županije (eng. Publih Health Teaching Institution of Split-Dalmatia County). Data on freshwater fish are collected through periodic monitoring activities by Hrvatsko ihtiološko društvo (eng. Croatian Ichtyological Society).

Data related to coastal ecosystem, in area near river Jadro mouth, are collected by the Institute of Oceanography and Fisheries as a part of an ongoing monitoring and research project, including those related to the Water Framework Directive and Marine Strategy Framework Directive, as a part of the Referral Marine Centre of the Republic of Croatia. For climate assessment of the area, AdriSC climate modelling suite run (https://vrtlac.izor.hr/ords/adrisc/interface_form, 1987-2017) may be used, providing meteorological and oceanographic data for the area of Jadro.

The data availability in the area of Jadro River site has been described in deliverable D3.4.1 and here will be briefly presented. The lower part of the Jadro river is the most vulnerable to the climate change and the sea level rise, as the upper parts of the river are separated from the lower ones with cascade and dam system. Efforts should be devoted toward acquiring more data relevant for this area. According to the final report of the to Project integration EU Natura 2000 (2016) in the lower part of its flow, Jadro has almost completely anoxic conditions in sediments what prevents the development of specific macrophytic vegetation and in turn impacts distribution of different species. This document recommends the dislocation of small harbour that is currently located at the river Jadro mouth. River Jadro is inhabited by four fish species including soft-muzzled tout (*Salmothymus obtusirostris salonitana*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and the European eel (*Anguilla anguilla*). Soft-muzzled trout and the European eel are species native to this area and dominate in the community, while rainbow trout was introduced. According to the available data, it is considered that the brown trout was also introduced.

Tabular synthesis of the physical-chemical parameters available for the Jadro River.

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD	AVAILABILITY of the data (institution/web-site, ...)	NOTES
Water temperature	pdf	Data on drinking water quality	Jadro spring	actual measurements	Three times per week	https://www.vik-split.hr/korisne-informacije/izvjestaji-o-kvaliteti-vode	Vodovod i kanalizacija Split
Physico-chemical parameters of water quality	pdf; other	Data on drinking water quality	Jadro spring	actual measurements	Three times per week	https://www.vik-split.hr/korisne-informacije/izvjestaji-o-kvaliteti-vode	Vodovod i kanalizacija Split
Water level	Online numerical values	Near real time data on water level	Majdan	actual measurements	Every 30 minutes	http://vodostaji.voda.hr/	https://hidro.dhz.hr
Water salinity	pdf; other	Data collected by research cruises	Jadro river mouth	actual measurements	Monthly or bimonthly	http://jadran.izor.hr/roscop/	
Seawater temperature	pdf; other	Data collected by research cruises	Jadro river mouth	actual measurements	Monthly or bimonthly	http://jadran.izor.hr/roscop/	
Meteo and ocean parameters	other	Data acquired by numerical model	Jadro river mouth	numerical model	daily	www.izor.hr/adrisc	



Oceanographic stations in the area of Jadro River monitored by the Institute of Oceanography and Fisheries through the National Monitoring Programme.

Tabular synthesis of the biological parameters available for the Jadro River.

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD (and, if known, indicate the monitoring frequency)	AVAILABILITY of the data (institution/web-site, ...)
Microbiological quality	PDF	Data on drinking water quality	Jadro spring	Actual measurements	Three times per week	https://www.vik-split.hr/korisne-informacije/izvjestaji-o-kvaliteti-vode
Ichtyofauna	PDF	Inventory ond characteristics of ichtyofauna	Jadro river	Actual observations	Sampling conducted during 2014	PDF publication in Croatian – Mrakovčić et al. 2015. Inventarizacija i značajke ihtiofaune Rijeka Jadra, Žrnovnice i Vrljike. Hrvatsko ihtiološko društvo.
Phytoplankton	other	Phytoplankton community structure data	Vranjic bay (OC07)	Actual observations	2003-2017 Seasonally-monthly	http://baltazar.izor.hr/azopub/bindex
Zooplankton	other	Zooplankton community structure data	Vranjic bay (OC07)	Actual observations	2014-2017 2-4 times per year	http://baltazar.izor.hr/azopub/bindex
Marine ichytofauna	other	Data on fish community structure	Vranjic bay	Actual observations	2008-2017 ~ twice per year	http://baltazar.izor.hr/azopub/bindex

3.4.3 Sampling strategy for the future

The lower part of the Jadro River and the coastal area surrounding the Jadro river mouth are the most vulnerable to the sea level rise. Currently, most data are available for the upper part of the river and primarily include data on drinking water quality and status of protected freshwater fish species. In addition, there are data from nearby oceanographic station in Vranjic Bay (OC07, 18 m), and area near it, on phytoplankton, zooplankton and fish community composition. Following the list of Essential Climate Variables, efforts of a monitoring programme should be directed toward acquiring chemical, physical and biological data for coastal area near and at the Jadro river mouth, as well as the lower part of the Jadro river flow.

As monitoring campaigns and observational systems are not easy and cheap to conduct and manage, one may assess some of Essential Climate Variables to be collected either remotely, from global and regional reanalyses or satellite-derived products. In addition, verified regional atmosphere-ocean-land projects may be used to fill observational gaps, like the AdriSC climate numerical model, for which meteo and ocean data are available at regular grid of 3 km in the atmosphere and 1 km in the sea, with the daily resolution.

It is at hands of the organisation responsible for managing the Jadro River area, Public Institution for the Management of Protected Areas in the County of Split and Dalmatia "Sea and Karst", to define the monitoring programme for the Special Ichytiological Reserve Jadro. However, not all recommendable observations may be conducted in such a micro-area. In line with already ongoing monitoring programmes, the following observing platforms and data collection programmes may be used for the climate monitoring:

- meteo-ocean coastal station near the mouth of the Jadro River, capable to carry our observations of sea level (e.g. radar-type of water level monitoring sensor), atmospheric parameters (e.g. compact meteo station, measuring precipitation, surface radiation, wind speed and direction, air temperature and water vapour) and ocean parameters (e.g. temperature, salinity, some chemical parameters)
- limnological station measuring Jadro river discharge, water level and flow velocity
- microbial quality of coastal waters – to adjoin already existing programme for monitoring quality of bathing waters, which has the closest station in Vranjic
- phytoplankton and zooplankton biomass and diversity, fish abundance – to continue collection of data at the nearest oceanographic station
- products of the verified Adriatic climate hydrodynamic and biogeochemical models, from which the closest grid point to the Jadro may be used to assess climate changes of some essential atmosphere, land and ocean variables
- remote sensing products, focused on the Jadro River region, where choosing the closest pixel to the region to assess climate changes of some essential atmosphere, land and ocean variables

There should be one coordinating institution for managing the climate change monitoring programme, e.g. Public Institution for the Management of Protected Areas in the County of Split and Dalmatia "Sea and Karst", with the help of research institutions, here Institute of Oceanography and Fisheries, who has an experience in instrumentation and methodologies for collection of atmospheric, land and ocean data.

3.5 Neretva River

3.5.1 Site description

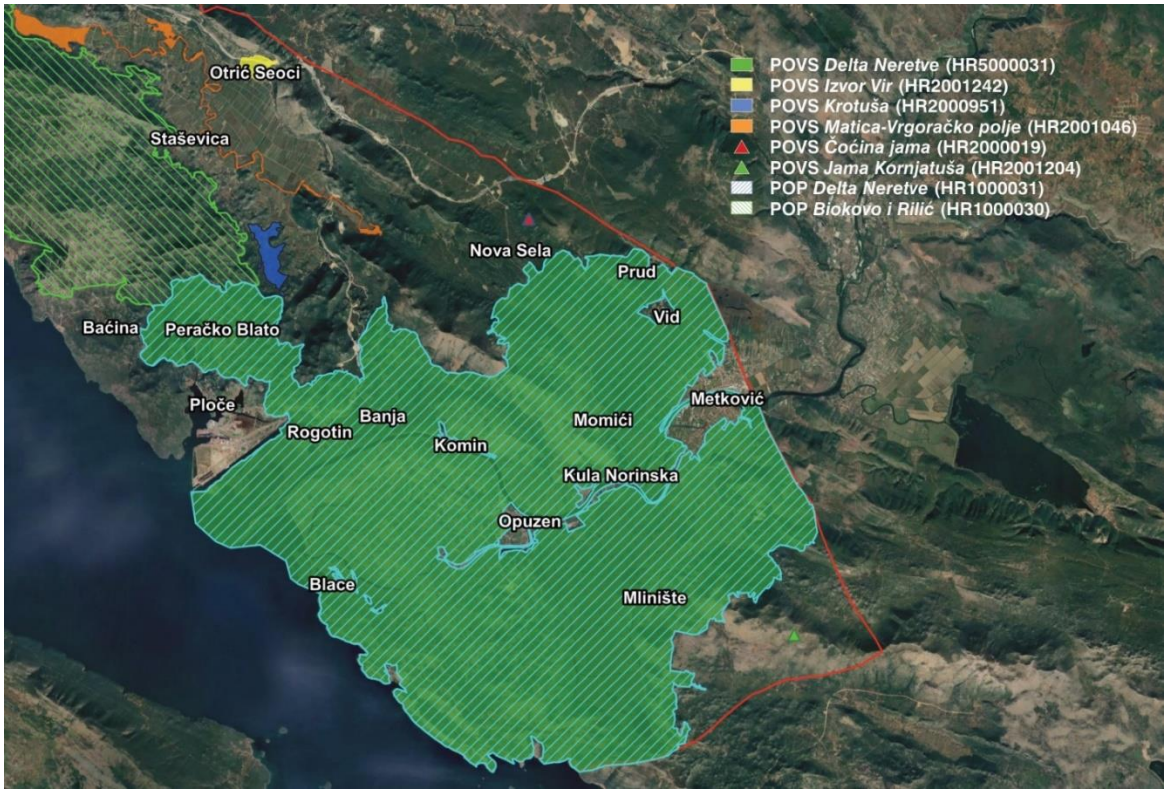
The Neretva Delta is a valley in the south of the Croatian Adriatic coast, formed at its mouth by the Neretva River itself. The Delta covers an area of 12,000 acres. The Neretva Delta from Metković to the estuary from the north and northeast is bounded by the branches of the Dinaric mountains, and from the south by the Podgradina-Slivno hills. The Neretva Delta area is very densely populated with about 35,600 inhabitants (2011), with the majority of the population living in the cities of Metković (16,788), Ploče (10,135) and Opuzen (3,254).

Neretva River originates southeast of Zelengora at an altitude of 1095 m, mainly flows through Bosnia and Herzegovina, and flows into the Adriatic Sea south of Ploče. It is about 218 km long, out of which in Croatia 22.3 km (Juračić, 1998). In the upper and middle part of the flow Neretva river is representing a typical mountain passing narrow valleys with steep slopes. Downstream of Počitelj Neretva leaves canyon and flows through the valley of the meander-nut (Vranješ and Ljubenkov, 2012). The stream base forms a main stream, which is navigable to Metković and Mala Neretva, which is separated from the main flow on the left from Opuzen. Watercourses of the left hinterland of Neretva River are Mislina and Jezerača with a source in the lake Kuti. Both after the composition passes in Prunjak that flows into Mala Neretva near Opuzen. Watercourses are right waterside Glibuša, Norin, Nut, Desanka and Crna rivers. Desne is a pit, which is spring zone of the upper horizons (Vrgorac field and Rastoka).

Neretva River is dominant watercourse of the area. Its main characteristics in this final section are: average annual water level of 91±13 cm (range 65-124 cm); average annual water flow of 269 m^3/s (range 44– 2,179 m^3/s); average annual water temperature near Metković being 11.9 °C (range 0-26 °C). River has a high water level in winter, while during summer there is a lack of water. This is partly due to several hydropower plants upstream in Bosnia and Herzegovina, which hold the most of Neretva waters with dams. In such situations when Neretva has a very small flow downstream of the dams, marine waters enter the river, spreading its influence upstream all the way to Metković (border with Bosnia and Herzegovina).

Neretva River and its delta is the major and dominating geomorphological feature in the area. Delta area is composed of three triangular extensions that are tectonically predisposed and created as a result of tectonic movements during the last orogenic phases. Neretva Delta took current form after the transgression of sea 10,000 years ago. Two of those extensions are in Croatia.

Protected areas in Neretva River Delta site.



NATURA 2000 site in Neretva River Delta site.

The most prominent factors in the past that adversely affected ecological character of Neretva Delta were connected to water management, including land reclamation activities with the purpose of turning wetland into agricultural land. Today the largest threats are also connected to issues of water management and agriculture sectors. As the consequence of water regulation activities in surrounding area of Croatia in Bosnia and Herzegovina, there is an obvious trend of decrease of water level and quantity in Neretva Delta that adversely affect not only wetland habitats and biological diversity of Delta but also agriculture. The less water in Neretva and its tributaries in Delta, the stronger influence of the sea and salinization of water and soil can be expected. There are different water management plans and projects currently going on in Neretva Delta. They deal with solving the problem of salinization; irrigation of agricultural land; flood control, treatment of sewage water of the town Metković and other activities. There are even plans for further meliorations of remained wetland areas. Other problems and threats to ecological character of the Neretva Delta include: expansion and intensification of agriculture; excessive use of pesticides and fertilizers; fragmentation of wetland habitats; spreading of urban zones on account of wetland; water pollution with non-purified urban and industrial waters; unsolved land property rights; illegal taking of state owned agricultural land, including marshes; non-regulated recreational and touristic activities, especially on the river mouth, illegal hunting and fishing; frequent fires in reedbeds.

The delta is surrounded with karst hills rich with underground water that supplies numerous springs, streams and lakes. More than 100 registered caves and other underground habitats in these karst surroundings are home for rich fauna with many threatened and endemic taxa.

Special Protected Area Neretva Delta is a Ramsar site with at least 313 registered bird species. Altogether there are around 193 regularly occurring species out of which around 89 are breeding birds (RSIS Neretva River Delta, 2012). The area is important stop-over place during migrations of birds from Middle and NE Europe to Africa, situated on the route of Central European (Black Sea/Mediterranean) Flyway. About 1/3 of registered species are wintering birds, accompanied with residents during the winter.

More than 10,000 waterbirds regularly winter in Neretva Delta (Ilić, HOD, pers.comm.), including several thousands of ducks, up to 3,000 Coots (*Fulica atra*), up to 2,000 ind. of *Larus ridibundus*, up to 2,000 ind. of *Larus michahellis*, cca 400 ind. of *Phalacrocorax carbo* and others. The most common are *Anas platyrhynchos* and *Fulica atra* but their numbers differ significantly from year to year, depending on weather conditions. During very cold winters, large numbers of geese stay in the estuary, mostly *Anser albifrons* and *Anser anser*. If we add wintering waterbirds of Hutovo Blato that has bigger numbers because of large open-water habitats the whole Lower Neretva area (transboundary Ramsar site) probably reaches the criterion of ≥20,000 waterbirds.

This area contains a high diversity of water habitats, the delta, lagoons, brackish waters, network of channels springs, streams with rheophilic characteristics and lakes that are inhabited with almost 20 fish species endemic to Adriatic basin. One of two important sites for endemic species *Squalius svallize*. Freshwater habitats with rheophilic characteristics are important for Salmothymus (*Salmo obtusirostris*). Freshwater habitats with rheophilic characteristics and oligotrophic lakes as the Lake Modro Oko are important for *Salmo marmoratus* with up to 60% of total Croatian population, this is only important site for that species. Brackish habitats of the site are important for *Pomatoschistus canestrinii* and *Knipowitschia panizzae*. One of two sites important for reproducing of *Petromyzon marinus*. One of two sites important for *Lampetra zanandraei*, endemic lamprey. One of three sites important for *Knipowitschia croatica*. Only important site for endemic species *Chondrostoma knerii* with the 100% of Croatian population. Only important site for *Alosa fallax*, important for reproduction. Only important site for endemic species *Alburnus neretvae* (syn. *Alburnus albidus*) with the 100% of Croatian population. Only important site for endemic species *Cobitis narentana* (syn. *C. taenia*) with the 100% of Croatian population. Baćina Lakes are important for *Cobitis illyrica* (syn. *C. taenia*), and *Delminichthys adspersus* inhabits them as well. Delta Neretva is important site for herpetofauna species *Elaphe quatuorlineata, Zamenis situla, Emys orbicularis, Mauremys rivulata* and *Testudo hermanii*. It is also southernmost site of distribution of *Lutra lutra*. Site is important for 8310 Caves not open to public - area important for *Congeria kusceri*, the only living underground bivalve in the world - species is found in altogether 7 localities in Delta Neretva site - two colonies (Jama u Predolcu hosting more than 72 000 individuals and Pukotina u tunelu polje Jezero - Peračko blato), one locality where only individual live specimens were found (Izvor špilja kod Kapelice) and four localities with only dead shells; five new underground taxa found and scientific described (*Cyphophthalmus neretvanus, Trichoniscus matulici, Emmericia narentana, Roncus narentae, Alpioniscus verhoeffi*); *Alpioniscus heroldi* known from seven localities of South Croatia, distribution area also in Herzegovina; *Saxurinator brandti* known from five localities of South Croatia.

In the surrounding area especially problematic are issues related to transboundary water management and numerous water regulations in catchment area of the Neretva and neighbouring Trebišnjica River in Bosnia and Herzegovina. Watersheds of these two rivers are connected through karst underground. Re-direction of waters from so called Upper horizons ("Gornji horizonti") of Trebišnjica River into the area of Lower horizons ("Donji horizonti") with three existing hydropower plants results in loss of water in lower Neretva area, lower summer water level, drying out of water springs and strengthening of influence of the sea. There are plans to even increase these activities and to take the most of available water for additional use of hydropower plants in eastern Herzegovina.

3.5.2 Present-day data collections

Public Institution for the Management of Protected Natural Areas of Dubrovnik Neretva County carries out activities of protecting, maintaining and promoting the protected areas in Dubrovnik-Neretva County, including Neretva River Delta (1 Ramsar Site, 7 Protected Areas and several Natura 2000 sites).

Public Institution together with external associates conducts annual monitoring activities include monitoring of ornithofauna (wintering and breeding), winter monitoring of ornithofauna. Through the years there has been several different researches conducted by Public institution concerning ornithofauna and ichthyofauna in Delta Neretva Natura 2000 site.

Hrvatske vode (Water management department for southern Adriatic basins) from Split collects data on physical-chemical parameters of water (Neretva River Delta).

Institute of Oceanography and Fisheries carries out the monitoring of ocean parameters off the Neretva River Delta mostly on seasonal basis.

Tabular synthesis of the physical-chemical parameters available for the Neretva River.

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD (and, if known, indicate the monitoring frequency)	AVAILABILITY of the data (institution/web-site, …)	NOTES
Water temperature	excel table	surface water, left and right river banks	Neretva River Delta (Rogotin, Metković, Pižinovac, Crepina)	actual measurements	2018-2020	PIDNIC	
Physico-chemical parameters of water quality	excel table	surface water, left and right river banks	Neretva River Delta (Rogotin, Metković, Pižinovac, Crepina)	actual measurements	2018-2020	PIDNIC	

Tabular synthesis of the biological parameters available for the Neretva River.

CATEGORY	TYPOLOGY (printed data, IT. data: .shp, .dwg, .tiff format, etc.)	DESCRIPTION	REFERENCE AREA (Pilot Areas)	DATA COLLECTED - by actual land measurements or by models	YEARS / REFERENCE PERIOD (and, if known, indicate the monitoring frequency)	AVAILABILITY of the data (institution/web-site, …)
Maps of different habitats	.shp	Map of habitats	Delta Neretva River	Actual measurements and models	2004, 2016	http://www.bioportal.hr/gis/
Flora (algae and vascular flora)	.pdf	Scientific papers	Delta Neretva River	Actual measurements	2007, 2015	In Croatian: Jasprica et al., 2007.; Glasnović et al., 2015;
Insecta (Lepidoptera)	.pdf	Scientific papers	Delta Neretva River	Actual measurements	2014	In Croatian: Kučinić et al., 2014.
Herpetofauna	.pdf	Scientific papers	Delta Neretva River	Actual measurements	2012	In Croatian: Koren et al. 2012.
Ichtyofauna	.pdf	Scientific papers	Delta Neretva River	Actual measurements	2010, 2017	In Croatian: Tutman et al., 2010. Buj et al., 2010. In Croatian: Salaj et al., 2017.
Ornithofauna	Printed data	Book	Delta Neretva River	Actual measurements	2007, 2016	In Croatian: Kitonić et al., 2007.;

						Ilić et al., 2016

3.5.3 Sampling strategy for the future

The Public institution will continue gathering and analysing data on all measuring stations for water quality and as well as biodiversity components with in situ measurements and remote sensing methods.

4. The sustainability instruments

4.1 European framework programmes for RTD

Horizon 2020 is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament. They agreed that research is an investment in our future and so put it at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs. By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation. Horizon 2020 is open to everyone, with a simple structure that reduces red tape and time so participants can focus on what is really important. This approach makes sure new projects get off the ground quickly – and achieve results faster. The EU Framework Programme for Research and Innovation will be complemented by further measures to complete and further develop the European Research Area. These measures will aim at breaking down barriers to create a genuine single market for knowledge, research and innovation.

Horizon Europe. Research and innovation provide new knowledge and innovative solutions to overcome our societal, ecological and economic challenges. Horizon Europe helps researchers and top class innovators to develop and deploy their ideas. It teams up the best talent and equips them with world-class research infrastructures. Moreover, it supports breakthrough innovations and helps to create new services and markets.

Horizon Europe will: (i) maximise its impact and deliver on the EU's strategic priorities, such as the recovery, green and digital transitions, and tackles global challenges to improve the quality of our daily lives; (ii) strengthen EU science and technology by increasing investment in highly skilled people and cutting-edge research; (iii) foster the EU's industrial competiveness and its innovation performance, notably supporting market-creating innovation via the European Innovation Council and the European Institute of Innovation and Technology; (iv) enhance access to excellence for researchers across Europe to foster participation and collaboration.

Article 185 initiatives. Article 185 of the Treaty on the Functioning of the European Union (TFEU) allows the EU to participate in research programmes jointly undertaken by several EU countries with the possibility to associate non-European countries. The criteria to identify potential article 185 initiatives are set out in the Horizon 2020 programme: (i) a clear definition of the objective to be pursued; (ii) a clear and firm commitment from the participating Member States; (iii) indicative financial commitments of the participating countries, including prior commitments to align national and/or regional investments for transnational research and innovation and, where appropriate, to pool resources; (iv) its relevance to the

EU policy objectives and the added value of the action at EU level; (v) the critical mass, with regard to the size and the number of programmes involved, the similarity or complementarity of activities and the share of relevant research they cover; (vi) a well-prepared joint programme and priorities; (vii) a well-organised implementation structure.

JPI – Oceans, https://www.jpi-oceans.eu. JPI Oceans is an intergovernmental platform that strives to increase the impact of national investments in marine and maritime research and innovation. It contributes to aligning national priorities and implement joint actions including the launch of joint calls for transnational research and innovation projects and sharing of research infrastructures. JPI Oceans has 20 member countries including two non-Member States of the EU (Norway and Turkey).

BLUEMED Initiative, http://www.bluemed-initiative.eu. The BLUEMED Initiative aims to advance a shared vision for a more healthy, productive, resilient, better known and valued Mediterranean Sea, promoting the citizens' social well-being and prosperity, now and for future generations, and boosting economic growth and jobs. The BlueMed Research and Innovation Initiative is an intergovernmental regional-scale initiative launched in 2014 during the Italian Presidency of the European Union, aiming to advance a shared vision for a healthier, productive, resilient, better-known and valued Mediterranean Sea. It addresses research and innovation through a multi-disciplinary approach, linking economy, environment and humans, to build sustainable Blue Growth by means of networks of actors and international science diplomacy efforts. Since 2017, with the signature of the Valletta Declaration, the Initiative is formally joined by 16 EU and non-EU Mediterranean countries and steered by the EuroMediterranean Group of Senior Officials BlueMed Working Group (GSO BlueMed WG), co-chaired by the European Commission and the co-chair of the Union of the Mediterranean (currently Jordan) and supported by the Secretariat of the Union of the Mediterranean.

PRIMA Initiative, https://prima-med.org. PRIMA - Partnership for Research and Innovation in the Mediterranean Area - is the most ambitious joint programme to be undertaken in the frame of Euro-Mediterranean cooperation. By funding R&I through competitive calls, PRIMA aims to build research and innovation capacities and to develop knowledge and common innovative solutions for agro-food systems, to make them sustainable, and for integrated water provision and management in the Mediterranean area, to make those systems and that provision and management more climate resilient, efficient, cost-effective and environmentally and socially sustainable, and to contribute to solving water scarcity, food security, nutrition, health, well-being and migration problems upstream. PRIMA also aims at to contribute to United Nations' Agenda 2030 through the achievement of the Sustainable Development Goals (SDGs).

PRIMA consists of European Union Member States, Horizon 2020 Associated Countries and Mediterranean Partner Countries on an equal footing basis (co-ownership, co-management and co-funding) with the Participation of the European Commission, under the framework of an art.185 TFEU. The partnership will be financed through a combination of funding from PRIMA Participating States (currently €274 million), and a €220 million contribution from the EU through Horizon 2020, its research and innovation funding programme (2014 – 2020).

NATO Science for Peace and Security (SPS) Programme, https://www.nato.int/cps/en/natohq/78209.htm: The Science for Peace and Security (SPS) Programme

promotes dialogue and practical cooperation between NATO member states and partner countries based on scientific research, technological innovation and knowledge exchange. The SPS Programme offers funding, expert advice and support to tailor-made, civil security-relevant activities that respond to NATO's strategic objectives. Among other, NATO SPS Programme funds environmental security issues, arising from key environmental and resource constraints, including health risks, climate change, water scarcity and increasing energy needs, which have the potential to significantly affect NATO's planning and operations; Disaster forecasting and prevention of natural catastrophes; Defence-related environmental issues.

4.2 Regional cooperation programmes

Interreg Italy-Croatia Programme, https://www.italy-croatia.eu. The Italy-Croatia CBC Programme is the financial instrument supporting the cooperation among the two European Members States territories overlooking the Adriatic sea. With 236.8 M € of total budget, the Programme enables regional and local stakeholders to exchange knowledge and experiences, to develop and implement pilot action products and services, to support investments by creation of new business models, to test the feasibility of new policies, having as the final aim the improvement of the life quality and conditions of more than 12.4 M citizens living in the Area.

The Italy-Croatia cooperation area shows a distinct blue and green pattern, featuring the sea basin, coastal landscapes, green but also urban areas. The location of the Adriatic Sea in the very centre of the territory – although shared with other Countries – on one hand, requires more efforts to accomplish collaboration aims related with the cross-border integration of economic, educational and labour markets. On the other, it is a joint economic and environmental asset, and a natural platform for cooperation building on long-dating trade exchange contacts reflected in some common traits of cultural heritage. The whole Programme area, which comprises parts of the territory of Italy and Croatia, spreads over 85.562 km2 and, according to the last census (2011), its population is 12.465.861 inhabitants. In total, the cross-border cooperation area is made up of 33 statistical NUTS III territories (25 provinces in Italy and 8 counties in Croatia).

Interreg Italy-Slovenia Programme, https://www.ita-slo.eu: With a financial allocation of more than € 90 million, Interreg V-A Italy –Slovenia Programme will support a smart, sustainable and inclusive growth as planned by the Europe 2020 Strategy, spending significant resources on growth, innovation, quality of life and environmental sustainability, also through the improvement of the efficiency of public administration. The Programme will cover the seven-year period of the European Programme 2014-2020, which will be developed to provide continuity with the previous 2007-2013 Programme, which has funded 87 projects aimed at enhancing competitiveness, research and innovation, protection and promotion of cultural and natural resources, and cross-border activities.

EUSAIR, https://www.adriatic-ionian.eu: The EU Strategy for the Adriatic and Ionian Region (EUSAIR) is a macro-regional strategy adopted by the European Commission and endorsed by the European Council in 2014. The Strategy was jointly developed by the Commission and the Adriatic-Ionian Region countries and stakeholders, which agreed to work together on the areas of common interest for the benefit of each country and the whole region. The general objective of the EUSAIR is to promote economic and social prosperity and growth in the region by improving its attractiveness, competitiveness and connectivity. With four EU members and four non EU countries the strategy will contribute to the further integration of the Western Balkans. The participating countries of the EUSAIR agreed on areas of mutual interest with high relevance for the Adriatic-Ionian countries, being it common challenges or opportunities. The countries are aiming to create synergies and foster coordination among all territories in the Adriatic-Ionian Region in the four thematic areas/pillars: (1) Sustainable tourism; (2) Environmental quality; (3) Connecting the region; and (4) Blue growth.

Interreg ADRION Programme, https://www.adrioninterreg.eu. The ADRION programme is a European transnational programme that invests in regional innovation systems, cultural and natural heritage, environmental resilience, sustainable transport and mobility as well as capacity building. By bringing together eight Partner States, ADRION aims to act as a policy driver and governance innovator for the benefit of more than 70 million people in the Adriatic and Ionian region.

As a transnational cooperation programme, ADRION main contribution will be to exchange and transfer experiences between regions, support transnational interventions and capacity building, as well as to answer to current needs and challenges within the region. To this end, the Programme focuses its investments in four Priority Axes, namely:

1. *Innovative and smart region:* Promoting business investment in R&I, developing links and synergies between enterprises, research and development centres and the higher education sector, in particular promoting investment in product and service development, technology transfer, social innovation, ecoinnovation, public service applications, demand stimulation, networking, clusters and open innovation through smart specialisation.

2. *Sustainable region:* Conserving, protecting, promoting and developing natural and cultural heritage; Protecting and restoring biodiversity and soil and promoting ecosystem services, including through Natura 2000, and green infrastructure.

3. *Connected Region:* Developing and improving environment-friendly (including low-noise) and low-carbon transport systems including inland waterways and maritime transport, ports, multimodal links and airport infrastructure, in order to promote sustainable regional and local mobility.

4. *Supporting the governance of the EUSAIR:* Enhancing institutional capacity of public authorities and stakeholders and efficient public administration by developing and coordinating macro-regional and sea-basin strategies.

Interreg MED Programme, https://interreg-med.eu. The main objective of the Interreg MED Programme is to promote sustainable growth in the Mediterranean area by fostering innovative concepts and

practices and a reasonable use of resources and by supporting social integration through an integrated and territorially based cooperation approach. Interreg MED Programme will promote cooperation between a varied typology of actors of these thirteen Mediterranean countries. Our aim lies in optimizing existing results achieved in the previous period as well as facilitating new cooperation frameworks for all partners situated in the Programme cooperation area. Accordingly, Interreg MED Programme establishes the following key cooperation principles aiming at consolidating the character of future projects and their related activities. These fundamental principles represent the DNA of the Interreg MED Programme and are coherent with the promotion of development, of good governance and supported by the European Union Cohesion Policy: (i) Thematic concentration, (ii) Result-orientation, (iii) Transnationality, (iv) Territorial relevance, (v) Sustainability, (vi) Transferability, (vii) Capitalisation.

Interreg Central Europe Programme, https://www.interreg-central.eu. Interreg CENTRAL EUROPE improves capacities for regional development in innovation, carbon dioxide reduction, the protection of natural and cultural resources as well as transport and mobility. With our funding, we support transnational cooperation like yeast supports baking. We are the small but important ingredient that helps innovative yet isolated ideas grow: into jointly developed, tested and accepted solutions for a better central Europe. We are currently funding 138 cooperation projects across central Europe. In total, around 246 million Euro from the European Regional Development Fund (ERDF) will be transferred to transnational partnerships in the coming years. The projects address shared regional challenges in the fields of innovation, low-carbon economy, environment, culture and transport.

Interreg Europe Programme, https://www.interregeurope.eu. Interreg Europe helps regional and local governments across Europe to develop and deliver better policy. We create an environment and opportunities for sharing solutions and policy learning. We aim to make sure that government investment, innovation and implementation efforts all lead to integrated and sustainable impact for people and place. We know that better performance leads to better results. By building on its forerunner, INTERREG IVC (2007-2013), Interreg Europe aims to get maximum return from the EUR 359 million financed by the European Regional Development Fund (ERDF) for 2014-2020. This time round, it's still about doing good, but doing it better! Solutions exist that can help our regions become the best that they can be. Today, the EU's emphasis is very much on paving the way for regions to realise their full potential – by helping them to capitalise on their innate strengths while tapping into opportunities that offer possibilities for economic, social and environmental progress. To achieve this goal, Interreg Europe offers opportunities for regional and local public authorities across Europe to share ideas and experience on public policy in practice, therefore improving strategies for their citizens and communities.

Interreg Croatia – Bosnia and Herzegovina – Montenegro Programme, https://www.interreg-hr-ba-me2014-2020.eu. The Interreg IPA Cross-border Cooperation Programme Croatia – Bosnia and Herzegovina – Montenegro 2014-2020 is a trilateral programme dedicated to achieve harmonious development of the cross-border area and the European Union as a whole. A lengthy title indeed, but every term in it carries great importance for Croatia's, Bosnia and Herzegovina's and Montenegro's cooperation: (i) Interreg stands for territorial cooperation among countries of Europe. It is a framework developed by the EU that allows joint actions and policy exchanges between different states; (ii) IPA is an abbreviation for Instrument for Pre-Accession Assistance, meaning the EU framework that allows

cooperation among EU Member States and candidate and/or potential candidate countries; (iii) Cross-border Cooperation (Programme), oftentimes shortened to CBC, refers to one of Interreg's three strands of cooperation: cross-border, transnational and interregional; (iv) Croatia, Bosnia and Herzegovina and Montenegro refers to countries participating in the Programme which have agreed to jointly overcome challenges crossing national borders and mutually use untapped growth potential in the cross-border area; (v) 2014 – 2020 stands for the current multiannual financial framework, i.e. the seven-year timeframe and planning horizon of using EU resources.

4.3 National research and environmental agencies

Croatian Science Foundation, https://hrzz.hr. Croatian Science Foundation was established by the Croatian Parliament in December 2001 under the name The National Foundation for Science, Higher Education and Technological Development of the Republic of Croatia. Its mission is to promote science, higher education and technological development in Croatia in order to ensure the development of economy and to support employment. The Foundation provides support to scientific, higher education and technological programmes and projects, fosters international cooperation, and helps the realization of scientific programmes of special interest in the field of fundamental, applied and developmental research. The Foundation operates from two offices - Zagreb and Opatija. The Executive Director and the Department for Legal Affairs and Contracting are situated in Zagreb, while the departments for Project Evaluation, Finance and International Relations, and Assistant to the President of the Board are located in Opatija. Several external associates also contribute to the Foundation's work on a daily basis, such as the bookkeeping and accounting services and IT support. By joining the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers in 2011, the Foundation accepted the alignment of its rules with those of other European countries.

Unity Through Knowledge Fund, http://www.ukf.hr. The mission of the Unity through Knowledge Fund is to unite scientific and professional potential in Croatia and Diaspora in development of the knowledge based society. Unity through Knowledge Fund accomplishes its mission through following goals: (i) *Supporting research that is competitive on international level*. The Fund encourages basic and applied scientific research that creates new knowledge and exhibits potential to compete on an international level. Two project types will be financed: those that attract experts and investments into Croatia and those that enable the cooperation/leading of European and other international projects. In particular, support will be given to collaborative projects with Diaspora that enable transfer of knowledge and technology from leading international research and scientific institutions to Croatian private and public sector; (ii) *Fostering research that creates new values in Croatian economy*. The Fund supports projects that directly and indirectly strengthen the Croatian economy. The development of innovations, commercial and other application of scientific results will be financed. In particular, support will be given to the investments made by the business sector into scientific projects. In particular, support will be given to the investments made by the business sector into scientific projects. With the use of the resources of scientific and

professional Diaspora, companies that apply new knowledge will be supported; (iii) *Supporting projects that help the development of research infrastructure in Croatia*. The Fund supports all initiatives that contribute to the development of scientific system in Croatia. UKF supports and encourages the development that results in competitiveness on international level, supports education and scientific excellence in order to make Croatia a desirable place for top scientists from abroad (including those from Diaspora). Projects that are in accordance to the mission of UKF through the work in administrative, infrastructural and managing segment of science and technology will be financed.

The Environmental Protection and Energy Efficiency Fund (EPEEF), https://www.fzoeu.hr. The Environmental Protection and Energy Efficiency Fund (EPEEF) is the central point for collecting and investing extra budgetary resources in the programmes and projects of environmental and nature protection, energy efficiency and use of renewable energy sources. In the system of management and control of utilisation of EU structural instruments in Croatia, the Fund performs the function of Intermediate Body level 2, for the specific objectives in the field of environmental protection and sustainability of resources, climate change, energy efficiency and renewable energy sources. The activities of the Fund comprise the tasks related to financing of the preparation, implementation and development of programmes and projects and similar tasks in the field of conservation, sustainable use, protection and improvement of the environment, and in the field of energy efficiency and use of renewable energy sources, and in particular: (i) Expert and other tasks in relation to the collection, management and utilisation of the Fund's resources; (ii) Acts as an intermediary in the matters related to the financing of environmental protection and energy efficiency from foreign funds, international organisations, financial institutions and bodies, as well as national and foreign legal and natural persons; (iii) Maintaining the database of programmes, projects and similar activities in the field of environmental protection and energy efficiency, and of the required and available financial resources for their implementation; (iv) Promoting, establishing and carrying out cooperation with international and national financial institutions and other legal and natural persons, for the financing of environmental protection and energy efficiency in accordance with the National Environmental Strategy and the National Environmental Action Plan, the Energy Development Strategy and the Implementation Programme for the Energy Development Strategy, national energy programmes, other programmes and acts in the field of environmental protection and energy efficiency, and international treaties to which the Republic of Croatia is party, for the purposes specified in the provisions of the Act on the Environmental Protection and Energy Efficiency Fund; and (v) Other tasks related to promoting and financing environmental protection and energy efficiency that are set out in the Statute of the Fund.

Ministry of Education, Universities and Research (MIUR), Italy, https://www.miur.gov.it: The Ministry of Education, Universities and Research (MIUR) is assigned the functions and tasks pertaining to the State in the field of school, university and advanced artistic, musical and dance training, scientific and technological research. In these three main channels of intervention, except for areas of competence reserved to other bodies and organizations, the Ministry also performs functions of regulation, support and enhancement of the autonomy recognized to schools, universities and research institutions.

In the Research sector MIUR is entrusted with the tasks of addressing, planning and coordinating the national and international level, including the definition of the National Research Program and the

coordination and monitoring of European research objectives; guidance, planning and coordination, general legislation and financing of non-instrumental research bodies and related monitoring of activities; integration between applied research and public research, coordination of Italian participation in national and international research programs; analysis, processing and dissemination of Community legislation and the methods of interaction with Community bodies and related assistance to businesses; scientific cooperation at national, EU and international level, also through specific links between universities and research institutions; promotion and support of business research also through the use of specific subsidy funds; enhancement of researchers' careers, their autonomy and their access to specific national and international funding programs and their international mobility; definition of information needs, in the fields of higher education and research and design of databases for student registries, research, evaluation; promoting the internationalization of higher education and research enhancement of researchers' careers, their autonomy and their access to specific national and international funding programs and their international mobility; definition of information needs, in the fields of higher education and research and design of databases for student registries, research, evaluation; promoting the internationalization of higher education and research enhancement of researchers' careers, their autonomy and their access to specific national and international funding programs and their international mobility; definition of information needs, in the fields of higher education and research and design of databases for student registries, research, evaluation; promoting the internationalization of higher education and research.

4.4 Private foundations and NGOs

Created within large private companies or as NGOs, foundations are committed - sometimes with very significant resources - to supporting well-defined actions in line with their missions and which may involve public or private actors. Many foundations have stated objectives of supporting research and innovation, environmental preservation, sustainable development, capacity building and education.

One Ocean Foundation, https://www.1ocean.org, develops specific projects that help safeguard marine life. Recently it has launched a “Business for Ocean Sustainability” research project. Produced with the support of SDA Bocconi, McKinsey & Company and CSIC, the project – focusing for this first edition on the Mediterranean Sea, but with cross-border potential – examines the current relationship between ocean sustainability and the economy from a new perspective. More than 220 international companies, start-ups, associations and NGOs are involved, spanning 13 industry sectors.

Prince Albert II of Monaco Foundation, https://www.fpa2.org/home.html: The Prince Albert II of Monaco Foundation (PA2F) is dedicated to the protection of the environment and the promotion of sustainable development on a global scale. The Foundation supports initiatives of public and private organizations, in the fields of research and studies, technological innovation and socially-aware practices.

The Foundation supports projects in three main geographical zones and focuses its efforts focus on three main areas.

4.5 Bilateral cooperation and in kind contributions

Aside from all above instruments, the cooperation between all the Adriatic institutions through bilateral cooperation agreements may help in achieving some of the proposed measures and activities. This also include the work of staff engaged for some other activities, the use of equipment and other items that might help to fulfil the goals of the climate monitoring in the Adriatic Sea. In addition, philanthropy might help for fundraising of some proposed activities, in particular related to purchase of equipment necessary for carrying out the necessary ecological measurements.

5. Summary and conclusions

In this deliverable we have developed the framework for long term sustainability of the climate observations in the Adriatic Sea. Development of such a framework, based on global climate monitoring approaches and dedicated to specific Pilot Sites of the CHANGE WE CARE project with specific recommendations, is of utmost importance in the present era of climate changes, as quantifying the effects of climate changes on the physical, biogeochemical and biological systems is a prerequisite for proper assessment of climate changes and is allowing for definition of measures that might mitigate the impacts of climate changes.

The recommendations is establishing a playground for proper monitoring of climate changes in the Adriatic region, which is presently lacking and should be better developed for some regions. Dedicated action and implementation plans should follow, if not developed for the pilot sites in question and in general. Further, the sustainability of the monitoring activities is a key for establishing multidecadal observing platforms and systems, and for that all available possibilities for securing sustainability are overviewed in the document. Hopefully, such a plan will become a reality through fostering collaborations between scientists, managers and policy-makers, for the selected sites and in general.

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