Report on existing data and relative gaps

Activity 3.4

Task 3.4.1

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PROJECT CHANGE WE CARE

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Activity:	3.4
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Deliverable:	3.4.1 *Report on existing data and relative gaps: This report will describe the main results of the data collection for each site, reviewing the status and trend of protected habitats, species and ecological quality elements. Maps of coastal and Intertidal habitats trend and maps of coastal and aquatic transitional ecological quality elements trend will be included. The report will also include the Operational Plan of acquisition data in situ to complete the main uncertainties and knowledge gaps.*

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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.

1. INTRODUCTION

This document reports the efforts in collecting and harmonizing the information on protected habitats and species and on biological communities, as well as on the main physical-chemical characteristics of the different pilot sites considered in CHANGE WE CARE (Activity 3.4). The activity related to this deliverable also had the goal of identifying the main uncertainties and knowledge gaps, to definerelevant data to be acquired within the Project or in future monitoring programmes. The analysis allowed to identify the most informative data, not only in relation to the spatial and temporal continuity of the series but for the sensitivity of considered taxa to the physical changes of the shoreline. A geospatial database associated with this activity was also build and it is stored as a GIS, organized to mirror the structure of this document. The GIS is available for the Project partners and it is presented in D3.4.2.

This document is organized in five main chapters – beside this brief introduction- each reporting the information considered for each Pilot Site. The pilot sites (Figure 1) are:

1. Neretva River
2. Jadro River
3. Nature Park Vransko Jezero
4. Banco di Mula di Muggia
5. Po River Delta

After a brief description of the pilot site, each chapter presents the status and trend (when it was possible to reconstruct the temporal dynamic) of the most relevant species and habitats. To anticipate the next steps of the Projects, aimed at analysing the relationships among the abiotic characteristics and the species and habitats evolution, also the status and trend of the main (i.e. the most relevant for the Pilot Site and for the species and habitat considered in the case study) physical chemical variables are presented. To present these information each chapter is structured as follow:

Presentation of the data collection system in place

Review of the status and trend of protected habitats, species and ecological quality elements, including maps of coastal and Intertidal habitats.

Operational Plan of acquisition data in situ to fill the main uncertainties and knowledge gaps.

The complete list of available data identified during the review carried out to gather the data presented here, including the ones not reported in this document, is presented in Annexes, in tables summarizing the main characteristics of the available information (reference period, frequency of acquisition, owner of the data…).

Figure 1. Overview of the Pilot Sites of CHANGE WE CARE

2. Pilot Site 1 - Neretva River Delta

2.1. General site description

In the Neretva River Delta, there are protected areas of nature according to Croatian Law of nature protection:

- ornithological special reserves: Prud, Pod Gredom, Orepak,
- ichthyological - ornithological special reserve: Delta Neretva – southeastern part,
- significant landscapes: Modro oko i Lake Desne, Predolac – Šibenica.

Neretva River Delta is designated as internationally important wetland under the Convention on Wetlands (Ramsar, 1971). It contains the largest complex of wetlands in Croatian littoral with well- developed water-fringe vegetation (the largest reedbeds in the country that cover more than 3,000 ha, sedge communities, rush), floating and submerge vegetation around Neretva and its tributaries.

Also, it is a Natura 2000 site HR100031 Delta Neretva (SPA), HR5000031 (SCI).

Neretva Delta is the most valuable wetland on eastern Adriatic coast and one of only few wetlands remained in Mediterranean region of Europe. The mouth of the river Neretva is characterized by wide lagoons, sandflats and saltmarshes. Though a large area of the wetland habitat has been transformed into agricultural lands, due to the branching network of channels, these areas are still important habitatsfor aquatic birds and a very important ichthyological area. Reclaimed land is covered by agricultural landscape with many irrigation channels. The Neretva Delta has many lagoons, shallow sandy bays, low sandy shores, sand flats, salt beaches, etc. The delta, lagoons and brackish waters are an exceptionally important habitat which creates room for the intensive growth of fry, which later spend their life cycle inthe sea or fresh water. Furthermore, these areas are important for the migration of anadromous and catadromous fish species. Neretva Delta is important for breeding, migration and wintering of almost200 regularly occurring bird species.

Salt water intrusion in Neretva River Delta, reduced inflow of fresh water and reduced sediment deposit represent great threat for delta. Due to this, there is a change in the environment conditions in the coastal sea, and the fresh water ecosystems which results in reduction of wetlands. All of this directly affects the biodiversity of the area, target species and the habitat Natura 2000.

Furthermore, as a consequence of human activity in the area, there is the distribution of contaminants in water and soil. All previously listed has a direct impact on reducing the quality of life of local communities, and loss of extremely valuable areas of biodiversity.

Neretva River Delta is an area with a lot of different influences, so there are numerous activities that have or could have negative impact on the natural values site Delta Neretve, such as: planned tourist zone in Natura 2000 Illegal kite surfing activities in ichthyological - ornithological special reserve: Delta Neretve – southeastern part, illegal land reclamation, Illegal hunting etc..

The future of this area should be based on balancing the need for further development and the need to protect natural resources. Within the Project it’s important to define guidelines to effectively oppose salt water intrusion without obstructing fish migration, as well as guidelines for preservation of wetland area in Neretva River Delta, all respecting the needs of the development of the local communities.

2.2. Data collection

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, 6 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).

2.3. Physical-chemical parameters

2.3.1. Data availability

Available physical-chemical variables are reported in Table 1.

Table 1. Tabular synthesis of the physical-chemical parameters available for the Neretva River Delta.

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	NOTES
Water temperature	excel table	surface water, left and right river banks	Neretva River Delta (Rogotin, Metković, Pižinovac, Crepina)	actual measurements	2015-2017	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	2015-2017	PIDNIC	

2.3.2. *Reviewing the status and trend of physical-chemical parameter*

The trend of temperature and physico-chemical parameters of water quality at four sampled stations for surface waters in Neretva River Delta are reported in Table 2 and Table 3.

The physico-chemical parameters of water quality at three sampled stations for transitional waters in Neretva River Delta are reported in Table 4.

Table 2. Trend of temperature and physical-chemical parameter in Neretva River Delta in the period 2015-2017 (Source: Hrvatske vode, 2018.)

Name of location	Statistic	Temperature	pH value	Electrical conductivity (μS/cm)	Total suspended solids (mg/l)	Total residual chlorine ($mgCl_2$/l)	Alkalinity m-value ($mgCaCO_3$/l)	Alkalinity p-value ($mgCaCO_3$/l)	Total hardness ($mgCaCO_3$/l)	Ca hardness ($mgCaCO_3$/l)
Rogotin	n. obs.	18	18	18	18	12	18	18	18	18
	Maximum	21,4	8,1	9.103	10	<0,15	181	0	1.092	299
	Minimum	6,8	7,79	379	<1,5	<0,15	141	0	185	156
	Mean val.	13,866667	7,948333	3.386,111111	2,838889	<0,15	167,888889	0	502,666667	217,166667
	Stan.dev.	4,876836	0,0886	2.616,037998	2,648393	0	10,087201		265,94316	39,53591
	10%	8,61	7,87	388,1	<1,5	<0,15	158	0	196	162,5
	50%	11,95	7,915	3.605,5	1,75	<0,15	168	0	522	222
	90%	20,06	8,065	6.449,4	6,6	<0,15	180	0	821,1	262,2
Metkovic	n. obs.	34	34	34	34	34	34	34	34	34
	Maximum	19,6	8,1	1.807	17,1	<0,15	193	0	334	236
	Minimum	7	7,75	357	<1,5	<0,15	151	0	187	146
	Mean val.	13,173529	7,91	609,764706	2,832353	<0,15	168,882353	0	230,382353	176,764706
	Stan.dev.	3,886363	0,075317	372,25741	3,101756		10,53929		35,434117	17,805444
	10%	8,7	7,8	376,8	<1,5	<0,15	158	0	198,2	159,6
	50%	12,15	7,9	445,5	1,5	<0,15	166,5	0	217,5	173
	90%	18,27	8	1.287,2	5,42	<0,15	183,8	0	290,2	198,7
Pizinovac	n. obs.	35	35	35	35		35	35	35	35
	Maximum	28,7	8,41	3.630	29,5		246	12	531	376
	Minimum	6,8	7,5	693	<1,5		170	0	218	155
	Mean val.	17,777143	7,952286	1.815,028571	5,72		205,428571	0,457143	376,457143	230,342857
	Stan.dev.	6,821681	0,23153	627,882598	6,438797		20,446897	2,11914	75,812983	37,658639
	10%	9,82	7,7	1.017,6	1,5		175	0	278,8	188,2
	50%	17,6	7,97	1.725	3,7		210	0	370	233
	90%	26,8	8,224	2.401,2	12		229,2	0	473	261,6
Crepina	n. obs.	34	34	34	34	34	34	34		
	Maximum	29	8,2	4.576	28	293	778	436		
	Minimum	3,7	7,5	1.707	<1,5	179	323	182		
	Mean val.	17,35	7,769412	2.966,441176	5,167647	236,970588	534,352941	284,735294		
	Stan.dev.	7,32841	0,15719	630,231664	5,504968	32,222225	107,931482	65,5283		
	10%	8,07	7,6	2.314,4	1,5	194,3	409,2	214,9		
	50%	17,25	7,8	2.861,5	3,5	238	530,5	277		

Table 3. Trend and status in physical-chemical parameter at Metkovic site (Neretva River Delta) in the period 2011-2015 (Source: Hrvatske vode, 2018.)

	2011	2012	2013	2014	2015
pH value	8	8,1	8,1	8	7,9
BPK5 (mgO2/L)	<1.5	<1.5	<1.5	<1.5	<1,8
KPK-Mn (mgO2/L)	<1.5	0,9	0,6	0,7	0,8
ammonia (mgN/L)	<0.01	<0.01	<0.01	<0.01	0,016
nitrates (mgN/L)	0,4345	0,442	0,5405	0,39	0,3855
total nitrogen (mgN/L)	0,702	0,4458	0,543	0,4394	0,49
ortophosphates (mgP/L)	<0.003	0,0085	<0.006	<0.006	<0,006
total phosphorus (mgP/L)	0,043	0,033	<0.015	<0.015	0,0165
supporting physical-chemical quality elements (status)	GOOD	GOOD	GOOD	VERY GOOD	GOOD
arsenic (µg/L)					0,4965
copper (µg/L)	<1	0,4695	0,6077	0,4957	0,567
zink (µg/L)	<30	1,007	3,5175	0,954	1,039
chromium (µg/L)	<1	0,638	1,319	0,4573	0,3685
fluroides (PGKµg/L)					40
fluorides MGK (µg/L)					1288
AOX (µg/L)					<50
specific pollutants (status)	VERY GOOD/GOOD	VERY GOOD/GOOD	VERY GOOD/GOOD	VERY GOOD/GOOD	VERY GOOD/GOOD
Ecological status	GOOD	GOOD	GOOD	VERY GOOD	GOOD

Table 4. Trend and status in physical-chemical parameter in Neretva River Delta in the period 2013-2015 (Source: Hrvatske vode, 2018.)

	year	oxygen saturation (%)	inorganic nitogen (µmol/dm³)	orthophosphates (µmol/dm³)	total phosphorus (µmol/dm³)	supporting physicochemical quality elements (status)	coper (µg/L)	zink (µg/L)	specific pollutants (status)	Ecological status
Rogotin	2013	P: 96.2	P: 40.71	0,21	<0,484	GOOD	1,3623	1,6718	VERY GOOD/GOOD	GOOD
	2014	P: 103.4	P: 31.76	<0,19	<0,48	GOOD				GOOD
	2015	100,9	27,07	0,195	0,373	GOOD	1,802	1,9003	VERY GOOD/GOOD	GOOD
Crepina	2014	P: 81.2	P: 11.8	1,14	3,37	MODERATELY				MODERATELY
	2015	95,5	34,71	1,656	3,345	MODERATELY				MODERATELY
Pizinovac	2014	P: 117	P: 8.8	0,21	1,23	MODERATELY				MODERATELY
	2015	110,9	8,36	0,227	0,812	MODERATELY				MODERATELY

2.4. Biological parameters

2.4.1. Data availability

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 our Public institution concerning ornitho fauna and ichthyofauna in Delta Neretva Natura 2000 site.

Public institution participates in flood control planning with Hrvatske vode in order to reduce potential risk for biodiversity of the area.

Table 5 shows the available scientific papers that can be found on the Internet. Data on mammals and other invertebrates found in various studies addressing the biodiversity of the entire Dubrovnik-Neretva County or the Republic of Croatia are not included here. The mammals and invertebrates of the Neretva Delta are poorly researched.

Table 5. Tabular synthesis of the biological parameters available for the Neretva

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
Maps of different habitats	.shp	Map of habitats	Delta Neretva River	Actual measurments and models	2004, 2016	http://www.bioportal.hr/gis/	
Flora (algae and vascular flora)	.pdf	Scientific papers	Delta Neretva River	Actual measurments	2007, 2015	In Croatian: Jasprica et al., 2007.; Glasnović et al., 2015	
Insecta (Lepidoptera)	.pdf	Scientific papers	Delta Neretva River	Actual measurments	2014	In Croatian: Kučinić et al., 2014.	
Herpetofauna	.pdf	Scientific papers	Delta Neretva River	Actual measurments	2012	In Croatian: et al., 2012.	
Ichtyofauna	.pdf	Scientific papers	Delta Neretva River	Actual measurments	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 measurments	2007, 2016	In Croatian: Kitonić et al., 2007; Ilić et al., 2016	

2.4.2. Reviewing the status and trend of biological parameters

With a large number of endemic species and a great diversity, the mouth of the Neretva River is one of the most interesting areas of Croatia.

The delta is surrounded with karst hills rich with underground water that supplies numerous springs, streams and lakes. More than 80 registered caves and other underground habitats in these karst surroundings are home for rich fauna with many threatened and endemic taxa.

SPA 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.

Neretva Delta is a part of the wider transboundary wetland with Hutovo Blato Ramsar site in Bosnia and Herzegovina. The same birds use both sites during migration, wintering and even breeding. Some species breed in Hutovo Blato and feed in Neretva Delta, like *Phalacrocorax pygmeus* and *Plegadis fascinellus*.

Neretva Delta regularly supports > 1% SE Europe/Turkey population of *Phalacrocorax pygmaeus*.

During the breeding season *Plegadis fascinellus* that breeds in Hutovo Blato in B&H (Ilić, HOD, pers. comm.) regularly feeds in Croatian part of Neretva Delta, depending on the phase of the breeding.

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

As Neretva Delta is situated on the Central European (Black Sea/Mediterranean) Flyway, this area is also important for migration of *Grus grus*. During February and March, flocks of cranes are flying over the delta and up to several hundred of birds per day have been registered (Ilić, HOD, pers.comm.). Although monitoring started only in 2011, data indicate that probably around 3,000 cranes migrate over Neretva Delta (threshold for the 'bottleneck' of European importance according to the BirdLife criteria). The river mouth with its shoals, sandbanks and saltmarshes is of greatest importance for migration of waders, representing one of the two most important coastal sites for waders, along with the SW Dalmatia and Pag. Bird monitoring on the river mouth during last several years indicates that Neretva Delta probably satisfies 1% level for Central and SE population of *Platalea leucorodia*. The river mouth represents the one of only two breeding sites of *Charadrius alexandrinus* in Croatia and one of only two coastalbreeding sites of Himantopus himantopus – the other one being the SPA SW Dalmatia and Pag.

Reedbeds in Neretva Delta are especially important for breeding of *Botaurus stellaris* (50% of national population), *Porzana pusilla* (83% of national population), *Porzana parva* (25% of national population) and *Porzana porzana* (17% of national population). It also holds 12.5% of Croatian population of *Ixobrychus minutus* as well as 17.5 of Circus aeruginosus.

The breeding of *Ardea purpurea* in Neretva Delta was confirmed for the first time in 2013 when the collony of 25-30 p. was found in reedbeds (Bariša Ilić, HOD, pers. comm.). Neretva Delta is the only breeding site for *Aythya nyroca* in Mediterranean region of Croatia. The breeding of *Acrocephalus melanopogon* was registered for the first time in Neretva Delta in 2011. Along with the SPA Cetina River, this is the only breeding site in Mediterranean region of Croatia for this species. Reedbeds of Neretva Delta represent the only breeding site in Mediterranean region of Croatia for *Panurus biarmicus* and for *Acrocephalus* *schoenobenus*. They are also important for migrating and wintering birds, especially for wintering populations of *Acrocephalus melanopogon*, *Porzana parva*, *Porzana porzana*, *Porzana pusilla* and *Rallus aquaticus*.

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.

This is one of on two sites important for the conservation of *Coenagrion ornatum* in the Mediterranean Biogeographical Region. Because of the large population (cca. 40% of the national population) the site is of great importance for the conservation of *Lindenia tetraphylla* in Croatia.

The largest *Miniopterus schreibersii* hibernation colony in the mediterranean biogeographical region in Croatia is in Delta Neretve. As well as one of the 34 underground sites with 10,000 or more bats recorded in Europe. Internationally important undergorund site for *Rhinolophus ferrumequinum* (nursery, migration), *Myotis emarginatus* (nursery, migration) and *Miniopterus schreibersii* (hibernation) and the southernmost known *Myotis capaccinii* nursery. Site is important for *Rhinolophus hipposideros* nursery and migration. Also, *Rhinolophus euryale* summer roost.

Important site for Mediterranean salt meadows (*Juncetalia maritimi*), as well for Mediterranean and thermo-Atlantic halophiles scrubs (*Sarcocornetea fruticosi*) and *Salicornia* and other annuals colonizing mud and sand; these two habitat types occurs together on the site, with *Salicornia* represented in much smaller area. The area is considered to support a significant presence of coastal lagoons. It is important site for 3130 habitat type, with some plant communities known only from this part of Croatia. Important site for habitat type 62A0 and 9320. One of the best areas for 92D0 Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae) in Croatia. It is one of the most representative sites for Estuaries and important site for Mudflats and sandflats not covered by seawater at low tide.

According to the IUCN Red List of Threatened Species (IUCN, 2012), Neretva Delta with surrounding area supports significant number of globally threatened species in categories CR, EN, VU and NT*. They include: 1 VU and 2 NT mammals; 5 NT birds; 2 NT reptiles; 1 VU amphibian; 2 CR, 1 EN and 5 VU fishes;1 VU mollusk. Neretva Delta is also important site for a number of species of European concern that are protected by the Birds Directive and the Habitats Directive as well as by the Convention on the conservation of European wildlife and natural habitats. European Red List species include: 3 NT vascular plants; 1 VU and 4 NT mammals; 2 NT reptiles; 1 VU amphibian; 2 CR, 1 EN and 5 VU fishes; 1 VU dragonfly and 1 VU mollusk. Regarding regularly occurring ornithofauna, Neretva Delta supports 80 birdsunder BirdLife categories of Species of European Concern (SPEC 2 and SPEC 3 – 8 vulnerable, 34 declining, 5 rare, 32 depleted and 1 localized) and 46 birds protected as the Annex I species of the Birds Directive. Neretva Delta is important for 60 Croatian Red List species (8 CR, 19 EN, 10 VU and 23 NT).

2.4.3. Maps of habitats trend and maps of ecological quality elements trend

Map of Natura 2000 and all habitats are available on the web portal (partially translated in English) of Nature Protection Information System – Bioportal

(http://www.bioportal.hr/gis/?lang=en&theme=neptune).

2.5. Operational Plan of acquisition data in situ to complete the main uncertainties and knowledge gaps.

Coastal and aquatic transitional habitats in Neretva River Delta (the wider area of the mouth of Mala Neretva, the mouth of the Neretva River, Parila Lagoon, Vlaška Lake, Neretva River to the city of Opuzen) are scarcely investigated and have to be mapped based on salinity criteria for brachish water from 1 to 25 ppt (30 ppt). Except biodiversity that should be investigated, the ecological status of this transitional habitats should be defined by WFD classification.

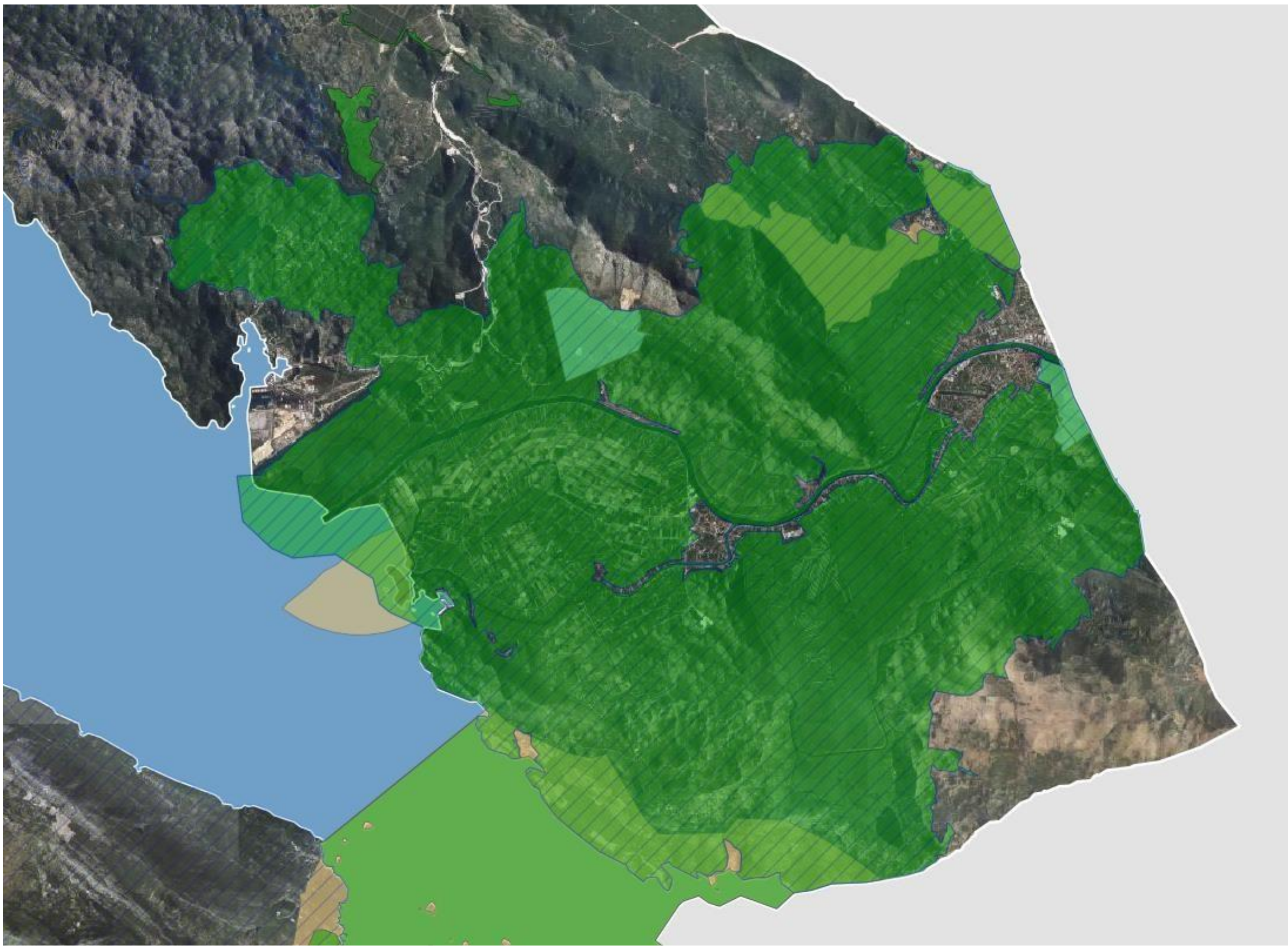


Figure 2. Site map and quick identification of the study domain (from: http://www.bioportal.hr/gis/)

3. Pilot Site 2 - Jadro River

3.1. General site description

Jadro is a typical karst river with short course of ~4.5 km that originates in mountain Mosor and flows into the Adriatic Sea in the Kaštela Bay (Vranjic) near Solin. The upper part of the river Jadro watercourse, from its spring to the bridge Uvodić, has been proclaimed the special ichtyological reserve in year 1984. Jadro river is not in contact with other freshwater bodies, what resulted in creation of endemic species and subspecies including soft-muzzled tout also known as Solin salmon (*Salmothymus obtusirostris salonitana*). The reserve has been proclaimed to protect this trout species and covers area of 78 000 m^2. River Jadro is included in Natura 2000 sites.

Water from river Jadro is used as drinking water source for ~260 000 inhabitants that live in Split urban agglomeration area. Management methods, for protection of drinkable water sources, actively contribute to the protection of this important freshwater body. However, large number of inhabitants in the city of Solin and nearby areas, that live in close proximity to the river, industrialization of nearby areas, road infrastructures and inadequate use do pose threats to it. Through its freshwater input, the river Jadro influences the coastal ecosystem near its mouth – Vranjic (Kaštela bay).

3.2. 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 (www.izor.hr/adrisc, 1987-2017) may be used, providing meteorological and oceanographic data for the area of Jadro.

3.3. Physical-chemical parameters

3.3.1. *Data availability*

Table 6. 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	

3.4. Biological parameters

3.4.1. Data availability

According to study conducted by Mrakovčić et al. (2016) 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 (Table 7), it is considered that the brown trout was also introduced. Periodic monitoring of freshwater fish community is conducted by the Croatian Ichtyological Society in cooperation and with the support of the Public Institution for the Management of Protected Areas in the County of Split and Dalmatia "Sea and Karst". Biological data related to the coastal ecosystem, in nearby area Vranjic Bay, are collected by the Institute of Oceanography and Fisheries.

Table 7. 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

3.4.2. Reviewing the status and trend of biological parameters

As stated above, Jadro has been declared protected area due to presence of endemic subspecies of fresh water fish (*Salmothymus obtusirostris salonitana*). This species is listed in the Red book of freshwater fish of Croatia as critically endangered species, and due to its presence parts of river Jadro and its catchment area are included in the Natura 2000 sites. The soft-muzzled trout is thought to be endangered by historic river diversions, increasing urbanisation, overfishing and by the presence of the introduced rainbow trout (*Oncorhynchus mykiss)*.

Public Institution for the Management of Protected Areas in the County of Split and Dalmatia "Sea and karst" is responsible for the management of the Special Ichytiological Reserve Jadro. Currently, significant protection and conservation efforts are taking place as this organization is partner on several relevant project including project "Jadro – source of life" (2016-2021), financed by the European Regional Development Fund (measure 6c.2.2.). This project includes infrastructural works near Jadro source as well as development of an integral study that will define strategic guidelines for the treatment of its flow from source to river mouth. Infrastructure works include unique recreational-educative walking trail. The Project RiTour (2017-2019) is financed by the programme Interreg – IPA CBC and its objective is to diversify and promote touristic offer of urban destinations on rivers in the Adriatic and includes cooperation on sustainable tourism development, education of service providers in tourism, revitalization of cultural heritage and sustainable use of natural resources.

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 harbor that is currently located at the river Jadro mouth.

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.

3.4.3. Maps of habitats trend

The Map of Natura 2000 site is available at the web portal of the European Environment Agency (https://natura2000.eea.europa.eu/) as well as on the web portal of Nature Protection Information System – Bioportal (http://www.bioportal.hr/gis/).

3.5. Operational Plan of acquisition data in situ to complete the main uncertainties and knowledge gaps.

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. Efforts 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 from the AdriSC climate numerical model, 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.

4. Pilot Site 3 - Nature Park Vransko Jezero

4.1. General site description

Vransko lake, the largest natural lake in Croatia by surface area, was declared a Nature Park in 1999. This shallow lake (max depth -3,9 m a.s.l.) is located in the karst in close proximity to the Adriatic Sea to which it is directly connected by the Prosika canal, dug in the 18th century. Climate change (seawater level rise and decreased precipitation) and increased water usage in the catchment area caused oscillation of freshwater level resulting in increased lake salinity due to seawater inflow directly through Prosika canal and indirectly through the karst ridge between the lake and the sea. Water level range and salinity variations (<1-4 ‰) increased remarkably during the last two decades, especially during dryyears (max. recorded salinities: 2008 - 11,3‰; 2012 - 18,2‰). At that time, also the most pronounced minimums of water level was observed in more than 50 years of data records.

4.2. Data collection

As part of the state water quality monitoring program of Croatian Waters, data on water quality are monitored at three localities in Lake Vrana - at the Crkvina motor camp, at the mouth of the Kotarka River, and at Prosika (Figure 3). Due to the decrease in sampling frequency in the monitoring of Croatian Waters**.** At the Kotarka estuaries and Crkvine camps, the first intermittent causes began in 1982, uninterrupted monthly at the beginning of 1996, and at the beginning of 2010, the causes were carried out every two months (Faculty of Civil Engineering Rijeka, 2016, according to Rubinić, 2014). Since 2014, the causes have been repeated once a month, but in some months and even throughout the years (2014at Kotarka and 2015 at Prosika and Crkvine camp), the causes have not been implemented. At the Prosika station, located at the other end of the lake, in front of the beginning of the Prosika channel, the monitoring system began only in early 2000, after it was observed that intensive salinisation of the lake system was predominantly taking place in that part of the lake. In 2017, the causes were implementedat all three stations once a month, unfortunately only in the period from April to December.

Also, during the observed period, the method of sampling was partly changed - from the former sampling from the surface and bottom of the lake, to the reduction only to the surface and finally to the taking of composite sampling. Such an inconsistent way of quality monitoring within the mentioned state monitoring program is not appropriate if one wants to monitor the spatio-temporal changes in the state of salinity of the Vransko Lake in a longer time series. However, it does provide an insight into the fluctuations in salinity over the longer term shown, since global changes are extremely significant with respect to variations in chloride content, depending on the depth of sampling, because Lake Vrana is very shallow and does not show any more stratified water. In order to complete the knowledge on the dynamics of changes of chloride content in the lake, as well as to supplement the data provided through state monitoring of Croatian Waters, additional monitoring of water quality is carried out by the expert services of the Vransko Lake Nature Park, at sites P2, P4, P6 and P7, which can be seen at Figure 3.

Figure 3. Water sampling sites in Croatian Waters monitoring programs (yellow) and within the internal monitoring of the Vransko Lake Nature Park (highlighted in blue) (Faculty of Civil Engineering, Rijeka, 2016). It should be noted that at Kotarka station there is a confluence between 2010-2015. e.g. reduced frequency of monitoring, and that there is a lot of missing data that has not been supplemented as in the other two stations.

4.1. Physical-chemical parameters

4.1.1. *Data availability*

Data reported in this work are listed in Table 8, while the complete overview of available data is reported in Annex 2.

Table 8. Tabular synthesis of the physical-chemical parameters considered for the Vransko area

CATEGORY	TYPOLOGY	DESCRIPTION	REFERENCE AREA	DATA COLLECTED	YEARS / REFERENCE PERIOD	AVAILABILITY	NOTES
Chlorides	.xls	Measuring point Prosika, Crkvine, and mouth of the Kotarka channel		measured	2010-2019 (monthly / quarterly)	Croatian Waters (Hrate vode, Danko Biondic, danko.biondic@voda.hr)	
Water Electrical conductivity	.xls	Measuring point Prosika, Crkvine, and mouth of the Kotarka channel		measured	2010-2019 (monthly / quarterly)	Croatian Waters (Hrate vode, Danko Biondic, danko.biondic@voda.hr)	

4.1.2. *Reviewing the status and trend of physical-chemical parameters*

From Table 9, it is evident that the mean value of chloride content (and electrical conductivity), for the period 2000 to 2017, at the Prosika measuring point is 1571 mgL-1 (4786 μScm^{-1}), at Crkovine 1212 mgL^{-1} (3814 μScm^{-1}), and at the mouth of the Kotarka 901 mgL-1 (3249 μScm^{-1}). We see that during 2017 the chloride and electrical conductivity content is slightly lower than average. At Prosika and Crkvina stations, camp chloride content is lower by about 50%, while at Kotarka station it is lower by about 20%. However, 2017 data are incomplete, and mean annual values cannot be considered authoritative (indicated in red in the table). According to these results, the lower chloride content is probably the result of slightly more watery previous years during which the salty waters from the lake were changed, their runoff towards the sea and the inflow of fresh waters from the immediate Vransko Polje basin and its hinterland, which can also be seen from Figure 4. It gives a more detailed account of the course of observed (and on the basis of their reciprocal interrelations of complementary) values of electrical conductivity and chloride and the corresponding trends for the common observation period of all three stations from 2000 to 2017. (Rubinić and Radišić 2019.: Hidrological works on Vransko lake and its watershed during the year 2018.).

Table 9. Results of basic statistical data processing (Sr - string mean, Stdev - standard deviation, Cv - coefficient of variation, Max and Min - extreme registered values within the analysed series of mean monthly or annual values) of monthly and annual values of chloride content and electrical conductivity by location, and data for the year 2017. The table shows the values for 2017 obtained through correlations in yellow.

Mjesec	1	2	3	4	5	6	7	8	9	10	11	12	SR GOD
Prosika (2000. - 2017.)													
Electric conductivity													
Sr	6008	3702	3880	3649	3582	3687	4057	5355	6299	6465	6347	5951	4786
St.dev.	5650	3394	3544	3567	3526	3758	4196	5777	6429	6730	6161	6562	4649
Cv	0,940	0,917	0,913	0,977	0,985	1,019	1,03	1,08	1,02	1,04	0,971	1,10	0,971
Max	18000	12944	11987	13870	14534	15560	17720	24900	27069	26200	23000	22937	19369
Min	1222	1387	1173	1087	1184	1155	1139	1271	1336	1284	1360	1512	1355
2017				1853	1830	1900	2100	3550	5300	4760		3370	2786
Chlorides													
Sr	2114	1152	1308	1202	1112	1203	1317	1722	2158	2175	1951	2027	1571
St.dev.	2129	1192	1404	1406	1262	1455	1406	1921	2300	2284	1800	2413	1610
Cv	1,01	1,03	1,07	1,17	1,13	1,21	1,07	1,12	1,07	1,05	0,923	1,19	1,03
Max	7108	4474	4946	5478	5037	6045	5265	8135	9476	8525	6098	8013	6501
Min	372	322	240	272	264	266	246	168	320	334	400	393	315
2017				462	472	470	596	984	1637	1576		1084	813

Table 9 (*continued*) Results of basic statistical data processing (Sr - string mean, Stdev - standard deviation, Cv - coefficient of variation, Max and Min - extreme registered

values within the analyzed series of mean monthly or annual values) of monthly and annual values of chloride content and electrical conductivity by location, and data for the year 2017. The table shows the values for 2017 obtained through correlations in yellow.

Mjesec	1	2	3	4	5	6	7	8	9	10	11	12	SR GOD
Kotarka ušće (2000. - 2017.)													
Electric conductivity													
Sr	2690	1811	1703	2232	1683	2613	3774	5463	4222	4931	3773	3098	3249
St.dev.	3011	1413	1420	2155	863	1684	2332	1891	1789	2846	3473	2788	1891
Cv	1,12	0,780	0,834	0,966	0,513	0,644	0,618	0,346	0,424	0,577	0,920	0,900	0,582
Max	9870	5610	5000	8700	3750	5930	9020	8670	7570	10300	12790	9450	7132
Min	532	911	653	973	933	886	1470	2700	1166	1051	1150	1100	1326
2017				1207	1768		5400	7410	2050	2380	1348	1126	2836
Chlorides													
Sr	723	354	324	497	302	650	1240	1690	1236	1481	1058	857	901
St.dev.	1086	467	466	754	285	583	1043	707	628	992	1154	1069	687
Cv	1,50	1,32	1,44	1,52	0,945	0,897	0,841	0,419	0,508	0,670	1,09	1,25	0,762
Max	3250	1650	1600	2978	969	2039	3300	2954	2250	3200	4000	3260	2509
Min	50	90	72	98	90	122	294	581	121	96	108	94	189
2017				146	312		1671	2398	460	579	206	126	737

Table 9 (*continued*) Results of basic statistical data processing (Sr - string mean, Stdev - standard deviation, Cv - coefficient of variation, Max and Min - extreme registered values within the analyzed series of mean monthly or annual values) of monthly and annual values of chloride content and electrical conductivity by location, and data for the year 2017. The table shows the values for 2017 obtained through correlations in yellow.

Mjesec	1	2	3	4	5	6	7	8	9	10	11	12	SR GOD
Crkvine kamp (2000. - 2017.)													
Electric conductivity													
Sr	4909	2413	2787	3284	3213	3338	3430	4120	4506	4233	4760	4571	3814
St.dev.	4157	1447	1846	2847	2905	3109	2821	3084	3797	4044	4362	3816	3198
Cv	0,847	0,600	0,662	0,867	0,904	0,931	0,822	0,749	0,843	0,955	0,916	0,835	0,838
Max	15300	6680	6470	11750	12083	13380	11980	13050	15838	17100	17640	13139	13688
Min	1012	1049	1010	1028	999	1046	1222	1215	1127	958	1148	1059	1232
2017				1710	1811	1919	2090	2760	3480	4070	3890	3400	2792
Chlorides													
Sr	1671	704	830	1038	1001	1039	1106	1332	1480	1335	1522	1437	1212
St.dev.	1608	485	683	1088	994	1158	1061	1100	1306	1208	1362	1286	1102
Cv	0,962	0,690	0,823	1,05	0,993	1,11	0,960	0,826	0,882	0,905	0,895	0,895	0,909
Max	6027	2140	2420	4396	4045	4999	4396	4786	5329	4982	5264	4406	4625
Min	290	270	256	250	256	162	197	201	374	338	460	429	324
2017				410	437	465	547	780	976	1305	1193	878	632

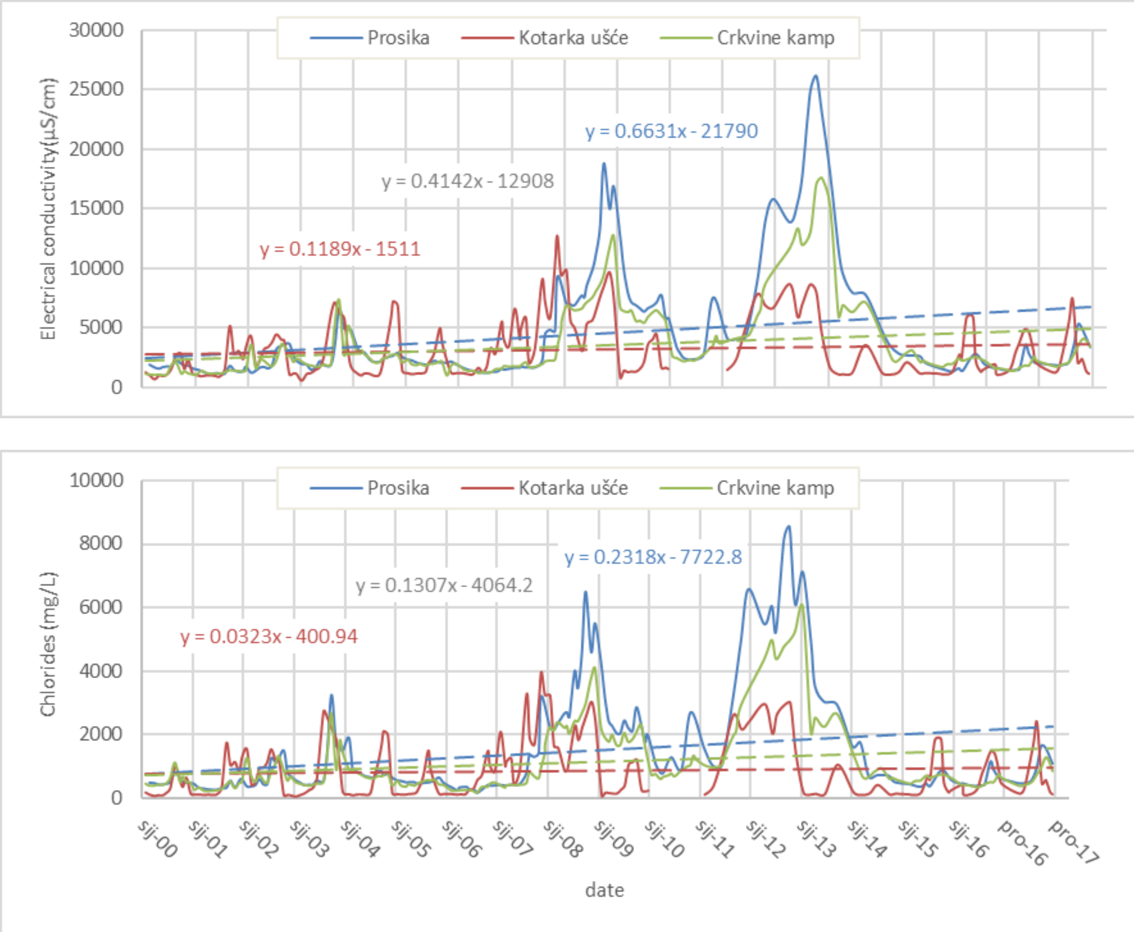


Figure 4. Trends in fluctuations in electrical conductivity (above) and chloride content (below) at three state monitoring stations in Vransko jezero (2000-2017) with a trend

Due to the very severe droughts of 2011 and 2012, there was a significant increase in chloride, ie the maximum recorded values since the beginning of the cause. However, at the end of 2012, winter water inflowed into the lake from its basin and more favorable hydrological conditions, and consequently it decreased the salinity of the lake system. Such a favorable state remained until the end of 2017, but that does not mean that the situation in 2011/12 cannot be repeated soon - Lake Vrana has low sluggishness and very fast reactions of the lake system, and relatively low accumulation of freshwater reserves in its basin and karst aquifer.

4.2. Biological parameters

4.2.1. Data availability

Characeae Family

The objectives of the study of algae from the Characeae family in the Vransko Lake Nature Park are to determine Algae species present, Current algae cover, changes in the composition of all types and land cover compared to previous research (2010-2014, 2018, Figure 5, Figure 6).

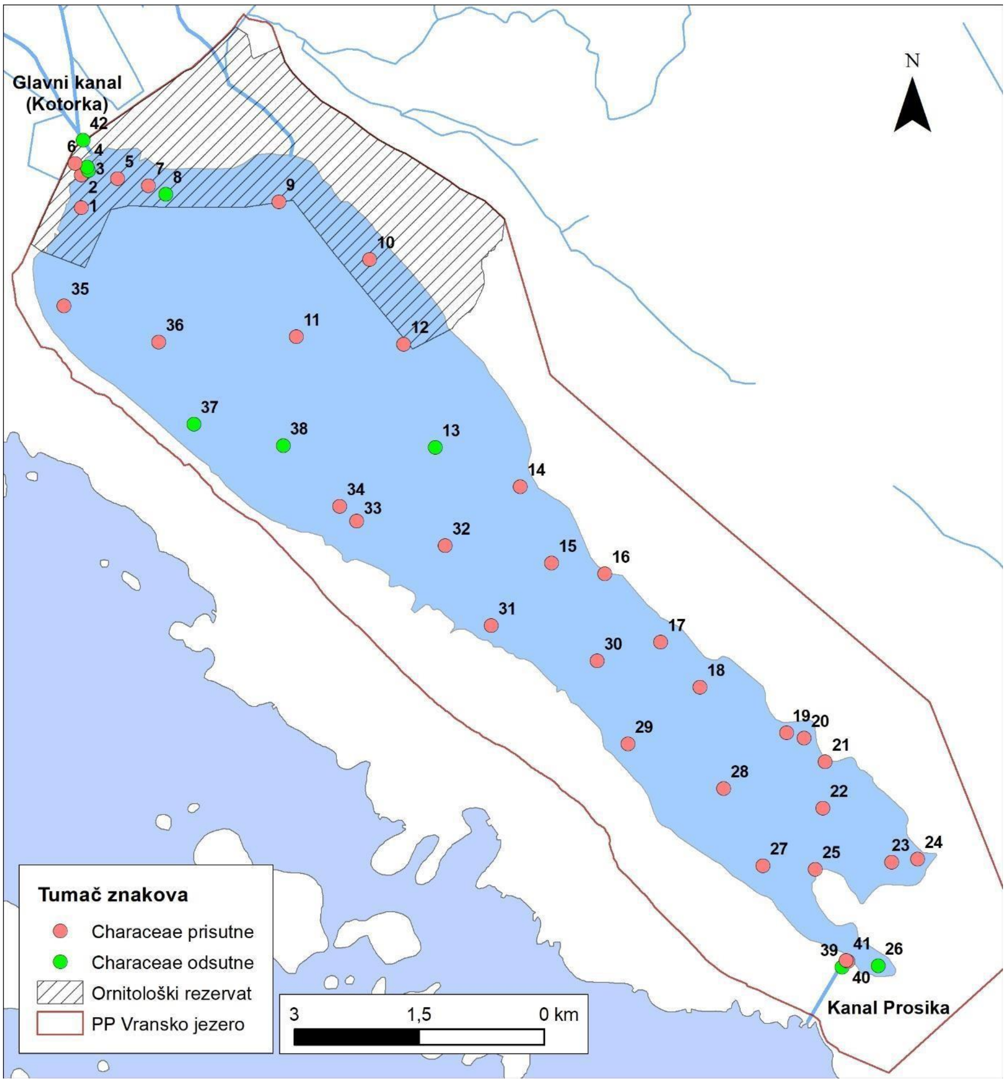


Figure 5 Display of sampled Characeae points on Vransko lake (green – Characear not present, Red Characeae present)

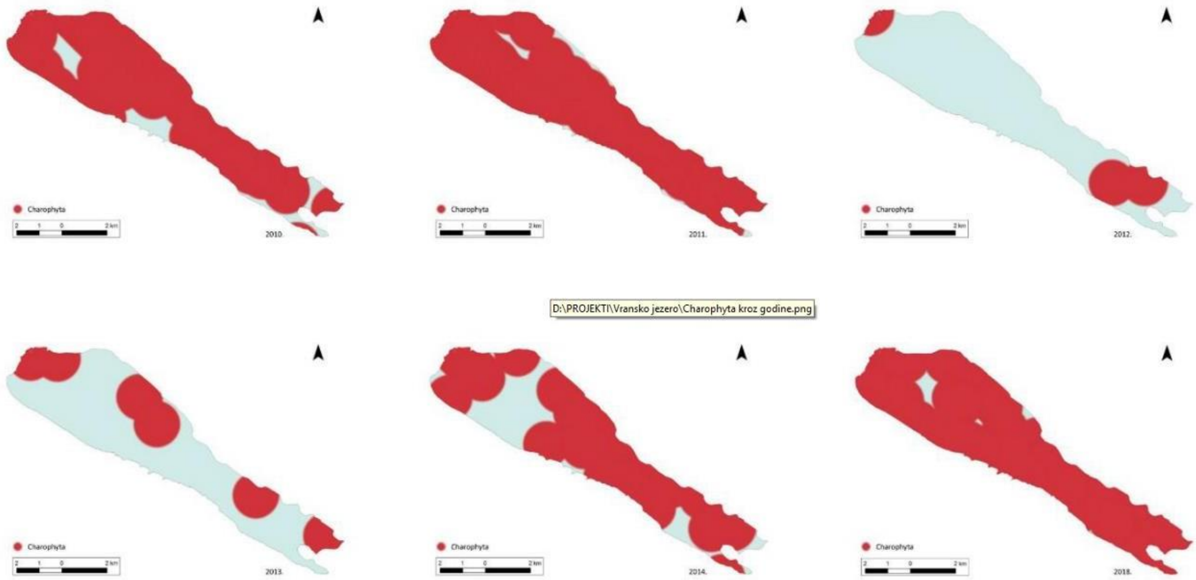


Figure 6 Coverage of algae from the Characeae family in Vransko Lake from 2010 to 2014 and 2018 (Alegro 2014; Alegro et al. 2018)

Table 10. Resume table of the Biological parameters considered in the Vransko area

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 (43/92 / EEC)	shp wms	Establishment of monitoring of occasional Mediterranean puddles and grassland habitats (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 2017. Natura 2000 habitats.	Vransko lake		2017	Vransko lake Nature Park
Phytoplankton	other					
Macroalgae	shp	Characeae	Vransko lake	Field collection	2010-2019, gaps in certain years	Vransko lake Nature Park

4.2.2. Reviewing the status and trend of biological parameters

During the 2010 and 2011 surveys, the estimated cover of algae from the Characeae family, as well as the most common species of Chara intermedia, was about 80% (Stanković 2010, Stanković 2011). In 2012, there was a significant decrease in coverage (Stankovic 2013). The main cause of the decline in thediversity and coverage of algae from the Characeae family in the PP Vransko Lake in the year of 2012. is considered to be habitat changes, ie environmental conditions. In doing so, it came to a situation of extreme fouling development with the dominance of the algae flint species Halamphora sp. which covered in thick layers most of the lake bottom and macrophytic vegetation. This phenomenon resulted in reduced sunflower flow and impeded growth of macroalgae and aquatic plants. *In 2013 there was an increase in coverage, both by the most represented species of Chara intermedia and by other family members (Stankovic 2014). A survey conducted in 2018 estimated the algae cover of the Characeae family at more than 90% (Alegro et al. 2018), an increase over previous research (Alegro 2014) (Figure 6).*

4.2.3. Maps of habitats trend

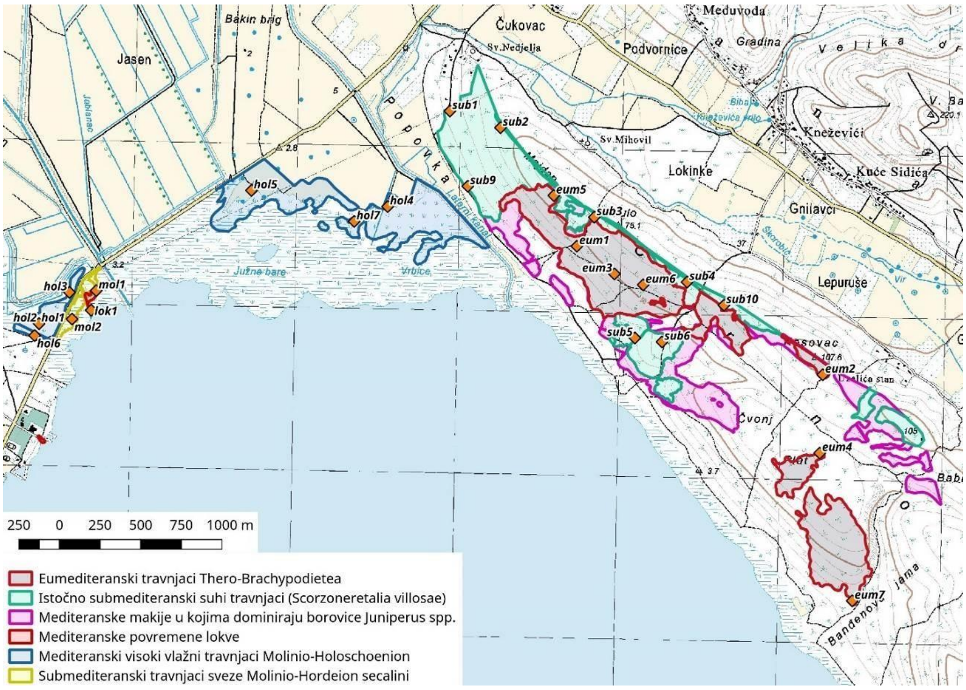


Figure 7. Excerpt from a map of habitats with marked polygons of interest in the northern part of the Park.

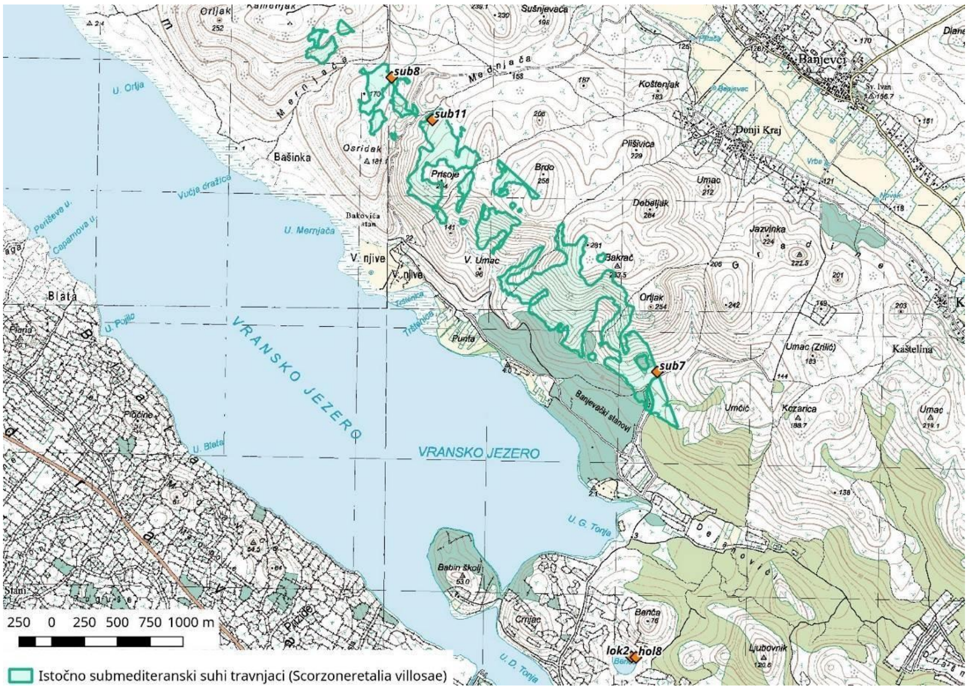


Figure 8. Excerpt from a map of habitats with marked polygons of interest in the southern part of the Park.

Maintaining grasslands in a good state of conservation and preventing succession is a problem that affects not only Vransko Lake or even Croatia, but is also present in many parts of the population thatare struggling with a lack of agriculture or livestock production. Extensive agriculture and animal husbandry should be encouraged in order to preserve these habitats, and if this is not possible due to lack of population or interest, other methods of habitat maintenance should be considered. For areas where succession is just beginning to occur, these may be different mechanical methods such as mowingor felling shrubs and trees up to a percentage of land that is acceptable for maintaining grasslands. Such actions can be realized through the organization of public events where such activities can be carried out in the short term with the help of volunteers. In areas where such methods are not profitable, because succession is already far advanced, or where the use of machinery is not possible, considerationshould be given to the method used by pastoralists in these areas, which is controlled ignition.

In addition to the succession or overgrowth of grassland habitats in maki, the threat to grasslands arriving on deeper, more fertile soil that can be used for agricultural production is, of course, the intensification of agriculture. Ponding such habitats to produce arable land or to plant orchards and olive groves can be a serious problem. Therefore, the use of these grasslands should be encouraged as hayfields or pastures with the optimum number of sows whenever possible, since complete absence of use as well as intensive use of such areas leads to the same result, ie degradation and ultimately the disappearance of these habitats.

There are no maps of ecological quality elements trend available for the Natura 2000 habitats in the Vransko lake Nature park.

4.3. Operational Plan of acquisition data in situ to complete the main uncertainties and knowledge gaps.

As an activity conducted in this project and as a result of gap analisys, research is being carried out on phytoplankton (2014 - 2019), zooplankton (2019), macrozoobenthos (2011 - 2019) and macrophytes (2010 - 2019) groups over extended periods of time (specified in parentheses) together with an analysis of the influence of physicochemical parameters on the abundance, coverage and species composition of individual communities. Based on this analysis, the potential impact of climate change on these communities will be determined and potential biological indicators of the effects of climate change will be defined, depending on the results of the research. Biological indicators should also contribute to the performance evaluation of adaptation measures planned by adaptation plan. The results of these studies will be available after 30/04/2020.

5. Pilot Site 4 -Banco Mula di Muggia

5.1. General site description

The pilot site “Banco Mula di Muggia” is located in the Friuli Venezia Giulia region, within the municipality of Grado. The coordinates are between 13°24’36” and 13°28’15” East and between 45°21’17” and 45°39’30” North (Figure 9).

The “Banco Mula di Muggia” comprises a succession of sandy bars (between -2 m and -5 m), arranged in the form of an arc, representing the outer limit of a wide muddy intertidal zone partially covered by seagrass. The back-barrier is dominated by muddy sand, commonly covered by dense seaweed meadows. The fore-barrier presents higher-energy conditions and rippled sand. It is commonly assumed that it represents the remnants of the former Isonzo river delta having formed during the Middle Ages. External sandy bars tend to migrate toward south-west, following the littoral drift generated by waves. Sediment supply derives from east, from the fluvial source of the Isonzo River. 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 the final sink for the whole up-drift sector.

This site is a portion of the Site of Community Importance/Special Protection Area (SCI/SPA IT3330006 Valle Cavanata and Banco Mula di Muggia), and Special Area of Conservation since 2013 (Figure 10).

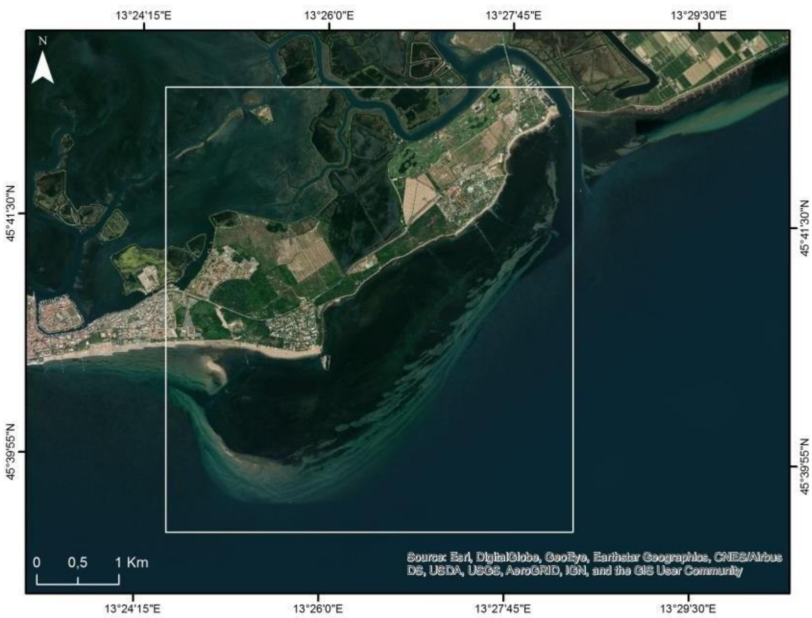


Figure 9. The Banco della Mula di Muggia

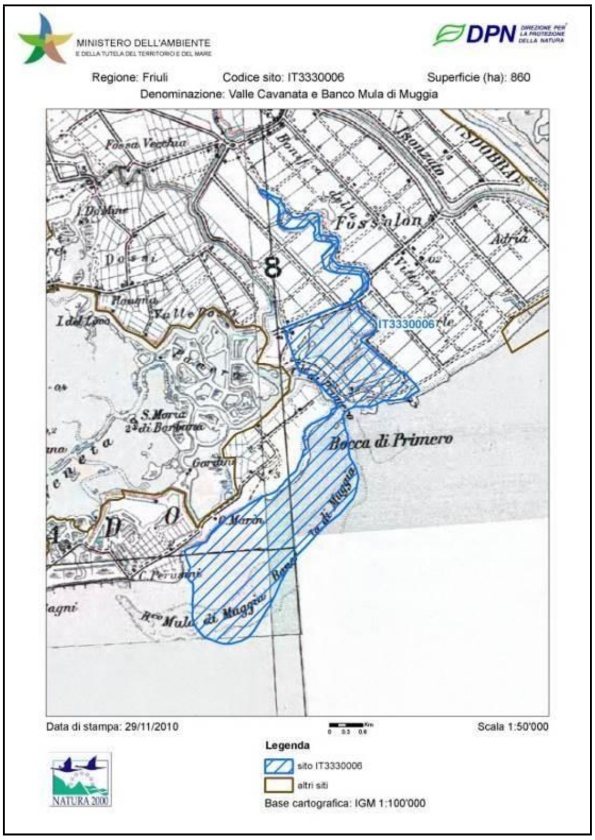


Figure 10. Delimitation of Natura 2000 site

(map from https://www.minambiente.it/pagina/sic-zsc-e-zps-italia).

5.2. Data collection

Data collection within the CHANGE WE CARE Project has targeted the institutional information made available by the Friuli Venezia Giulia Region and the Regional Environmental Protection Agency of Friuli Venezia Giulia (ARPAFVG) (sampling stations in Figure 11). The timeframe considered for the ARPAFVG dataset collection cover the period 2009-2019. This activity was focused on the acquisition of following the parameters:

- Physical-chemical parameters (Figure 11): Water temperature, salinity, pH, Dissolved Inorganic Nitrogen (DIN), Orthophospates, Turbidity, Oxygenation.
- Biological parameters (Figure 11): 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:

- Zoobenthos
- Phytoplankton
- Biocoenosis distribution map
- Other physical – chemical variables

Figure 11. Physical-chemical and biological parameters. Banco Mula di Muggia stations sampled (red dot) in the period 2009-2019.

5.3. Physical-chemical parameters

5.3.1. Data availability

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

Table 11, while the complete database is reported in Annex 3.

Table 11. 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	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

5.3.2. Reviewing the status and trend of physical-chemical parameters

Data collected in the period 2009-2019 are presented and analyzed under different modalities. In particular, for each parameter results are presented as:

- a resume table, including the summary statistics (Average, S.D., Min, Max, N. obs.) of data collected in Banco Mula di Muggia on annual basis (the yearly average is reported only if data for 12 months were available);
- a graphical representation of the trend observed in Banco Mula di Muggia, on yearly basis;
- a graphical representation of the trend observed in Banco Mula di Muggia considering the whole

data collected

- In each case the most appropriate statistical trend representation, to identify the existence of relevant trends on annual or seasonal scale, was chosen on the basis of a model selection procedure, in order to evaluate different *a priori* hypotheses on the type of temporal trend. In particular the model formulations consider if: a) there is a temporal linear trend; b) there is any seasonal effect.

  The choice of the best model representing the temporal trend was assessed on the basis of the Akaike Information Criterion corrected for small samples (AICc, Burnham and Anderson, 2002) and the Akaike Information (AIC, Burnham and Anderson, 2002). The models where fitted as linear models for yearly and quarterly data (sampling data, see above), and as Generalized Additive Models (GAM; Hastie and Tibshirani, 1990; Wood, 2017), as implemented in the mgcv packages (Wood, 2017) for the R software environment for statistical computing (version 3.6.2;R Core Team, 2019).

Temperature (Table 12, Figure 12, Figure 13)

A temperature trend cannot be detected on yearly aggregated data, but a weak positive linear tendency can be seen on monthly/periodic data, taking into account the seasonality.

Table 12. Summary statistics for the yearly temperature values (°C) in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2009	NA	6.12	8.49	25.35	11
2010	15.55	5.93	6.90	24.10	12
2011	15.72	5.93	7.50	24.35	12
2012	16.12	6.94	4.45	25.65	12
2013	16.17	5.81	8.66	23.78	12
2014	17.46	4.93	10.90	24.74	12
2015	16.41	5.93	8.49	25.23	12
2016	NA	5.66	9.53	23.72	6
2017	NA	6.51	7.16	24.88	7
2018	NA	6.75	7.66	24.98	6
2019	NA	0.94	8.40	10.25	3

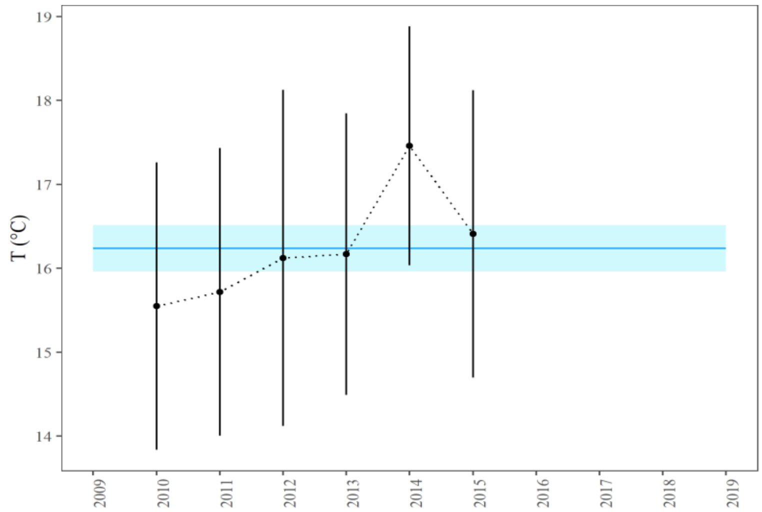


Figure 12. Water temperature trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I.; in this case no trend has been detected).

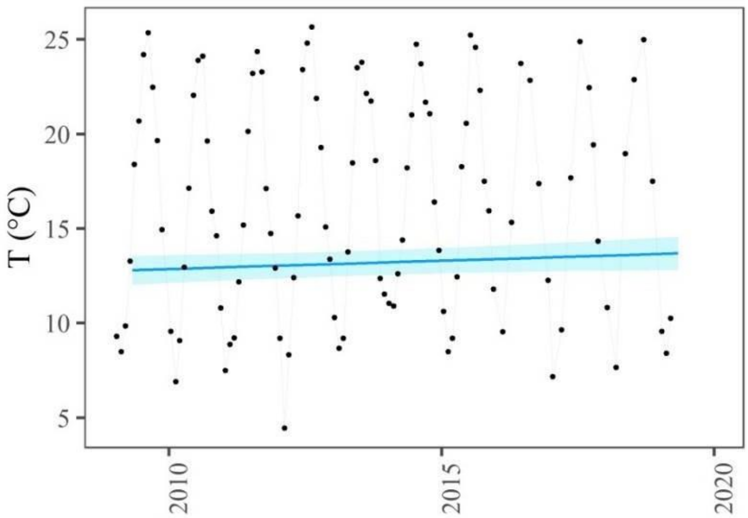


Figure 13. Water temperature trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

pH (Table 13, Figure 14, Figure 15)

Even if the variability is relatively small (Table 13), a positive trend can be observed on both yearly and monthly aggregated data. The assumption of a linear tendency, though, does not look very adequate, as in the last years the pattern suggests a decreasing trend.

Table 13. Summary statistics for the yearly pH values in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N. months
2009	NA	NaN	NA	NA	11
2010	NA	NaN	NA	NA	12
2011	8.19	0.04	8.11	8.23	12
2012	8.18	0.05	8.10	8.23	12
2013	8.19	0.03	8.14	8.23	12
2014	8.26	0.07	8.15	8.38	12
2015	8.20	0.06	8.06	8.31	12
2016	NA	0.03	8.16	8.24	6
2017	NA	0.04	8.22	8.32	7
2018	NA	0.05	8.08	8.20	6
2019	NA	0.13	8.11	8.36	3

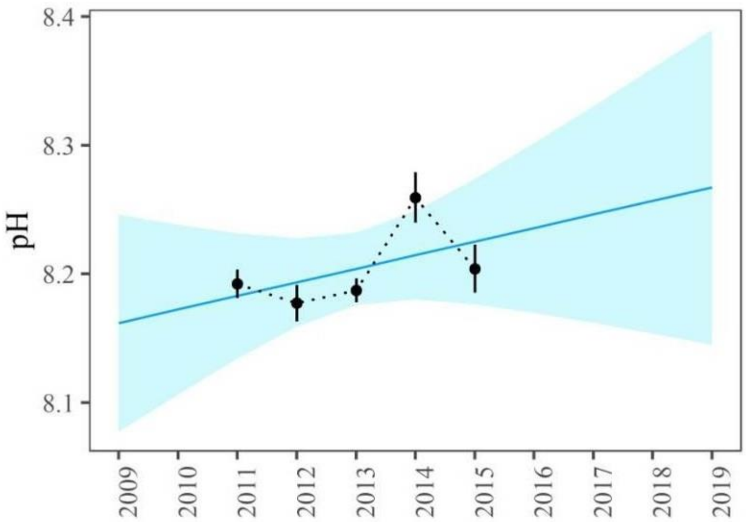


Figure 14. pH trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I.).

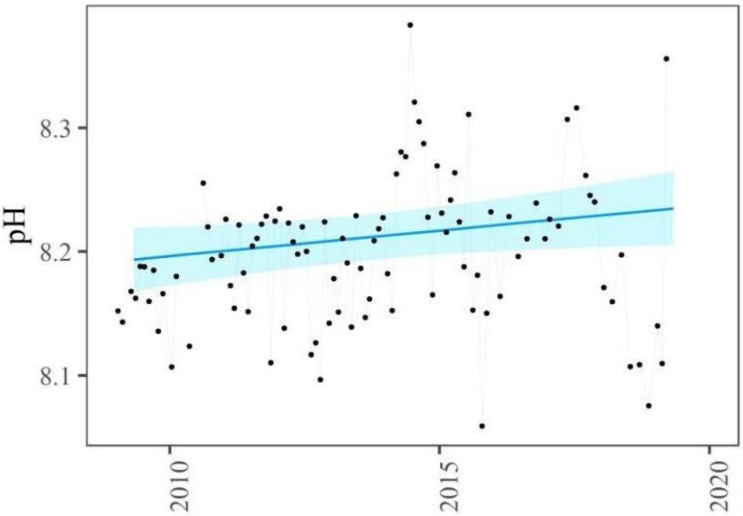


Figure 15. pH trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

Salinity (**Table 14, Figure 16, Figure 17**)

An increasing salinity trend in the area could be detected only taking into account of the seasonal evolution, characterized by a late spring minimum.

Table 14. Summary statistics for the yearly salinity values in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2009	NA	0.92	33.06	35.94	11
2010	32.83	1.89	29.97	35.54	12
2011	34.88	1.79	29.95	36.69	12
2012	36.02	1.37	33.56	38.24	12
2013	34.82	1.57	31.18	37.30	12
2014	33.23	2.26	28.49	36.59	12
2015	35.49	1.08	33.71	36.76	12
2016	NA	1.02	34.08	37.02	6
2017	NA	1.29	34.39	37.94	7
2018	NA	1.28	34.35	37.90	6
2019	NA	0.62	36.50	37.70	3

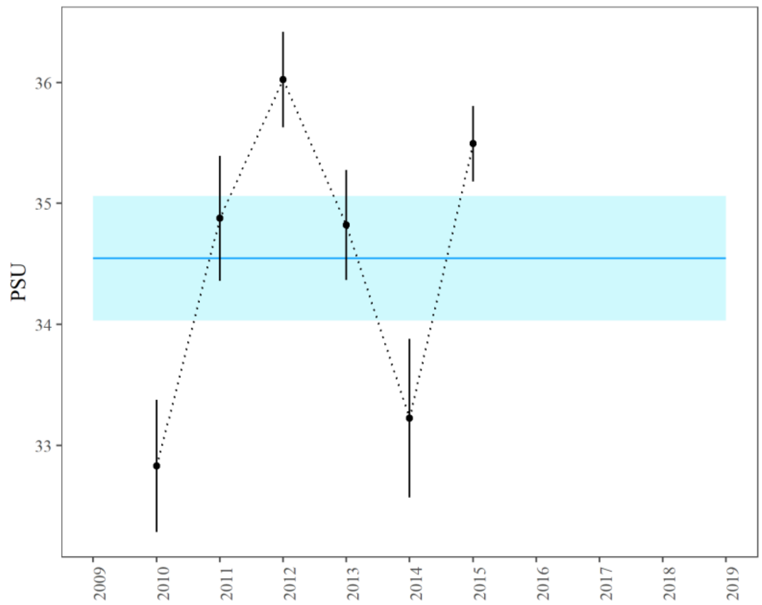


Figure 16. Salinity trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I. – no trend detected).

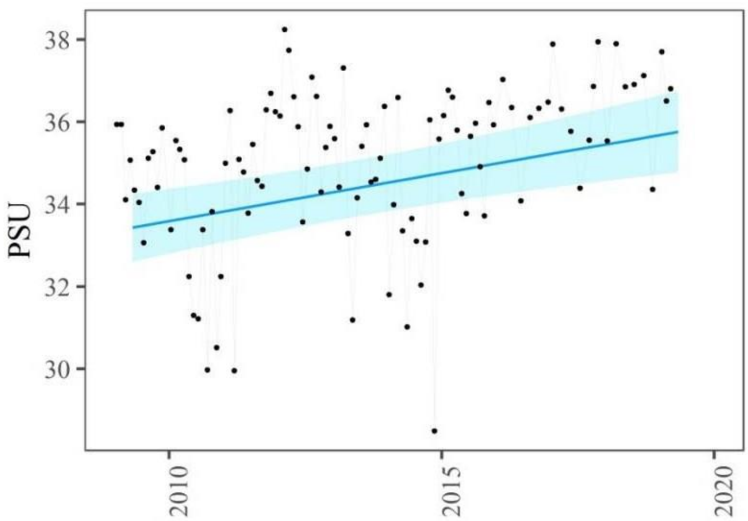


Figure 17. Salinity trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

Dissolved oxygen (**Table 15**, **Figure 18**, **Figure 19**)

No trend can be detected for dissolved oxygen content, for which only a seasonal pattern can beobserved

(minimum levels in late summer)

Table 15. Summary statistics for the yearly dissolved oxygen values in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2009	NA	0.68	4.55	6.59	11
2010	5.67	0.77	4.27	6.70	12
2011	5.71	0.83	4.65	7.34	12
2012	5.76	0.75	4.70	7.15	12
2013	5.81	0.80	4.56	6.88	12
2014	5.76	0.60	4.98	7.04	12
2015	5.66	0.76	4.35	6.67	12
2016	NA	0.53	4.61	6.18	6
2017	NA	0.78	4.92	6.90	7
2018	NA	0.73	4.48	6.44	6
2019	NA	0.34	6.32	6.99	3

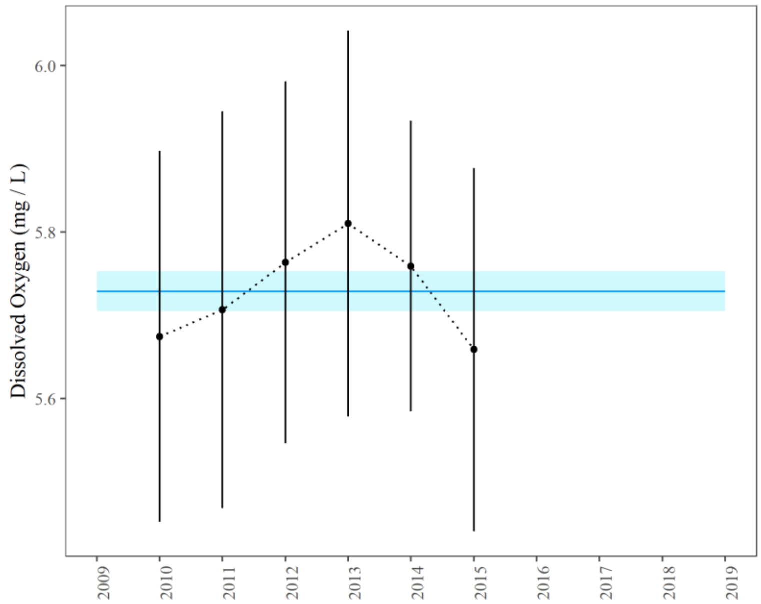


Figure 18. Dissolved oxygen trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I. – no trend detected).

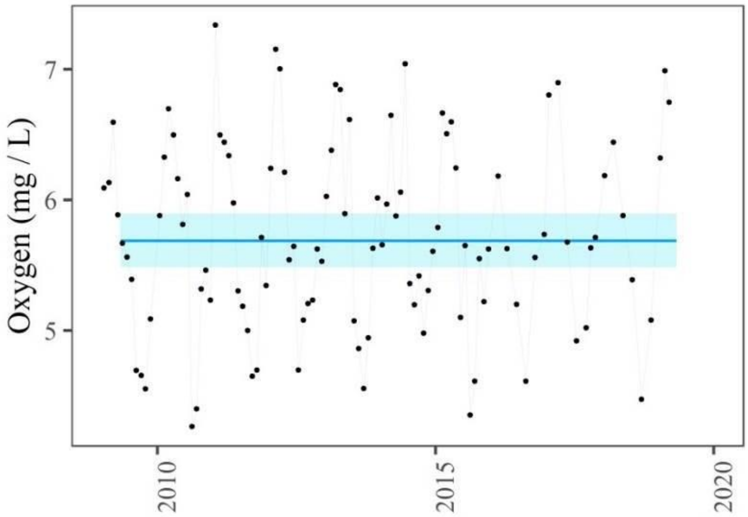


Figure 19. Dissolved oxygen trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

<u>Turbidity</u> (Table 16, Figure 20)

A decreasing tendency can be observed for turbidity on monthly data. This pattern can be observed on periodic data only (yearly data are too sparse), even if a clear seasonality can not be extracted.

Table 16. Summary statistics for the yearly turbidity values (NTU) in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2014	NA	2.05	2.64	9.23	11
2015	4.5	2.49	1.38	10.88	12
2016	NA	1.16	1.90	4.74	6
2017	NA	0.97	0.32	3.12	7
2018	NA	0.76	1.60	3.49	6
2019	NA	0.76	0.12	1.63	3

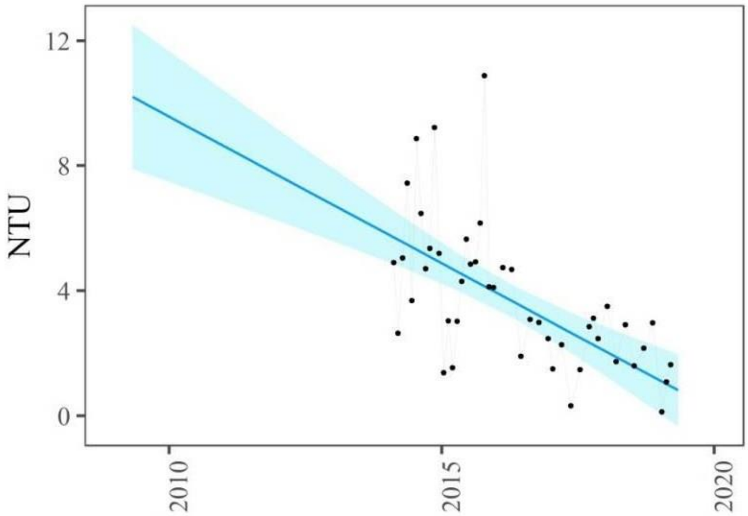


Figure 20. Turbidity trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

DIN (Table 17, Figure 21, Figure 22)

No temporal trend can be detected for Dissolved Inorganic Nitrogen, for which only a seasonality pattern can be observed, with autumnal higher observed values.

Table 17. Summary statistics for the yearly DIN values (µg·L^{-1}) in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2010	220.21	143.92	59.43	545.37	12
2011	212.40	248.83	36.10	922.68	12
2012	204.55	259.13	32.46	968.97	12
2013	244.72	157.75	61.36	528.26	12
2014	NA	226.35	100.39	817.28	11
2015	NA	132.76	109.09	512.04	11
2016	NA	117.60	64.46	349.90	6
2017	NA	219.33	93.41	691.63	6
2018	NA	248.02	57.33	714.24	6

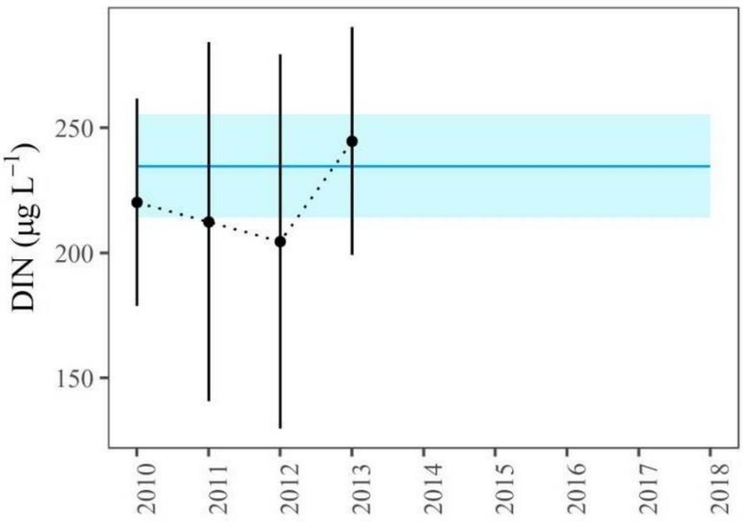


Figure 21. DIN trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I. – no trend detected).

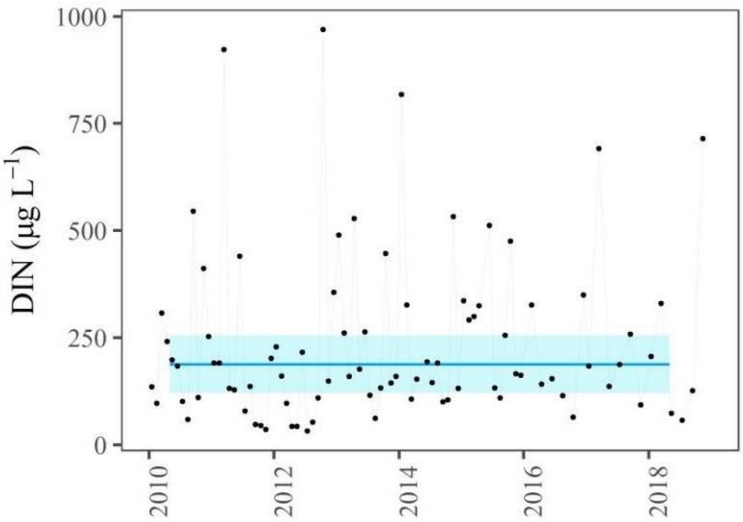


Figure 22. DIN trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

$\underline{PO_4}$ (Table 18, Figure 23, Figure 24)

No temporal trend can be detected for Orthophospate concentration on annual basis, while a positive trend can be detected observing monthly data (no seasonality present, though)

Table 18. Summary statistics for the yearly PO_4 values ($\mu g \cdot L^{-1}$) in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2010	0.94	0.53	0.31	2.32	12
2011	0.72	0.58	0.31	2.11	12
2012	0.79	0.95	0.31	3.58	12
2013	1.32	1.24	0.31	4.34	12
2014	NA	2.45	0.31	7.84	11
2015	NA	1.49	0.31	4.58	11
2016	NA	0.48	0.39	1.54	6
2017	NA	5.56	0.19	13.39	5
2018	NA	0.50	0.79	2.25	6

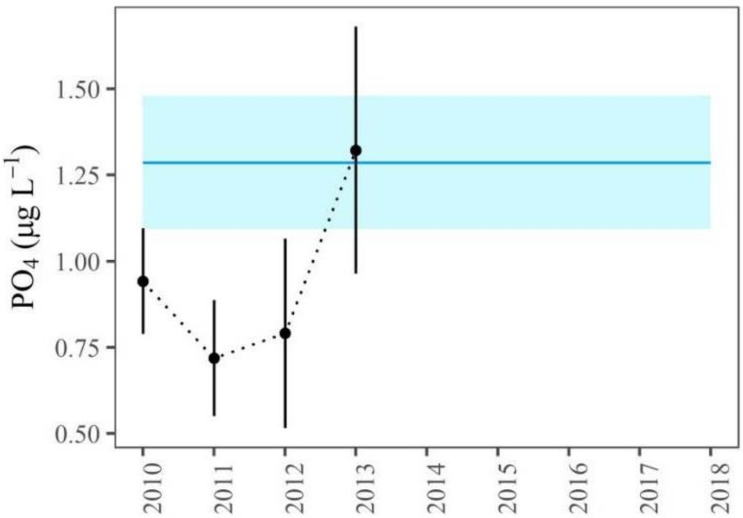


Figure 23. PO_4 trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I. – no trend detected).

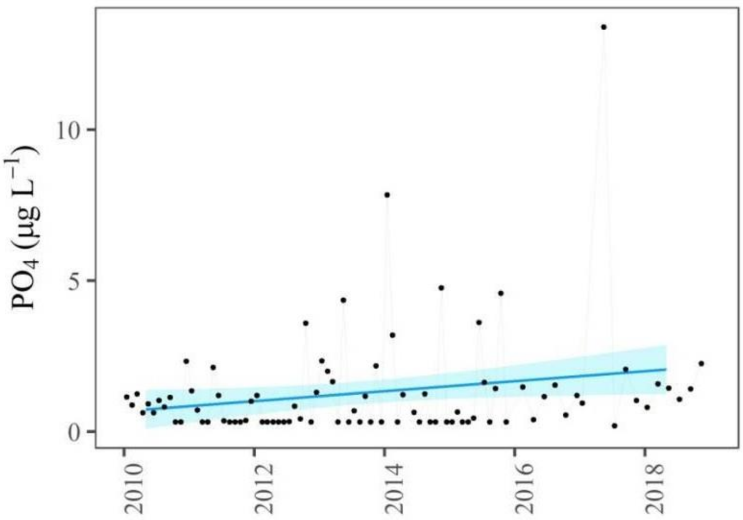


Figure 24. PO_4 trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

5.4. Biological parameters

5.4.1. Data availability

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 Table 19, while a more exhaustive table, including all the collected data and further information about its availability is reported in Annex3.

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 (see paragraph 5.5.1). 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), both included in the management plan SCI/SPA IT3330006 Valle Cavanata e Banco Mula di Muggia.

Table 19. 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	AVAILABILITY of the data
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
Habitat	.shp .pdf	Natura 2000 map	Pilot site		2011	FVG Region
Habitats	.shp .pdf	Habitats map according to the Regional classification system	Pilot site		2008	FVG Region

5.4.2. *Reviewing the status and trend of biological parameters*

Chlorophyll *a* (Table 20, Figure 25, Figure 26)

No temporal trend can be detected for Chlorophyll *a* concentration on annual basis, while a positive trend can be detected observing monthly data, after taking into account the seasonality

Table 20. Summary statistics for the yearly Chlorophyll *a* values (µg·L^{-1}) in the Banco Mula di Muggia

Year	Average	St.Dev	Min	Max	N.
2010	0.64	0.16	0.42	0.97	12
2011	0.67	0.31	0.25	1.48	12
2012	0.62	0.14	0.34	0.76	12
2013	0.53	0.18	0.15	0.77	12
2014	NA	0.34	0.32	1.31	11
2015	0.71	0.39	0.16	1.31	12
2016	NA	0.36	0.38	1.40	6
2017	NA	0.52	0.28	1.62	6
2018	NA	1.76	0.20	4.87	6

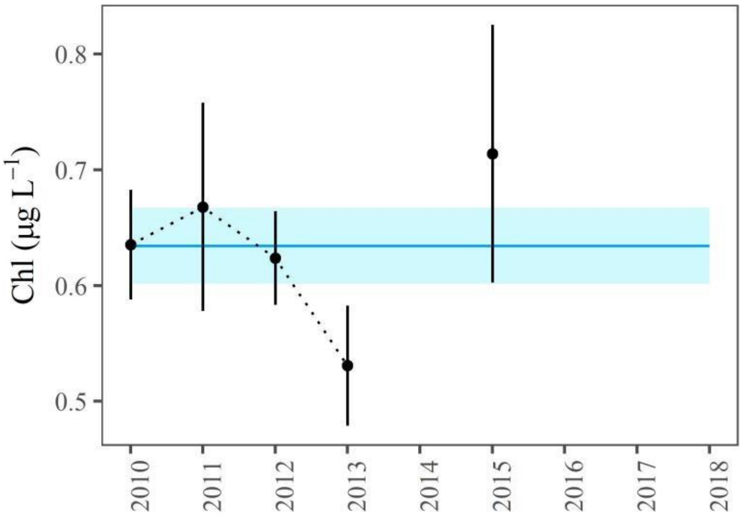


Figure 25. Chlorophyll *a* trend evaluated on yearly average data. Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I. – no trend detected).

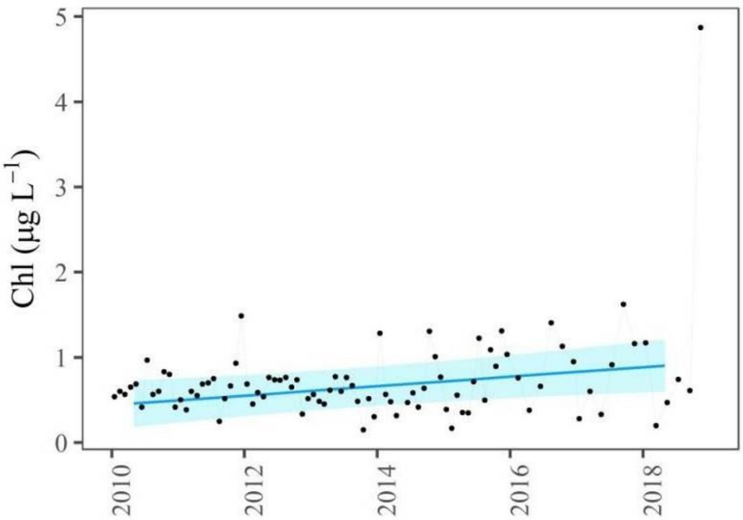


Figure 26. Chlorophyll *a* trend evaluated on periodic data. Dots represent monthly averages; the blue line represents the best fitted models (± 95% C.I.).

5.4.3. Maps of habitats trend

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 (Figure 27):

- **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.

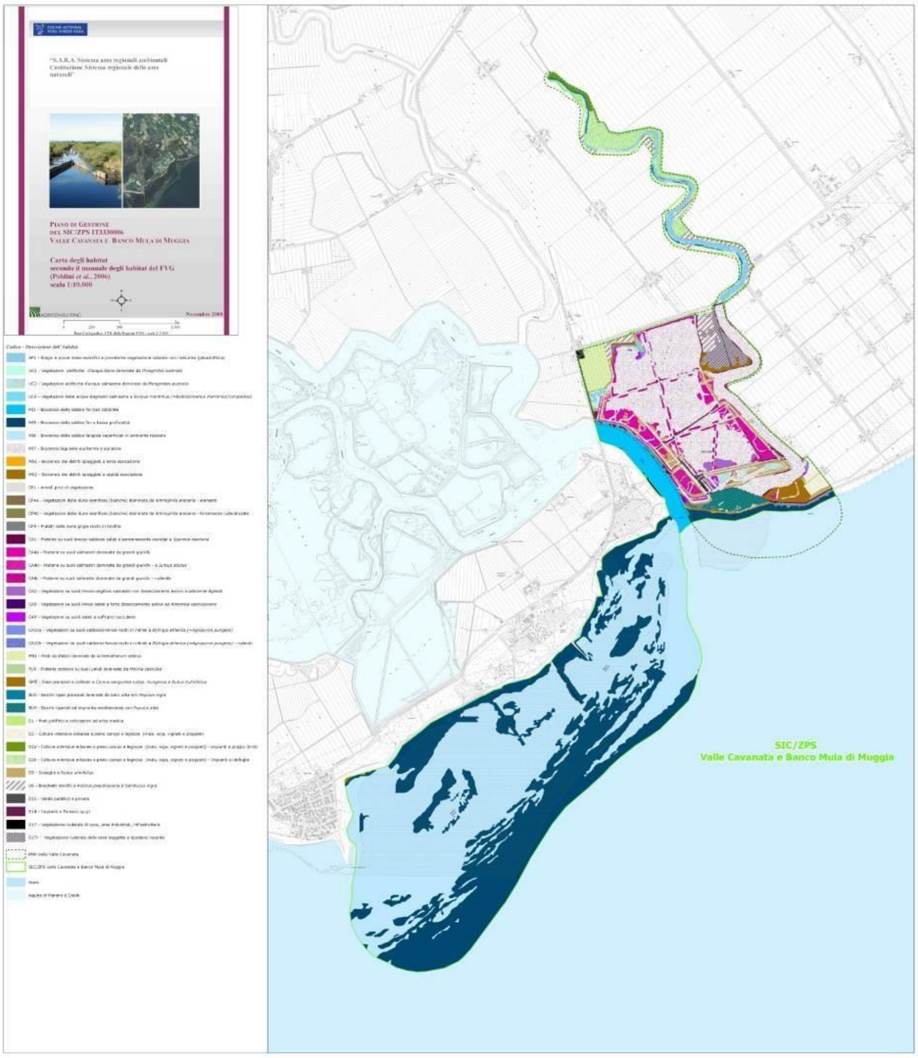


Figure 27. Habitats map (2008) according to the Regional classification system (from: Regione Autonoma Friuli Venezia Giulia, 2012)

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:

- **1110 Sandbanks which are slightly covered by sea water all the time**

In Banco Mula di Muggia, this habitat represents the coastal sands deep between 1,5m and 10m with the substratum characterized by homogeneous, terrigenous, sometimes muddy, sands. It includes biocoenosis that bear both the natural water movement and the boats traffic. They have different facies according to the different species of Pheanerogams, even if the most typical form is without submerged vegetation
In the Interpretation Manual of the EU habitats[1] the 1110 habitat is so described: "*Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than on the underlying hard substrata. "Slightly covered by sea water all the time" means that above a sandbankthe water depth is seldom more than 20 m below chart datum. Sandbanks can, however, extend beneath 20 m below chart datum. It can, therefore, be appropriate to include in designations such areas where they are part of the feature and host its biological assemblages.*
Plants: Mediterranean - The marine Angiosperm Cymodocea nodosa*, together with photophilic species of algae living on the leaves (more than 15 species, mainly small red algae of the Ceramiaceae family), associated with* Posidonia *beds. On many sandbanks macrophytes do not occur.*
Animals: Mediterranean - Invertebrate communities of sandy sublittoral (e.g. polychaetes). Banks are often highly important as feeding, resting or nursery grounds for sea birds, fish or marine mammals.

The management plan report also indicates the presence of the Nature 2000 habitat

- **1140 Mudflats and sandflats not covered by seawater at low tide**

Sands and muds of the coasts of the oceans, their connected seas and associated lagoons, not covered by sea water at low tide, devoid of vascular plants, usually coated by blue algae and diatoms. They are of particular importance as feeding grounds for wildfowl and waders.
In the rarely emerging areas *Zostera marina* communities can be present that remain emerged a few hours ("*velme*", mudflats) (Regione Friuli Venezia Giulia, 2012),

On the whole, the "Banco Mula di Muggia" is characterized by large banks of coastal and platform sand and more rarely of pelitic sand with weak seawater cover. Their maximum depths reach 2 m, except for

[1] http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf

the Primero Mouth. These banks are covered here and there by marine Pheanerogamae: the *Zostera noltei* was mainly observed but the presence of *Cymodocea nodosa* and *Zostera marina* in deeper areas cannot be excluded.

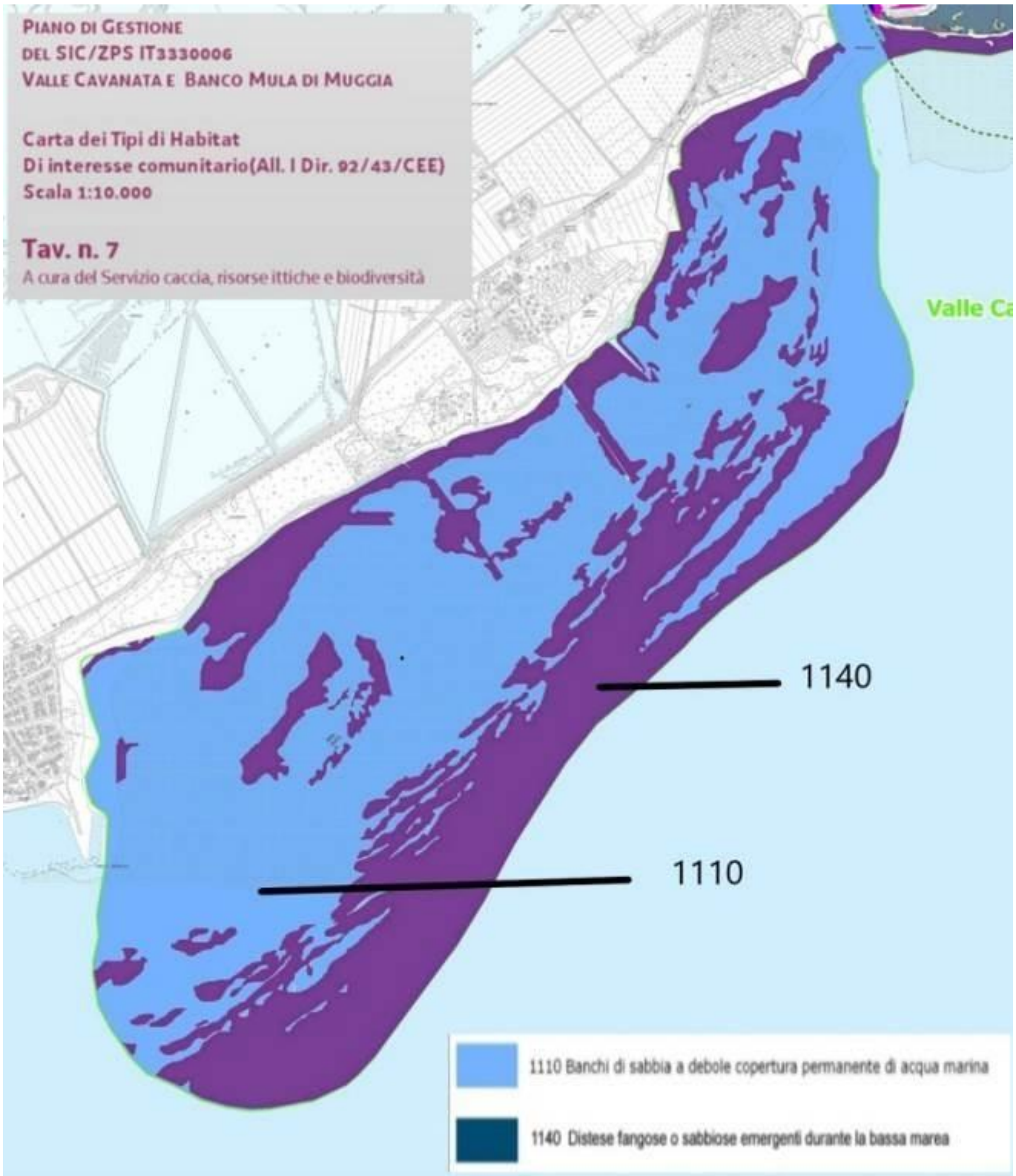


Figure 28. Natura 2000 habitat, 2011 (from Regione Friuli Venezia Giulia, 2012 modified).

In the Natura 2000-Standard Data Form it is reported that the area of the Banco Mula di Muggia is one of the most important sites for the wintering of *Anas Penelope*, *Numenius arquata*, *Clidris alpine*,*Pluvialis squatarola*, *Limosa lapponica*.

It is also reported that on seabed with *Cymodocea nodosa* there is a large population of *Pinna nobilis* and at the site borders there are some stations of *Branchiostoma lanceolatum* typical of sandy sea floor with bottom currents (biocoenoses of coarse sand and fine gravel under the bottom current). In the immediate surroundings many cetaceans have been sighted and among them the *Tursiops truncates*, *Grampus griseus* and *Stenella coeruleoalba*.

Seagrass distribution (Figure 29, Figure 30)

The vegetation is dominated (in terms of leaves density) by *Cymodocea nodosa* in association with *Zostera noltei*, the latter being more important in the strictly intertidal area. Seagrass coverage increased over time, ranging from 3.36 to 4.25 km^2. At a local scale, changes seem to be related both to direct human activities (negative impacts; e.g. by digging channels and building piers) and to the geomorphological dynamic (with both positive and negative effects), dominated by a south-western transport and accretion. The meadow coverage is increasing, after a preliminary contraction in the westernmost part of the bank (Figure 29, Figure 30).

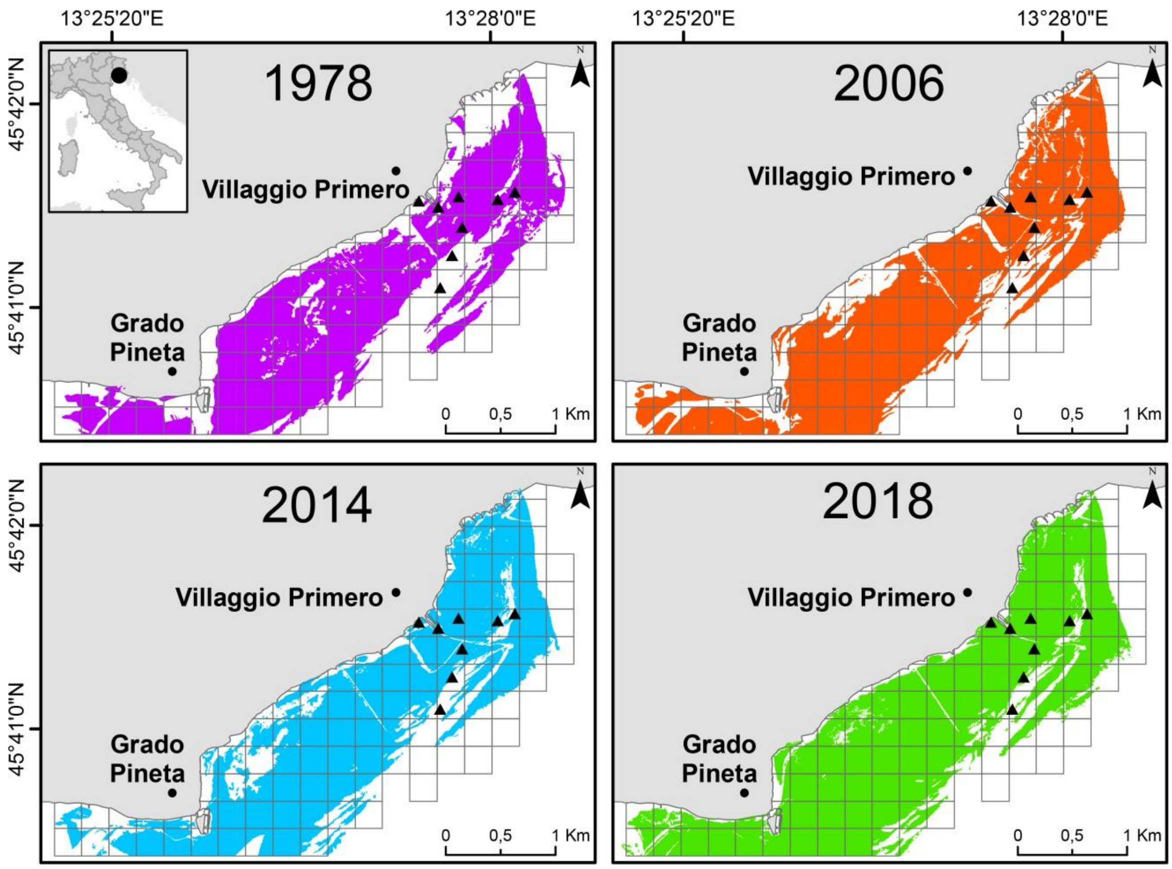
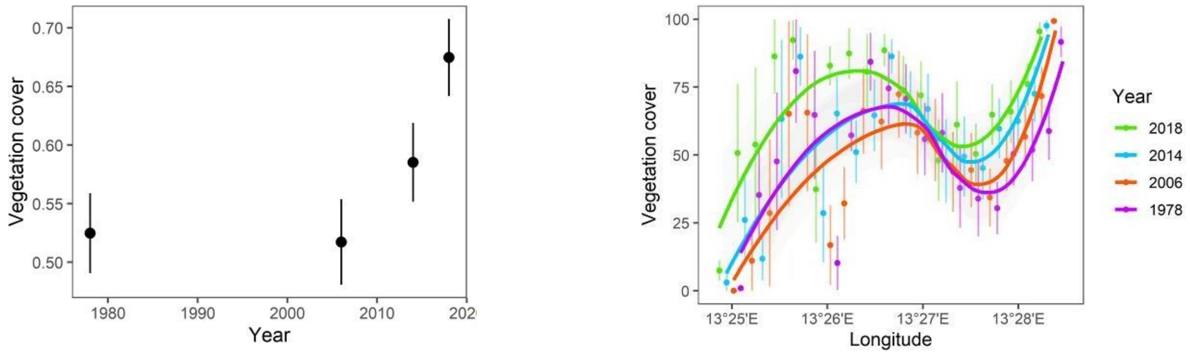


Figure 29. Estimated seagrass meadows distribution for 1978, 2006, 2014 and 2018. Triangles represent the stations sampled in 2019.



a b

Figure 30 a) vegetation cover change over time; b) longitudinal trends of estimated seagrass coverage in the four periods. - Below: longitudinal trends of estimated seagrass coverage in the four periods.

5.5. Operational Plan for the acquisition in situ of data to solve the main uncertainties and cover knowledge gaps.

Available data on the Banco Mula di Muggia were limited; therefore it was decided to acquire original data within the CHANGE WE CARE project. As limited information were available, in particular, for the species and distribution of phanerogams, a preliminary survey was carried out in October 2019 to schedule the following steps for data acquisition (see paragraph 5.5.1). Hence an Operational Plan for acquiring data in situ was prepared and reported in paragraph 5.5.2.

5.5.1. Survey on Pilot Site

The survey was carried out on 17 and 18 October 2019. Samplings were carried out by using boats suitable for navigation in very shallow water (during low tide some areas of the Banco emerged, elsewhere depths can be below 50 cm).

During the two days of survey sediment samplings were carried out in 15 stations (Figure 31) at variable depths, from 40 to 126 cm, and in some of these stations samplings of seagrasses were also carried out (stations from 1 to 8).

Then sediment samplings were sent to the University of Trieste for the necessary granulometric analyses.

Phanerogams samplings showed a predominating presence of *Cymodocea nodosa*, with some tracks of *Zostera noltei*. The collected data are synthesized in Table 21.

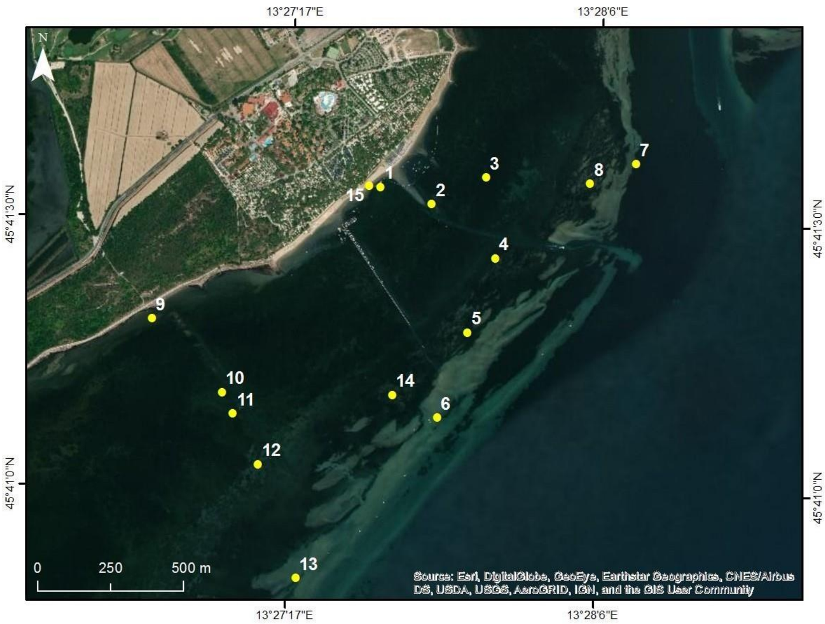


Figure 31- Sampling stations.

Table 21. Sampling stations and field observations of the preliminary survey on the Banco Mula di Muggia

Station	Date	Latitude	Longitude	Hour	Depth (cm)	Seabed features	Algae sampling	Sediment sampling	Plants description (sampling-related percentage)	Algae description
1	17/10/19	13,458689	45,692699	11:50	126	100% phanerogams	X	-	100% *C. nodosa*, 80% in senescence	
2	17/10/19	13,460964	45,692203	11:57	70	70% phanerogams	X	X	100% *Z. noltei* in senescence (around 50%), tracks of *C. nodosa*	*Ulva* (10% of the sampling) , *Chetomorpha*, *Gracilaria*
3	17/10/19	13,463340	45,693060	12:14	105	100% phanerogams	X	X	80% *C. nodosa*, p il 80% in senescence, 20% *Z. noltei*	*Ulva* (30% of the sampling) , *Chetomorpha*, red alga unidentified
4	17/10/19	13,463814	45,690564	12:28	94	100% phanerogams	X	X	100% *C. nodosa*, 80% in senescence, tracks of *Z. noltei*	
5	17/10/19	13,462645	45,688243	12:44	90	Sand. On the bench	-	X	-	
6	17/10/19	13,461374	45,685599	13:36	57	Sand. On the bench	-	X	-	

7	17/10/19	13,469932	45,693557	14:06	87	70% phanerogams	X	X	100% *C. nodosa*, 80% in senescence, tracks of *Z. noltei*	
8	17/10/19	13,467933	45,692928	14:23	42	60% phanerogams	-	X	-	
9	18/10/19	13,448722	45,688500	11:25	61			X		
10	18/10/19	13,451861	45,686257	11:56	75			X		
11	18/10/19	13,452361	45,685611	12:03	80			X		
12	18/10/19	13,453528	45,684056	12:10	85			X		
13	18/10/19	13,455278	45,680556	12:22	90			X		
14	18/10/19	13,459389	45,686278	12:38	78			X		
15	18/10/19	13,458194	45,692722	13:02	40			X		

Afterwards aerial photography taken by a camera mounted on a drone helped to understand whether these images can support the mapping of the meadows distribution and whether this methodologycould be used for this purpose. Some views of the Banco Mula di Muggia are reported in Figure 32.

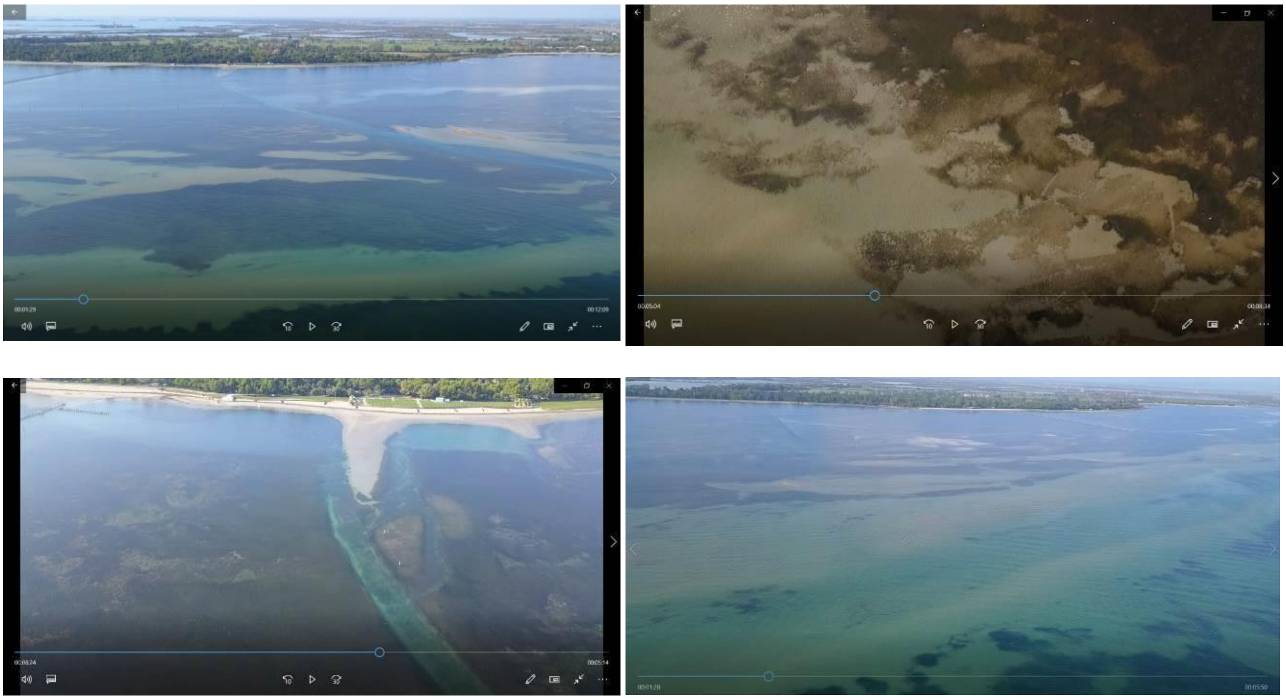


Figure 32. Examples of photos taken from the drone used during the survey.

5.5.2. Operational Plan

After the survey it was agreed to carry out the following field activities originally scheduled for spring 2020, but whose planning is now affected by the COVID19 emergency and needs to be rescheduled:

a) Sampling of phanerogams and sediment for granulometric analyses (rescheduled: autumn 2020)

b) Acquisition of bathymetric data with single beam echosounder and Side Scan Sonar through autonomous surface vehicle (OpenSWAP) (rescheduled: autumn 2020 and spring 2021)

c) Acquisition of geo-referenced images taken by a drone (rescheduled: autumn 2020)

d) Acquisition of pictures and videos through ROV (Remotely Operated underwater Vehicles) on the external and deeper zone of the Banco (rescheduled: autumn 2020)

e) Sampling and analysis of the benthic invertebrates assemblages and fish fauna in the area of the Banco Mula di Muggia (Grado) according to Art.32 paragraph 14 of the Legislative Decree N.50 dated 18 April 2016 (rescheduled: spring 2021).

Phanerogams and sediment sampling stations will be located along two coastal transects offshore in order to overlap some transects already sampled by the FVG Region and the University of Trieste (see Deliverable A3.2).

ROV pictures and videos will be acquired along the same transects.

As for the acquisition through single beam and SSS the investigated area will include the above-mentioned transects. These surveys will be carried out in autumn and repeated in the following spring.

Sampling and analysis of the benthic invertebrates and fish fauna will be carried out in 3 stations located in this pilot site.

6. Pilot Site 5 - Po River Delta

6.1. General site description

The Po delta, the largest delta in Italy, produced by the actions of the Po River and recent human activities, represents the largest national reserve of wetlands. It is on Italy's northern coast where the River Po divides into several smaller rivers before meeting the Adriatic Sea. It includes a wide coastal dune systems and sand formations, lagoons, fishing ponds, marshes, fossil dunes, canals and coastal pine forests, vast brackish wetlands and cultivated lands dominated by rice farming. The Po delta covers a surface area of approx. 140.000 ha, the half of which being represented by transitional areas and fishing ponds (Figure 33). The Po delta includes shallow coastal lagoons, with a mean salinity ranging from polyhaline to euhaline and a wide deltaic area, with 5 main Po branches (from the north to the south, Po di Maistra, Po della Pila, Po di Tolle, Po di Gnocca, Po di Goro). The main lagoons insisting in the Po Delta area included in Veneto Region are, from the north to the south: Caleri, Marinetta, Vallona, Barbamarco, Basson, Sacca del Canarin, Sacca di Scardovari. The Po delta area in Emilia Romagna Region includes the Sacca di Goro and other transitional water systems (such as Comacchio) that are located southward to the delta. The Po delta lagoons, like many others in the North Adriatic coast compound, underwent to profound changes in the last decades which have significantly reduced their extension andaltered the seabed morphology. The lagoons of the Po Delta are very shallow waterbodies with differentmorphological characteristics and a variable degree of connection between each other, the sea, and the river branches. Most of the lagoons have 75% of the total volume in the first 1–1.5 m of depth. Lagoons of the southern delta have a simplified shape, while Caleri and Marinetta lagoons have higher morphological variability due to the presence of salt marshes and a more pronounced channel network (Maicu et al., 2018). Saltmarshes are mostly present in Caleri and Vallona.

The Po delta lagoons are strongly influenced by nutrient loads coming from the Po river. The high trophic status together with a relatively shallow depth and an adequate hydrodynamic exchange sustain high primary production and, as a consequence, high production of mollusks that are locally farmed. The Po Delta lagoons represent the main production site of Manila clam (*Rudiptapes philippinarum)* in Italy, with a mean annual production in the period 2009-2017 near to 12000 tons for the Lagoons of Veneto region (elaboration of "Osservatorio Socio Economico della Pesca e dell'Acquacoltura" on data of the Regional Health Service "ASL" and of "Local fish Consoritia") and near to 13000 tons for the Goro lagoon (data collected and elaborated within the Flag Costa Emilia Romagna PO FEAMP project 2014-2020, Barbieri et al., 2019). Other molluscs farmed in the area include mussels (*Mytilus galloprovincialis*) and oysters (*Ostrea edulis*, *Crassostrea gigas*).

Figure 33. The Po Delta area and its main lagoons

The Po Delta area covers some of the most productive and rich in biodiversity areas in Italy; it includes two Regional Parks (“Po Delta Veneto Regional Park” with an extention of 12592 ha and “Institution for parks and biodiversity management - Po Delta Emilia-Romagna” of 53653 ha) and Natura 2000 sites, as Sites of Community Importance (SCIs) and Special Protection Areas (SPAs).

Birds, with over 370 species of nesting, migratory, and wintering birds, are among the most interesting component of the Po Delta fauna, which represents one of the most important ornithological areas in Europe both in terms of abundances and biodiversity.

Like other major world deltas, the site is highly threatened by global changes, with particular reference to the relative sea level rise (RSLR), mostly due to uneven subsidence rates ranging from a few mm/yr to more than 20 mm/yr (Da Lio and Tosi , 2019). Tectonics, sediment loading and sediment compaction are the main components driving natural subsidence rates, while the main anthropogenic cause of land subsidence is caused by methane extraction. Another major concern in the area is represented by the salt wedge intrusion (SWI), a phenomenon that covers large portion of the Po delta area, negatively affecting intensive and extensive agricultural activities locally carried out.

The main characteristics of the single lagoons are briefly described below. Information were collected considering different references (Articles, reports and technical documents) available for the area (Mistri, 2009; AAVV, 2003; AA.VV, 2013; AAVV, 2015)

Caleri

It is a large lagoon complex (approx. 1000 ha), mostly characterized by marine waters. It communicates with the sea with two accesses for sea water, positioned respectively in the center (Caleri channel) and in the south, in communication with the "Marinetta - Vallona" system. The input of fresh water is scarce, mostly depending by the irrigated waters of the fields and by modest contributions deriving from the water pumps of the fishing valleys ("valli da pesca"), consisting mainly of brackish water. Saltmarshesare quite abundant while reedbeds are absent. In the recent past the lagoon were characterized by scarce water exchange and therefore eutrophication phenomena occurred during summer leading to massive mortality of the fish and molluscs. To reduce this type of hydrodynamic problem, the Land Reclamation Authority intervened in the reactivation of water circulation in critical areas through excavation and recalibration of internal channels. The prevailing economy of the area is linked to the Manila clam (*Ruditapes philipippinarum*) farming, but also artisanal fishing plays a role of some interest.

Marinetta

Marinetta Lagoon is a basin of about 350 ha, with a north-west / south-east orientation. It communicates with the sea through a mouth in the proximity of the touristic port of Albarella and it’s in communication both with the Caleri lagoon in the north-eastern part area and with the Vallona lagoonin the south-western part. The Marinetta area includes the old terminal stretch of the “Po di Levante” branch that represents the main freshwater input of the lagoon. In this area waters appear low and brackish, with reeds, while in the rest of the lagoon is more influenced by seawater.

This lagoon was characterized by intense traditional fishing activities carried out with fixed gears but nowadays the main activity, as in the other lagoons of the North-Adriatic, is represented by Manila clam farming. In order to allow the mollusk farming and the natation of the vessel the riverbed of the Po di Levante is often excavated. Reedbeds are very scarce.

Vallona

Vallona Lagoon (approx. 700 ha) is directly communicating with the Marinetta lagoon. The north-east sector of Vallona is artificially separated from the mouth of the Po di Maistra by means of a ballast, with two openings for the entry of freshwater and the seawater (the direct connection to the sea was reopened in 2014). The lagoon is characterized by euhaline waters, with the presence of large surface areas dedicated to Manila clam farming; reedbeds are very scarce.

This system is in hydraulic communication with some valleys (valli da pesca), which, through siphons and drains, draw and drain the water inside. A large part of the basin is private property.

Barbamarco

The lagoon system of Busiura Barbamarco (approx. 800 hectares), with a north-west / south-east orientation, receives fresh water and river sediments in its distal parts, respectively from the Po di Maistra (Busiura) and the Busa di Tramontana (Barbamarco). In these areas, the environment is characterized by the presence of reedbeds. In the central part of the Barbamarco lagoon, however, the water becomes deep, with sandy bottoms, and it is more influenced by marine waters, due to the presence of two accesses to seawater, one of which recently reopened, after a closure due to the contribution of debris. In this area the environment is more halophilic, with Salicornia meadows on the emerging lands and a system of sandbanks deriving from the old coast line. The sublagunar canals are often dug, in order to improve the conditions for the farming of clams and to facilitate the exit of the fishing boats of the commercial port of Pila into the sea.

This lagoon supplies water to four fishing and hunting valleys. The hunting activity also appears to be quite intense, as consequence of its proximity to the valleys of Porto Tolle.

Basson

The Basson lagoon (approx. 400 ha) is bordered by the Po di Pila mouth (at the north), by Sacca del Canarin (at the west) and by the Adriatic sea (at the east). It is an area overlooking the open sea, with which it communicates directly through a narrow mouth which is located in the southern part of the lagoon. The diffused and abundant inputs of freshwater, coming from both the terminal stretch of thePo di Pila (Busa Dritta) and a terminal secondary branch of Po (Busa Scirocco) contribute to transport of silty materials in the basin. The margins of the Basson lagoon are characterized by shallow, often muddy waters, with diffuse mudflats of great value for aquatic birdlife and large reedbeds. The central part of this lagoon is free of reeds and sandbanks, with the entry of many river sediments but sometimes influenced by marine salinity.

Canarin

The Sacca del Canarin (approx. 800 ha) is characterised by polyaline waters, scarce presence of saltmarshes (mostly present in the southern portion of the lagoon) and by reedbeds, mostly located in the

western sector. Canarin is delimited northward by the channel Busa Diritta, to the west with the island of Polesine Camerini and to the east with the Busa di Scirocco and with the emerged sandbar that separate it from the Adriatic Sea.
Canarin receives marine water from the mouth (drainage from Busa Dritta), from the south (from the Busa del Bastimento) and from the west (dewatering pumps).
The Sacca del Canarin has an average depth of less than one meter and reaches peaks of 1.8 meters in the central area in front of the north mouth, while it has much lower values in the northern and southern areas.
The whole system is affected by a significant presence of both hunting and tourism, consisting inparticular of inland navigation.
In consideration of the limited exchanges with the sea, important works of vivification of the lagoon are underway, aimed at maintaining the delicate environmental balance and, therefore, conditions of high biodiversity. In fact, the Canarin lagoon has recently encountered eutrophic phenomena linked to the development of macroalgae of the Ulva and Gracilaria genera which have led to oxygen scarcity (hypoxia) and in some cases anoxia, especially in the layers of water close to the bottom. Marked phenomena of ecosystem collapse (dystrophy) have been recorded in internal areas where decomposing organic plant material tends to accumulate.

Scardovari

The Sacca di Scardovari is the largest lagoon body of the Delta, and one of the largest in Italy. This system, extended for over 3000 ha, is similar to a wide salt lake, almost free of sandbanks and reedbeds,with the seabed that always remains covered by water even during low tides. Scardovari is located in thesouthern area of the Po Delta, between the branches of the Po di Tolle to the north-east and the Po di Gnocca to the south-west. It has an average depth of 1.5-2 meters and communicates with the sea through an artificial mouth close to the mouth of the Po di Tolle branch and to another larger mouth locatad south-east area.
The distance between the lagoon mouths and the northern part of this basin determines a change in oxygenation, salinity and sediment with the subdivision of the Sacca into two sectors: the northern portion, characterized by greater depth, calmer waters and by an higher anthropic presence (i.e. mussel farming, harbors housing fishing vessels) and the southern portion that appears less anthropized. The Sacca is characterized by frequent macroalgal blooms that occur in the most part of the lagoon.
Thanks to this particular hydromorphology, Scardovari is an ideal lagoon area for fishing and aquaculture: the first fishermen's cooperative dates back to 1936. Currently the production of mussels, *Mytilus galloprovincialis*, clams (*R. philippinarum*) and, in minor part, of oysters (*Crassostrea gigas*), fromthis area is well developed.

Goro

The sacca di Goro (approx. 2600 ha) is characterized by a high hydrodynamism. Freshwater inputs come from the southernmost arm of the Po River, the Po di Goro, in the eastern part, by a large drainage canal, which flows into an ancient Po River bed, the Po di Volano, in the western part, and by two minor drainage canals in the northern part of the lagoon. High inputs of nutrients, mainly nitrates, carried by fresh water,

low depth and intense hydrodynamism are at the basis of the very high primary productivity. In the recent decades this features have favored the development of Manila clam farming but has also led to recurrent anoxic and dystrophic crises. Since the late ‘80s, extended blooms of nitrophilous macroalgae have occurred, mainly originating in the eastern portion of the lagoon, named Valle di Gorino and characterized by lower water circulation. The prevailing activity of the area is linked to clam farming and, in minor part, in oyster farming.
To contrast these occurrences, which led to mass mortality of the farmed clams, extensive hydraulic works were promoted with the aim of increasing water circulation. A side effect has been the marinization of internal, more confined, areas of the lagoon where the typical brackish water floristic associations have shifted to more alophylous ones. Recentely, fishermen, administrators, technicians and scientists on the basis of a more experienced awareness have adopted an innovative approach which led to the Life AGREE Project – coAstal laGoon long teRm managEmEnt (LIFE13 NAT/IT/000115). The project aims to a more sustainable use of the lagoon different areas by means of an integrated management that exploits, instead to contrast, the dynamism of the lagoon and its constant sedimentary deposit. The Life AGREE project area includes the internal south western part of the Saccadi Goro (Valle di Gorino). Licensed areas for clam farming have been moved to the outer portions, mostly on the lagoon mouth, while the internal ones, such as the Valle di Gorino, have been brought back to the original vocation of environments with intermediate salinity, where biodiversity conservation, green tourism and traditional fishing are nowadays the primary uses.

6.2. Data collection

The Po delta area is well covered by different monitoring activities of physical-chemical parameters carried out, within its institutional tasks, by respective Regional Environmental Protection Agency (ARPA) of Veneto and Emilia-Romagna, in the framework of different monitoring programs to assess the quality status of the regional water bodies. Other investigations carried out in the area include surveys and researches carried out by Scientific Institutions (Universities, National Research Institutions) and by National and Local Authorities for management purposes (Consorzio di Bonifica Delta del Po, Genio Civile). Data collection within CHANGE WE CARE project has targeted the institutional available information made available by Regional Environmental Protection Agencies of Veneto and Emilia Romagna Regions (ARPAV and ARPAE, respectively). This activity was focused on the acquisition of following parameters:

- Physical-chemical parameters. Water: temperature, pH, salinity, Dissolved Oxygen concentration (DO), Total Suspended Solids (TSS), Dissolved Inorganic Nitrogen (DIN), Orthophosphate ($P0_4$).

- 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.

The timeframe considered for the dataset collection covers the period 2008-2018. These data were available for 7 lagoons of the Veneto Region (Caleri, Marinetta, Vallona, Barbamarco, Basson , Canarin, Scardovari) and for 1 lagoon for the Emilia Romagna region (Goro). Basson lagoon is covered only by a single continuous analysis station, while the other lagoons are covered by multiple stations and by a diversified monitoring approach.

6.3. Physical-chemical parameters

6.3.1. Data availability

A description of the data collected and considered for the assessment of the status and trend of physical chemical parameters in the Po Delta is resumed in Table 22, while a more exhaustive table, including all the collected data and further availability information , is reported in Annex 4.

Table 22. Tabular synthesis of the physical-chemical parameters considered for the Po delta area

CATEGORY	TYPOLOGY	DESCRIPTION	REFERENCE AREA	DATA COLLECTED -	YEARS / REFERENCE PERIOD	AVAILABILITY	NOTES
Water temperature	Spreadsheet Excel format; pdf	1) Continuous acquisition data on 4 buoys (3 available) 2)sampled stations at lagoon scale (n=4)	Sacca di Goro	Field measurements	1) 2008-2018 Acquisition rate; 1h 2) 2009-2018 Quarterly data	ARPAE -RER- Servizio Meteo e Clima ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	2) data of 2009 only available in 2 stations
Water temperature	Spreadsheet Excel format; pdf	1) Continuous acquisition data on 6 Po Delta lagoons (7 buoys) 2) CTD data on 6 Po Delta lagoons	Caleri, Marinetta, Vallona, Barbamarco, Basson, Canarin, Scardovari	Field measurements	1) 2010-2018 acquisition rate: 30 2) 2008-2018 monthly	ARPA VENETO Servizio dati ambientali	Basson only continuous data. No continuous data for Caleri
pH	Spreadsheet Excel format; pdf	1) Continuous acquisition data on 4 buoys (3 available) 2)sampled stations at lagoon scale (n=4)	Sacca di Goro	Field measurements	1) 2008-2018 Acquisition rate; 1h 2) 2009-2018 Quarterly data	ARPAE -RER- Servizio Meteo e Clima ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	2) data of 2009 only available in 2 stations
pH	Spreadsheet Excel format; pdf	1) Continuous acquisiton data on 6 Po Delta lagoons (7 buoys) 2) CTD data on 6 Po Delta lagoons	Caleri, Marinetta, Vallona, Barbamarco, Basson, Canarin, Scardovari	Field measurements	1) 2010-2018 acquisition rate: 30 2) 2008-2018 monthly	ARPA VENETO Servizio dati ambientali	Basson only continuous data. No continuous data for Caleri
Salinity	Spreadsheet Excel format; pdf	1) Continuous acquisition data on 4 buoys (3 available) 2)sampled stations at lagoon scale (n=4)	Sacca di Goro	Field measurements	1) 2008-2018 Acquisition rate; 1h 2) 2009-2018 Quarterly data	ARPAE -RER- Servizio Meteo e Clima ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	2) data of 2009 only available in 2 stations

Salinity	Spreadsheet Excel format; pdf	1) Continuous acquisiton data on 6 Po Delta lagoons (7 buoys) 2) CTD data on 6 Po Delta lagoons	Caleri, Marinetta, Vallona, Barbamarco, Basson, Canarin, Scardovari	Field measurements	1) 2010-2018 acquisition rate: 30 2) 2008-2018 monthly	ARPA VENETO Servizio dati ambientali	Basson only continuous data. No continuous data for Caleri
Oxygen (concentration and saturation)	Spreadsheet Excel format; pdf	1) Continuous acquisition data on 4 buoys (3 available) 2)sampled stations at lagoon scale (n=4)	Sacca di Goro	Field measurements	1) 2008-2018 Acquisition rate; 1h 2) 2009-2018 Quarterly data	ARPAE -RER- Servizio Meteo e Clima ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	2) data of 2009 only available in 2 stations
Oxygen (concentration and saturation)	Spreadsheet Excel format; pdf	1) Continuous acquisiton data on 6 Po Delta lagoons (7 buoys) 2) CTD data on 6 Po Delta lagoons	Caleri, Marinetta, Vallona, Barbamarco, Basson, Canarin, Scardovari	Field measurements	1) 2010-2018 acquisition rate: 30 2) 2008-2018 monthly'	ARPA VENETO Servizio dati ambientali	Basson only continuous data. No continuous data for Caleri
Total Suspended solids	pdf	sampled stations at lagoon scale (n=4)	Sacca di Goro	sampling and analyses	1) 2010-2017 Quarterly data	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	
Total Suspended solids	Spreadsheet Excel format	Sampled stations on 6 Po Delta lagoons (n=22 stat.)	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	sampling and analyses	2009-2017 Quarterly data (more data for spring and summer)	ARPA VENETO Servizio dati ambientali SINTAI/SOE	
Dissolved Inorganic Nitrogen,	Spreadsheet Excel format; pdf	1) sampled stations at lagoon scale (n=4)	Sacca di Goro	sampling and analyses	1) 2010-2017 Quarterly data	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	
Dissolved Inorganic Nitrogen,	Spreadsheet Excel format	Sampled stations on 6 Po Delta lagoons (n=22 stat.)	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	sampling and analyses	2009-2017 Quarterly data	ARPA VENETO Servizio dati ambientali SINTAI/SOE	
Orthophosphate	Spreadsheet Excel format; pdf	1) sampled stations at lagoon scale (n=4)	Sacca di Goro	sampling and analyses	1) 2010-2017 Quarterly data	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	
Orthophosphate	Spreadsheet Excel format	Sampled stations on 6 Po Delta lagoons (n=22 stat.)	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	sampling and analyses	2009-2017 Quarterly data	ARPA VENETO Servizio dati ambientali SINTAI/SOE	

For each parameter, different sources of data are available, as resumed below.

Water temperature, pH, Salinity, Dissolved Oxygen (DO) (Figure 34, Figure 35, Figure 36, Figure 37). Data collected include: field acquisition with frequency from quarterly to monthly (data from ARPAV and ARPAE); continuous acquisition recorded every hour or every 30'.

Total Suspended Sediments (TSS), Dissolved Inorganic Nitrogen (DIN), Orthophosphate (PO_4) (Figure 38, Figure 39, Figure 40). Data collected in this study include field acquisitions with quarterly frequency(data from ARPAV and ARPAE).

Further data collected within the same timeframe, resumed in Annex V – database of Pilot Site 5 Po Delta, not analyzed within this documents but reported in D3.4.2, include:

- Sediments data (granulometry, oxygenation, C, N and P compounds)
- Water data collected in estuarine stations (final stretch of the Po branches).
- Water data collected in the years 2014-2015 in a portion of the Goro lagoon (Valle di Gorino) during the first phase (ex-ante characterization) of the Life AGREE project (LIFE13 NAT/IT/000115) coordinated by Provincia di Ferrara.

The maps including the spatial distribution of the available sampling stations for each investigated parameters are shown below.

Figure 34. Temperature. Delta Po stations sampled in the period 2008-2018

Figure 35. pH. Delta Po stations sampled in the period 2008-2018

Figure 36. Salinity. Delta Po stations sampled in the period 2008-2018

Figure 37. Dissolved Oxygen. Delta Po stations sampled in the period 2008-2018

Figure 38. Total suspended sediments (TSS). Delta Po stations sampled in the period 2009-2017

Figure 39. Dissolved Inorganic Nitrogen (DIN). Delta Po stations sampled in the period 2009-2017

Figure 40. Ortophosphate (P-PO_4). Delta Po stations sampled in the period 2009-2017

6.3.2. Reviewing the status and trend of physical-chemical parameters

Data collected in different stations belonging to each Po delta lagoon were grouped and analyzed together; according to the national implementation of the WFD, each sampled lagoon corresponds to a separate water body.

Data collected in the period 2008-2018 are presented and analyzed under different modalities. In particular, for each parameter results are presented as:

- a resume table, including the summary statistics (Average, S.D., Min, Max, N. obs.) of data collected in each lagoon on annual basis (evaluated on data aggregated on daily basis for continuous data);
- a graphical representation of the trend, observed in each lagoon, on annual basis;
- a graphical representation of the trend, observed in each lagoon, taking into account seasonality, on a quarterly (sampling data) or monthly (continuous data) basis;
- a map showing the spatio-temporal evolution of all data (sampling and continuous data) collected, evaluated on annual basis (annual averages for all the variables, except for water temperature, considered as average spring values).

In each case the most appropriate statistical trend representation, to identify the existence of relevant trends on annual or seasonal scale, was chosen on the basis of a model selection procedure, in order to evaluate different *a priori* hypotheses on the type of temporal trend. In particular the model formulations consider: a) if there is a temporal linear trend; b) if there are differences among different lagoon (i.e. lagoon-specific intercept); c) if the trend is different for each lagoon (i.e. lagoon-specific slope); d) if there is any seasonal effect.

The choice of the best model representing the temporal trend was assessed on the basis of the Akaike Information Criterion corrected for small samples (AICc, Burnham and Anderson, 2002) and the Akaike Information (AIC, Burnham and Anderson, 2002). The models were fitted as linear models for yearly and quarterly data (sampling data, see above), and as Generalized Additive Models (GAM; Hastie and Tibshirani, 1990; Wood, 2017), as implemented in the mgcv packages (Wood, 2017) for the R software environment for statistical computing (version 3.6.2; R Core Team, 2019), for the continuous data. In the latter case, daily average values for each lagoon were considered and a cyclic cubic regression term for the day of the year was included to catch seasonality. All figures were produced using the package ggplot2 (Wickham, 2016).

Temperature (Table 23, Figure 41, Figure 42, Figure 43)

A positive temperature trend has been detected both for yearly and seasonal data. In the former case it's not possible to catch lagoon specific differences (i.e. the best model includes a common trend of about 0.058°C / year for all the lagoons), while in the latter there are lagoon-specific differences. The seasonal pattern describes a clear sinusoidal evolution during the year.

Table 23. Summary statistics for the yearly temperature values (°C) in the Delta Po lagoons (continuous data)

Lagoon	Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Barbamarco	Average	NA	NA	NA	NA	NA	16.20	NA	17.47	17.65	16.81	17.39
Barbamarco	St.Dev	NA	NA	NA	NA	NA	7.62	NA	7.33	6.76	7.66	7.92
Barbamarco	Min	NA	NA	NA	NA	NA	5.76	NA	6.30	6.27	3.00	2.29
Barbamarco	Max	NA	NA	NA	NA	NA	29.99	NA	31.49	30.32	30.37	30.58
Barbamarco	N. obs.	NA	NA	NA	NA	NA	323.00	NA	362.00	328.00	346.00	359.00
Basson	Average	NA	NA	16.31	17.62	16.41	17.46	NA	17.77	16.89	16.92	17.29
Basson	St.Dev	NA	NA	7.53	7.22	7.79	7.25	NA	7.56	7.08	7.79	7.97
Basson	Min	NA	NA	4.81	4.32	0.26	5.66	NA	5.11	5.81	3.30	1.85
Basson	Max	NA	NA	30.90	29.81	28.83	30.75	NA	30.80	29.83	31.02	30.64
Basson	N. obs.	NA	NA	346.00	329.00	356.00	314.00	NA	298.00	360.00	354.00	350.00
Canarin	Average	NA	NA	NA	NA	NA	17.64	17.54	17.81	16.47	17.23	17.54
Canarin	St.Dev	NA	NA	NA	NA	NA	7.00	6.11	7.02	6.30	7.37	7.61
Canarin	Min	NA	NA	NA	NA	NA	5.66	6.40	6.51	7.24	3.59	2.68
Canarin	Max	NA	NA	NA	NA	NA	30.52	28.47	30.39	28.27	30.83	30.36
Canarin	N. obs.	NA	NA	NA	NA	NA	325.00	351.00	336.00	338.00	362.00	365.00
Goro	Average	16.62	16.79	16.15	16.89	16.46	16.56	17.68	17.11	16.91	17.07	17.36
Goro	St.Dev	7.04	7.72	7.75	7.93	8.41	7.79	6.47	7.92	7.35	7.83	7.96
Goro	Min	5.02	2.20	1.91	3.63	0.13	4.70	4.41	2.77	4.07	3.02	3.51
Goro	Max	29.33	29.70	31.24	29.95	30.18	30.50	29.98	31.88	30.06	30.80	30.67
Goro	N. obs.	356.00	365.00	365.00	365.00	366.00	365.00	365.00	365.00	366.00	365.00	365.00
Marinetta	Average	NA	NA	15.86	16.34	NA	NA	17.77	17.88	16.77	16.87	17.17
Marinetta	St.Dev	NA	NA	7.35	7.37	NA	NA	5.80	6.76	6.88	7.59	7.94
Marinetta	Min	NA	NA	4.59	4.66	NA	NA	7.96	6.52	5.93	2.66	2.35
Marinetta	Max	NA	NA	29.38	28.61	NA	NA	27.06	30.74	28.89	29.99	29.82
Marinetta	N. obs.	NA	NA	365.00	356.00	NA	NA	346.00	311.00	344.00	340.00	357.00
Scardovari	Average	NA	NA	17.96	17.04	16.72	17.05	17.67	17.08	16.99	17.10	17.58
Scardovari	St.Dev	NA	NA	7.13	7.64	7.88	7.52	6.29	7.47	7.16	7.87	7.98
Scardovari	Min	NA	NA	3.38	4.32	1.30	5.83	5.60	3.51	5.53	2.60	3.48
Scardovari	Max	NA	NA	32.17	30.87	29.74	31.13	28.91	30.89	29.84	30.73	31.02
Scardovari	N. obs.	NA	NA	303.00	359.00	363.00	339.00	365.00	354.00	365.00	363.00	365.00
Vallona	Average	NA	NA	NA	NA	NA	NA	17.67	17.45	16.13	16.60	17.19
Vallona	St.Dev	NA	NA	NA	NA	NA	NA	6.11	7.99	7.30	8.09	8.35
Vallona	Min	NA	NA	NA	NA	NA	NA	4.97	2.93	4.56	1.58	1.37
Vallona	Max	NA	NA	NA	NA	NA	NA	28.57	31.70	31.64	30.70	31.10
Vallona	N. obs.	NA	NA	NA	NA	NA	NA	362.00	328.00	344.00	351.00	365.00

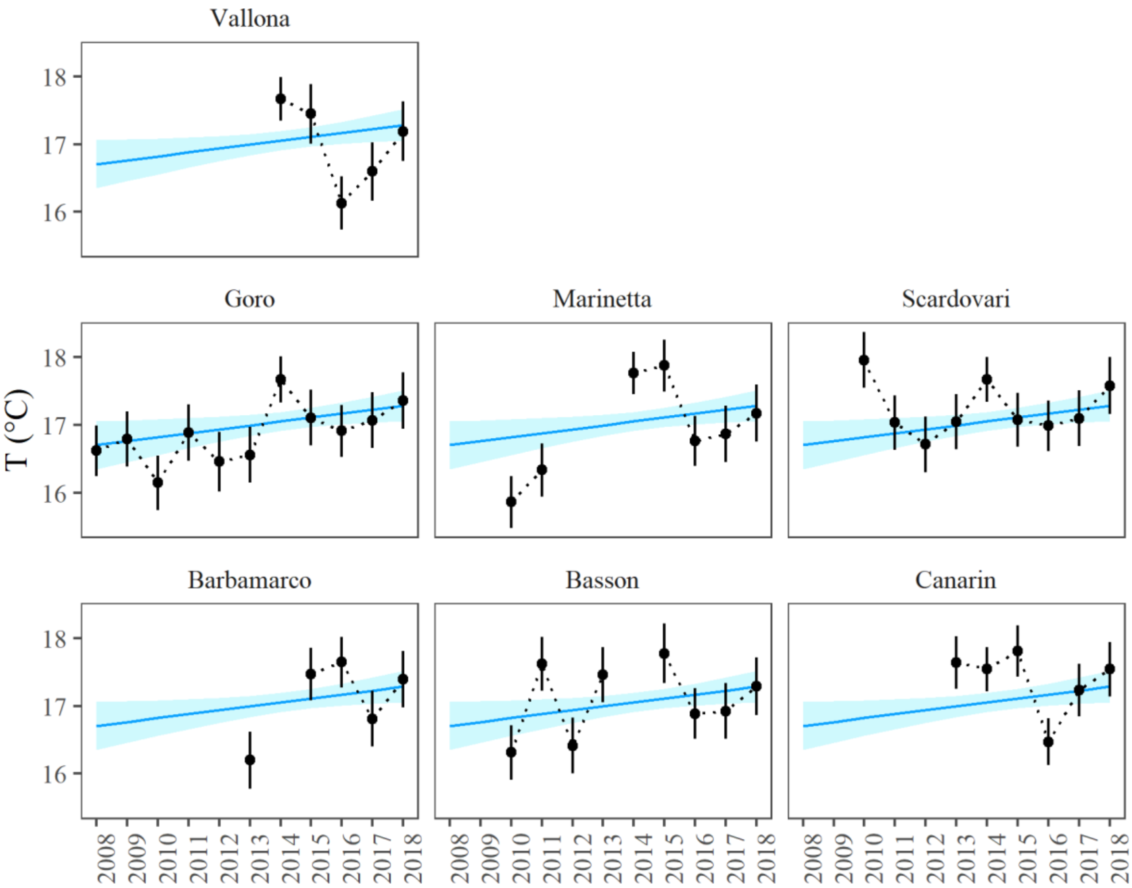


Figure 41. Water temperature trends evaluated on yearly average data (continuous data). Dots represent yearly averages (± standard error); the blue lines represent the best fitted models (± 95% C.I.; in this case the trend is the same for all the lagoons).

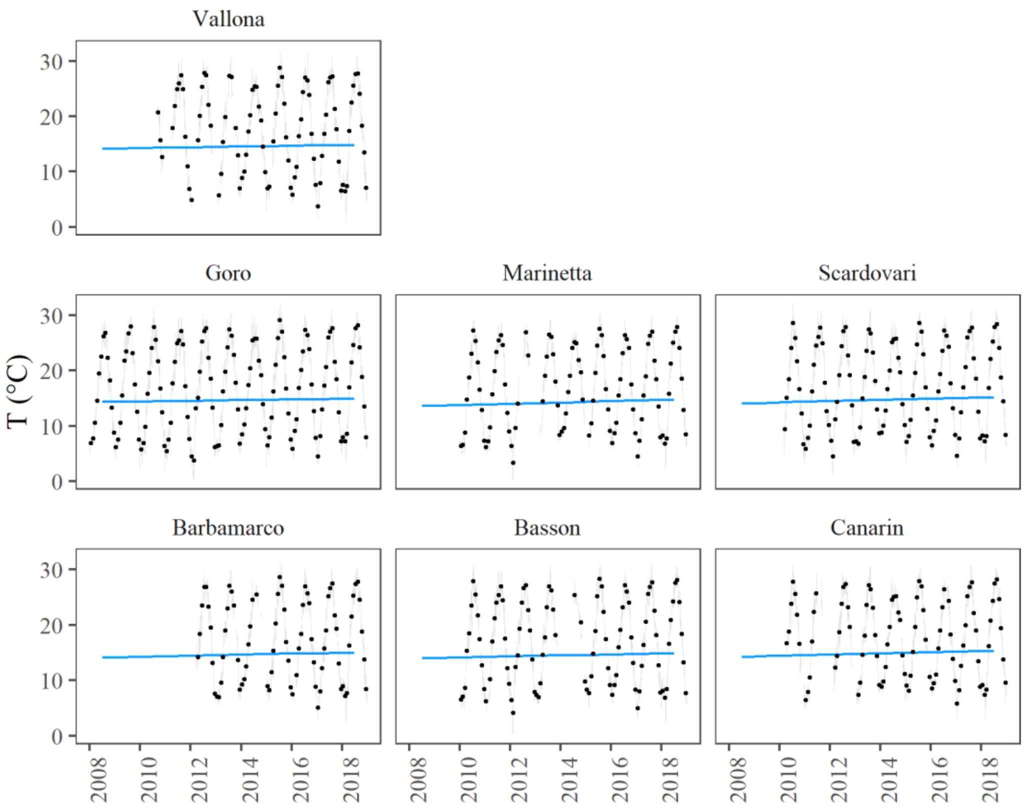


Figure 42. Water temperature trends (continuous data) evaluated on daily average data (light grey lines). Dots represent monthly averages the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

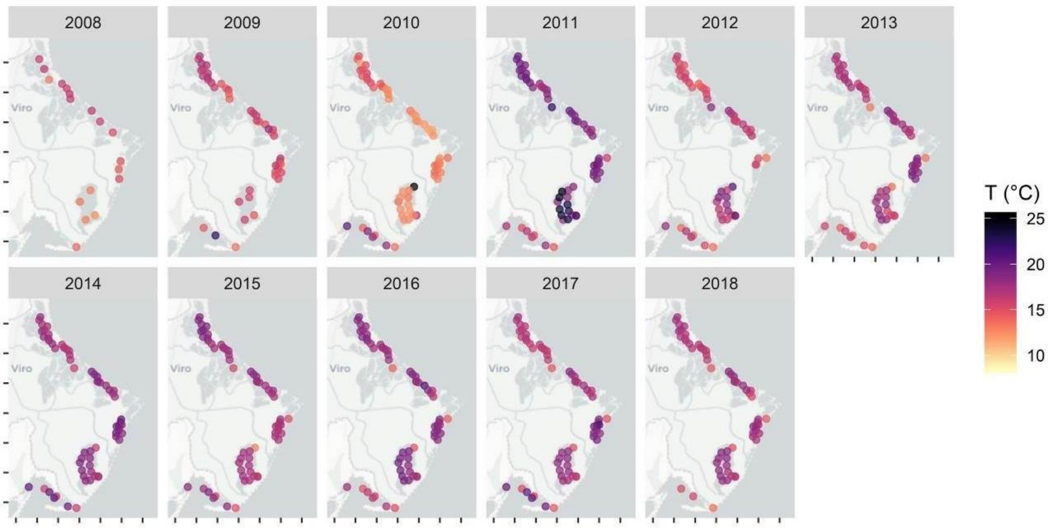


Figure 43. Average spring values of temperature for all collected data within the Po Delta case in the period 2008-2018 (yearly aggregations were not considered for temperature, as periodic sample is unevenly distributed in time in some lagoons, leading to biased average estimates)

pH (Table 24, Figure 44, Figure 45, Figure 46)

The best models for pH highlight the presence of site-specific trends both at yearly and seasonal scale, even if the range of values are relatively small. The seasonal term indicates that higher pH values are normally observed in late spring/early summer.

Table 24. Summary statistics for the yearly pH values in the Delta Po lagoons (continuous data)

Lagoon	Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Barbamarco	Average	NA	NA	NA	NA	NA	NA	NA	NA	8.25	8.30	8.34
Barbamarco	St.Dev	NA	NA	NA	NA	NA	NA	NA	NA	0.12	0.15	0.21
Barbamarco	Min	NA	NA	NA	NA	NA	NA	NA	NA	8.00	7.97	7.90
Barbamarco	Max	NA	NA	NA	NA	NA	NA	NA	NA	8.68	8.74	8.78
Barbamarco	N. obs.	NA	NA	NA	NA	NA	NA	NA	NA	324.00	340.00	344.00
Basson	Average	NA	NA	8.22	8.32	8.18	8.13	NA	NA	8.05	8.32	8.27
Basson	St.Dev	NA	NA	0.24	0.12	0.19	0.28	NA	NA	0.31	0.23	0.22
Basson	Min	NA	NA	7.57	7.91	7.62	7.42	NA	NA	7.07	7.64	7.80
Basson	Max	NA	NA	8.63	8.73	8.63	8.85	NA	NA	8.59	8.72	8.76
Basson	N. obs.	NA	NA	345.00	344.00	356.00	316.00	NA	NA	353.00	349.00	350.00
Canarin	Average	NA	NA	NA	8.34	NA	8.15	NA	8.22	8.05	8.12	8.45
Canarin	St.Dev	NA	NA	NA	0.17	NA	0.15	NA	0.22	0.19	0.26	0.18
Canarin	Min	NA	NA	NA	7.91	NA	7.64	NA	7.71	7.70	7.49	7.74
Canarin	Max	NA	NA	NA	8.95	NA	8.74	NA	8.68	8.47	8.79	8.83
Canarin	N. obs.	NA	NA	NA	296.00	NA	328.00	NA	306.00	320.00	312.00	358.00
Goro	Average	7.98	8.06	8.19	8.16	8.08	8.14	8.18	8.10	8.13	8.21	8.11
Goro	St.Dev	0.31	0.14	0.17	0.20	0.23	0.15	0.26	0.18	0.20	0.22	0.14
Goro	Min	6.62	7.77	7.79	7.54	7.48	7.59	7.52	7.48	7.63	7.61	7.68
Goro	Max	8.50	8.55	8.66	8.57	8.64	8.51	8.75	8.64	8.84	8.79	8.48
Goro	N. obs.	330.00	365.00	365.00	365.00	366.00	365.00	365.00	365.00	366.00	365.00	365.00
Marinetta	Average	NA	NA	7.96	8.16	NA	NA	8.12	8.10	8.33	8.06	8.28
Marinetta	St.Dev	NA	NA	0.15	0.11	NA	NA	0.19	0.16	0.25	0.26	0.13
Marinetta	Min	NA	NA	7.33	7.75	NA	NA	7.48	7.71	7.82	7.64	8.00
Marinetta	Max	NA	NA	8.27	8.38	NA	NA	8.50	8.40	8.73	8.69	8.60
Marinetta	N. obs.	NA	NA	365.00	356.00	NA	NA	346.00	311.00	344.00	340.00	357.00
Scardovari	Average	NA	NA	8.25	8.09	8.17	8.28	NA	8.18	8.40	8.35	8.33
Scardovari	St.Dev	NA	NA	0.16	0.20	0.14	0.26	NA	0.14	0.22	0.12	0.17
Scardovari	Min	NA	NA	7.78	7.70	7.85	7.62	NA	7.70	8.04	7.93	7.95
Scardovari	Max	NA	NA	8.61	8.64	8.56	9.00	NA	8.44	8.99	8.63	8.92
Scardovari	N. obs.	NA	NA	303.00	359.00	346.00	329.00	NA	330.00	358.00	363.00	365.00
Vallona	Average	NA	NA	NA	NA	NA	NA	NA	8.40	8.37	8.36	8.28
Vallona	St.Dev	NA	NA	NA	NA	NA	NA	NA	0.14	0.17	0.16	0.32
Vallona	Min	NA	NA	NA	NA	NA	NA	NA	8.11	7.94	7.85	7.46
Vallona	Max	NA	NA	NA	NA	NA	NA	NA	8.85	8.73	8.71	8.92
Vallona	N. obs.	NA	NA	NA	NA	NA	NA	NA	304.00	355.00	340.00	349.00

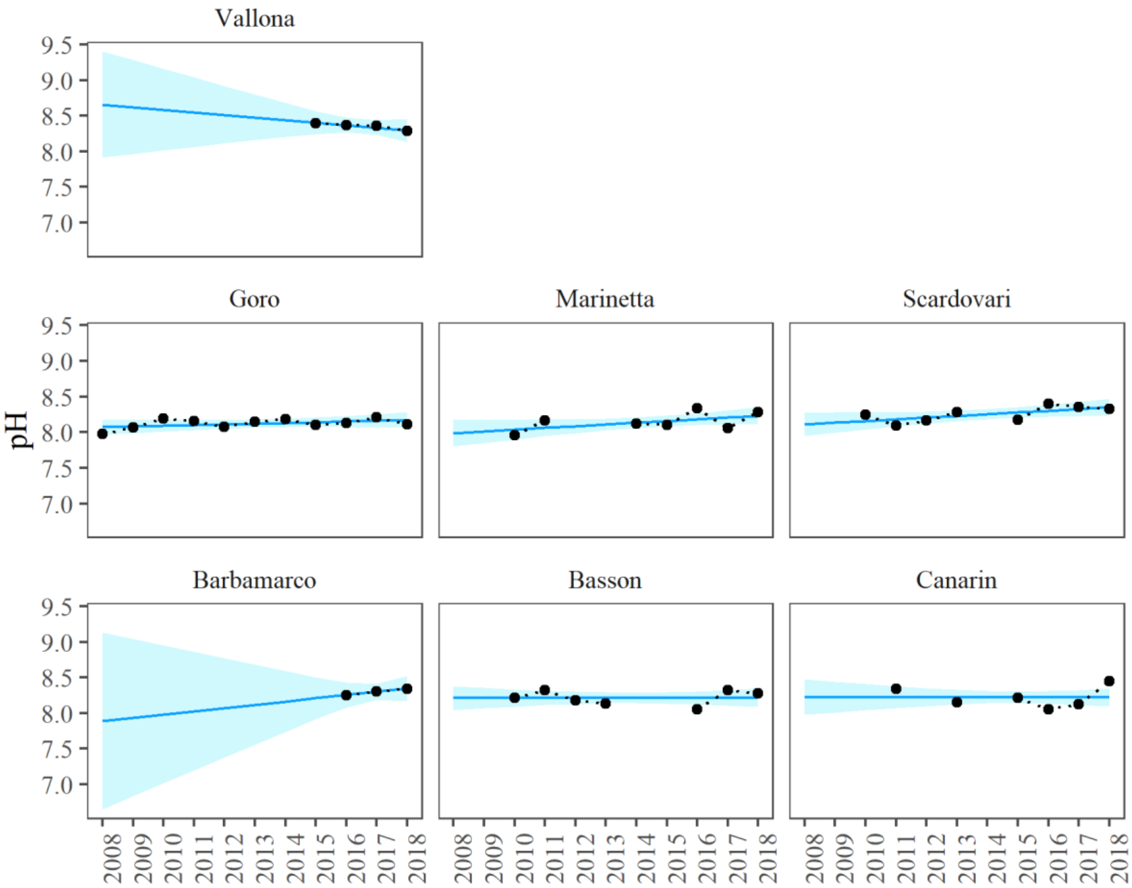


Figure 44. pH trends evaluated on yearly average data (continuous data). Dots represent yearly averages (± standard error); the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

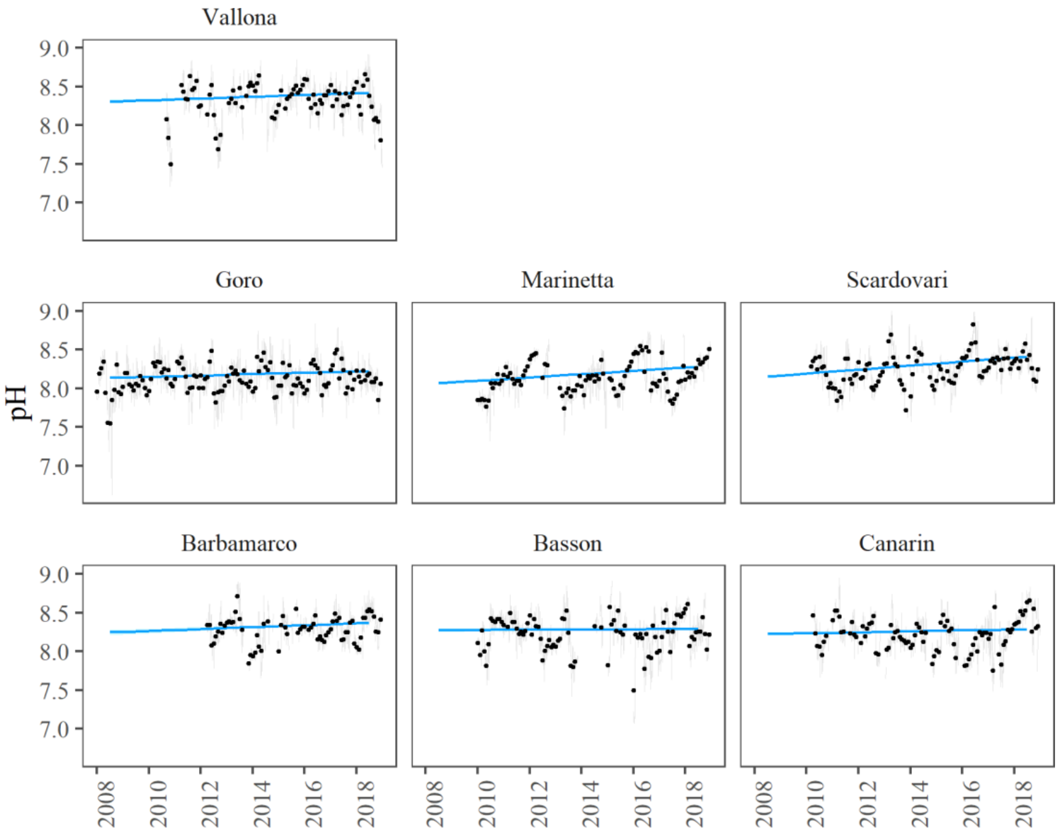


Figure 45. pH trends (continuous data) evaluated on daily average data (light grey lines). Dots represent monthly averages; the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

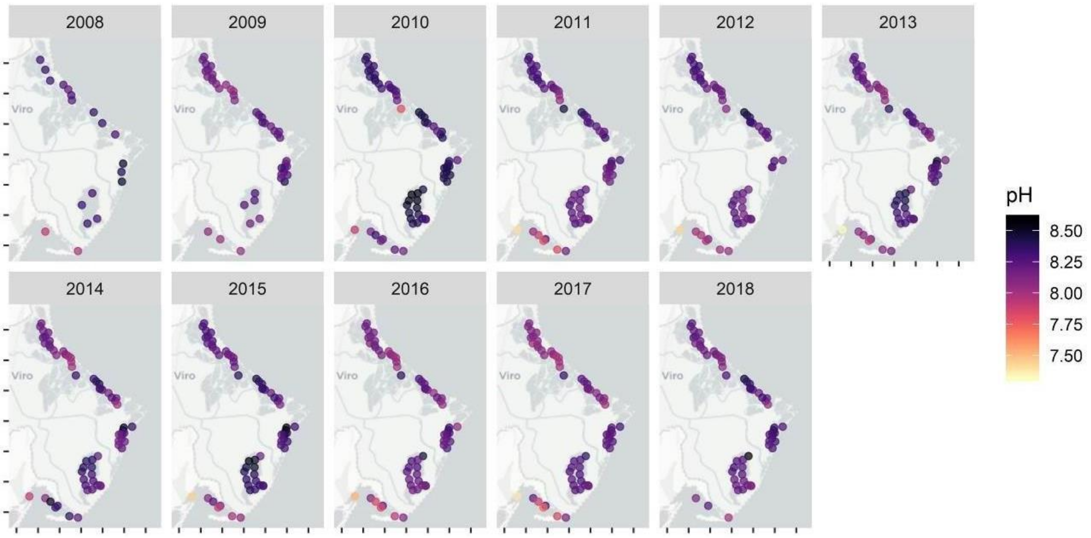


Figure 46. Yearly values (average) of pH for all collected data within the Po Delta case in the period 2008-2018

Salinity (Table 25, Figure 47, Figure 48, Figure 49)

The estimated trend for salinity resulted to be lagoon-specific (both at yearly and seasonal scale), positive for most of the lagoons, negative for Barbamarco and Basson and weakly negative for Goro. For several lagoons, anyway, it is clear that the assumption of a linear pattern approximating the trend isnot very adequate, as the salinity levels seem to be characterized by a high inter-annual variability. The seasonal smoother term shows a complex pattern with a strong peak in mid-summer.

Table 25. Summary statistics for the yearly salinity values in the Delta Po lagoons (continuous data)

Lagoon	Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Barbamarco	Average	NA	NA	NA	NA	NA	29.81	NA	28.28	29.08	30.26	26.86
Barbamarco	St.Dev	NA	NA	NA	NA	NA	5.31	NA	5.05	4.32	3.37	5.52
Barbamarco	Min	NA	NA	NA	NA	NA	10.12	NA	10.37	13.09	19.58	8.77
Barbamarco	Max	NA	NA	NA	NA	NA	40.47	NA	38.35	37.75	36.63	37.16
Barbamarco	N. obs.	NA	NA	NA	NA	NA	324.00	NA	357.00	324.00	342.00	358.00
Basson	Average	NA	NA	17.21	19.74	23.66	18.58	NA	NA	19.55	19.50	14.19
Basson	St.Dev	NA	NA	6.65	6.84	8.12	7.57	NA	NA	6.85	6.31	7.85
Basson	Min	NA	NA	2.26	3.81	5.82	1.60	NA	NA	3.64	3.83	0.27
Basson	Max	NA	NA	36.52	35.47	41.07	32.30	NA	NA	35.13	35.29	32.01
Basson	N. obs.	NA	NA	339.00	339.00	351.00	312.00	NA	NA	343.00	320.00	350.00
Canarin	Average	NA	NA	NA	21.31	NA	21.29	18.90	22.86	25.16	25.38	23.32
Canarin	St.Dev	NA	NA	NA	6.55	NA	7.79	6.87	7.43	4.83	4.79	6.75
Canarin	Min	NA	NA	NA	3.67	NA	2.07	3.50	6.63	7.55	9.64	4.56
Canarin	Max	NA	NA	NA	36.18	NA	35.48	32.11	36.58	35.75	35.87	33.92
Canarin	N. obs.	NA	NA	NA	296.00	NA	298.00	343.00	325.00	362.00	347.00	335.00
Goro	Average	19.06	19.90	20.67	23.01	24.58	21.56	19.24	21.98	18.77	19.00	16.66
Goro	St.Dev	5.00	4.87	3.30	3.79	3.33	4.23	2.94	3.42	4.45	3.82	5.29
Goro	Min	4.85	6.96	11.52	13.69	16.47	10.03	10.92	10.82	4.37	10.22	3.17
Goro	Max	31.56	29.25	28.93	30.64	32.03	31.37	26.28	29.26	30.15	27.64	26.46
Goro	N. obs.	356.00	365.00	365.00	365.00	366.00	365.00	365.00	365.00	366.00	365.00	365.00
Marinetta	Average	NA	NA	21.51	22.95	NA	NA	19.33	24.92	23.86	27.02	23.51
Marinetta	St.Dev	NA	NA	4.68	3.84	NA	NA	5.67	5.08	4.69	3.68	4.12
Marinetta	Min	NA	NA	1.47	10.24	NA	NA	0.79	9.00	6.78	13.09	6.49
Marinetta	Max	NA	NA	31.64	30.42	NA	NA	32.13	36.83	31.41	34.27	31.26
Marinetta	N. obs.	NA	NA	365.00	356.00	NA	NA	346.00	312.00	344.00	319.00	341.00
Scardovari	Average	NA	NA	21.57	26.90	32.24	27.78	22.27	26.90	28.13	29.02	28.08
Scardovari	St.Dev	NA	NA	4.20	5.22	4.41	5.06	3.65	3.87	2.64	3.01	4.14
Scardovari	Min	NA	NA	10.94	14.85	20.58	13.11	11.64	17.90	21.40	21.97	11.29
Scardovari	Max	NA	NA	31.86	39.14	39.88	35.33	30.47	35.97	33.87	36.48	37.52
Scardovari	N. obs.	NA	NA	303.00	347.00	363.00	340.00	364.00	358.00	365.00	362.00	336.00
Vallona	Average	NA	NA	NA	NA	NA	NA	17.98	NA	21.51	23.88	21.42
Vallona	St.Dev	NA	NA	NA	NA	NA	NA	4.77	NA	4.16	3.07	3.54
Vallona	Min	NA	NA	NA	NA	NA	NA	5.91	NA	9.36	14.16	9.72
Vallona	Max	NA	NA	NA	NA	NA	NA	27.80	NA	32.47	33.29	30.16
Vallona	N. obs.	NA	NA	NA	NA	NA	NA	357.00	NA	298.00	321.00	341.00

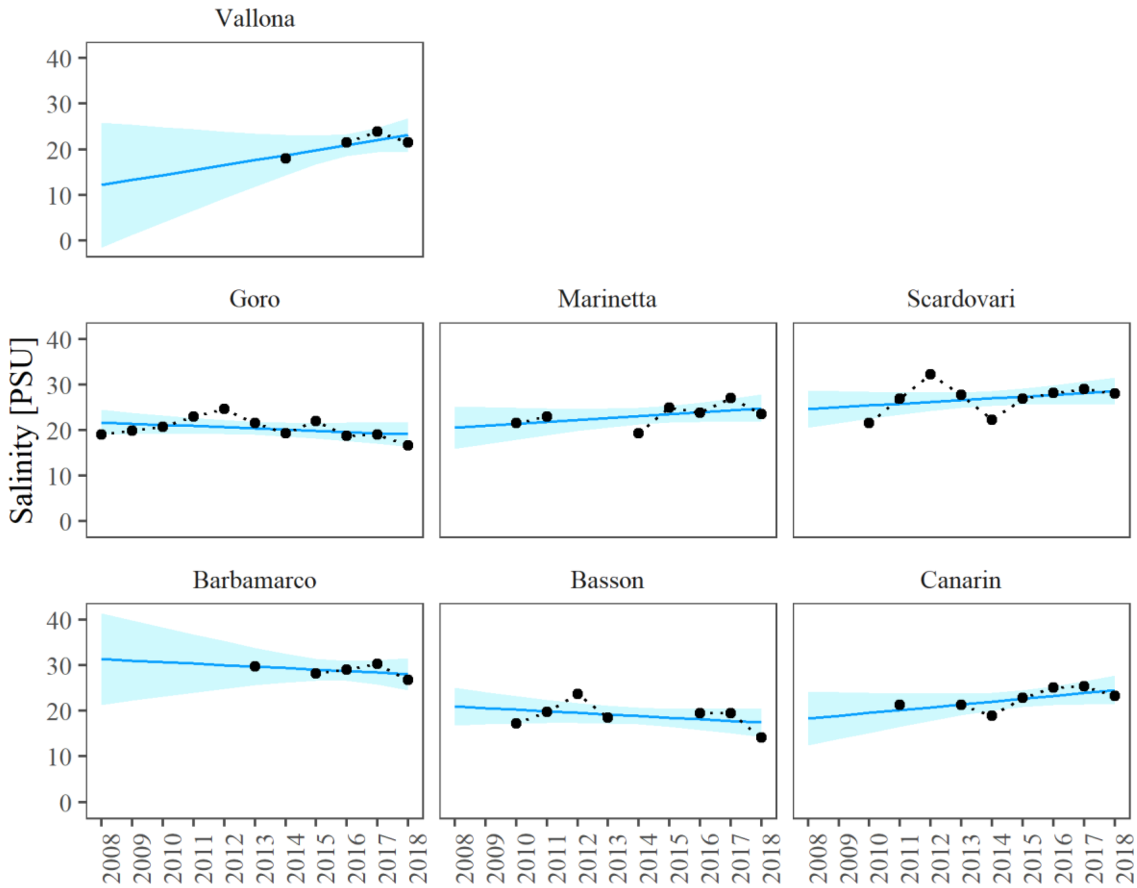


Figure 47. Salinity trends evaluated on yearly average data (continuous data). Dots represent yearly averages (± standard error); the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted is lagoon specific).

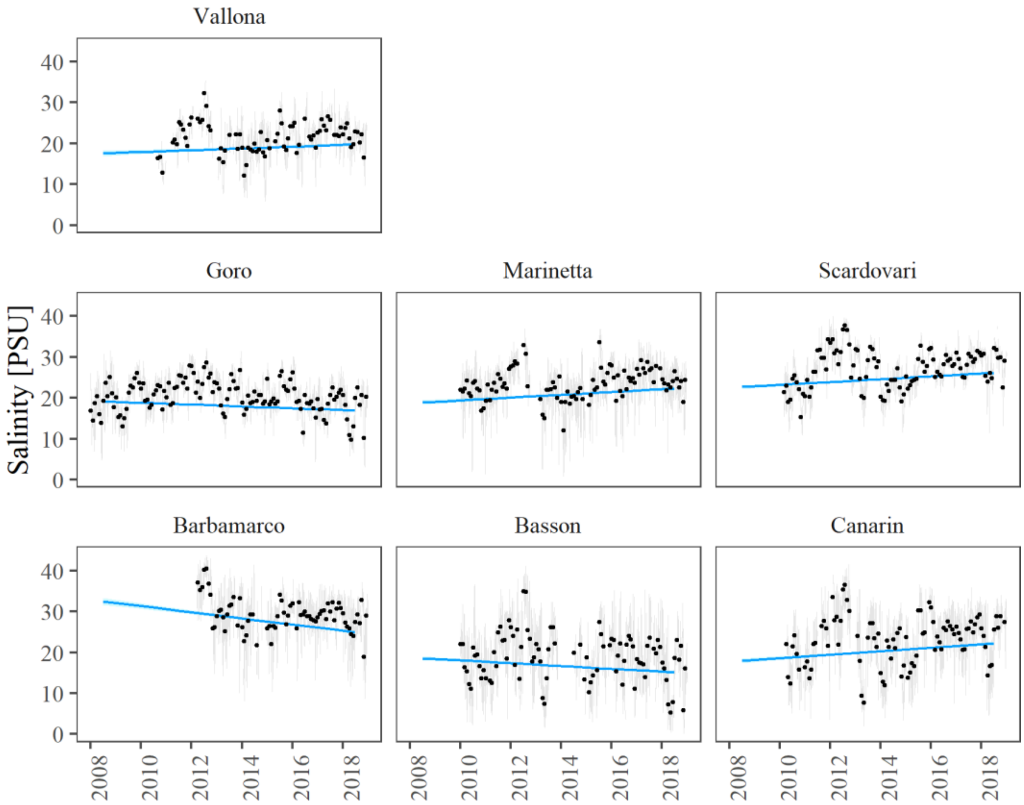


Figure 48. Salinity trends (continuous data) evaluated on daily average data (light grey lines). Dots represent monthly averages; the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

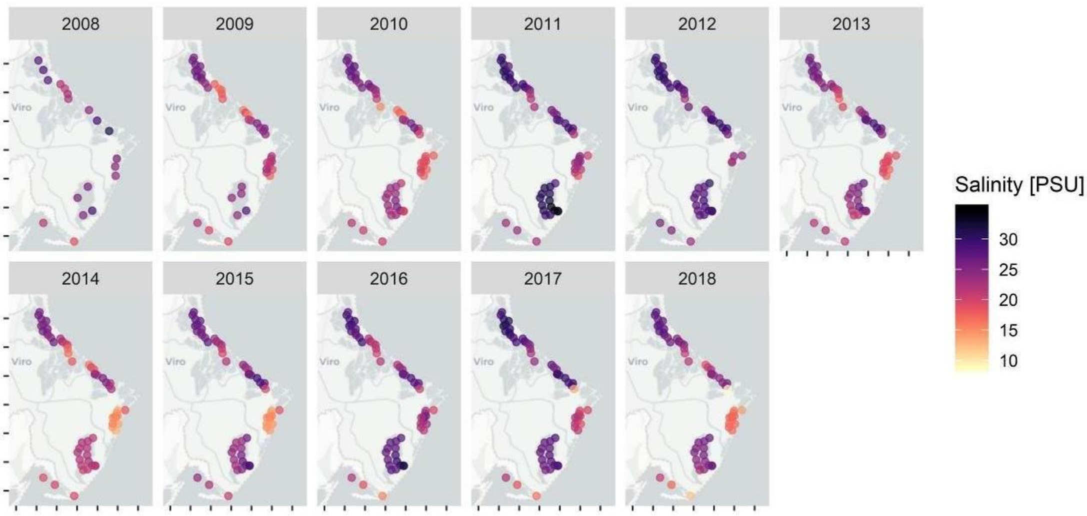


Figure 49. Yearly values (average) of salinity for all collected data within the Po Delta case in the period 2008-2018

Dissolved oxygen (Table 26, Figure 50, Figure 51, Figure 52)

Also the estimated trend for dissolved oxygen is lagoon specific, even if – in general– it shows an increase in dissolved oxygen content over time. The seasonality term shows that lower values are expected in the second part of the summer.

Table 26. Summary statistics for the yearly dissolved oxygen (mg/L) values in the Delta Po lagoons (continuous data)

Lagoon	Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Barbamarco	Average	NA	NA	NA	NA	NA	8.65	NA	9.09	8.71	9.26	9.07
Barbamarco	St.Dev	NA	NA	NA	NA	NA	1.72	NA	2.05	1.69	2.07	1.98
Barbamarco	Min	NA	NA	NA	NA	NA	4.95	NA	3.22	3.29	5.10	5.13
Barbamarco	Max	NA	NA	NA	NA	NA	14.26	NA	15.07	13.09	17.34	15.55
Barbamarco	N. obs.	NA	NA	NA	NA	NA	322.00	NA	347.00	310.00	340.00	357.00
Basson	Average	NA	NA	8.46	8.86	8.39	NA	NA	NA	8.76	9.46	9.18
Basson	St.Dev	NA	NA	1.61	1.78	1.66	NA	NA	NA	1.37	1.97	1.73
Basson	Min	NA	NA	4.06	4.50	3.68	NA	NA	NA	3.41	3.74	4.67
Basson	Max	NA	NA	11.88	14.38	12.21	NA	NA	NA	12.33	15.14	12.88
Basson	N. obs.	NA	NA	345.00	330.00	351.00	NA	NA	NA	340.00	329.00	350.00
Canarin	Average	NA	NA	NA	NA	NA	8.64	8.58	8.85	8.26	9.02	8.90
Canarin	St.Dev	NA	NA	NA	NA	NA	1.50	1.73	2.07	1.30	1.59	1.46
Canarin	Min	NA	NA	NA	NA	NA	4.93	5.09	3.11	4.73	5.60	6.11
Canarin	Max	NA	NA	NA	NA	NA	12.47	12.32	13.16	12.86	14.05	12.42
Canarin	N. obs.	NA	NA	NA	NA	NA	309.00	307.00	326.00	362.00	362.00	365.00
Goro	Average	7.13	7.88	8.86	8.95	8.77	8.41	9.14	8.47	8.96	8.84	8.95
Goro	St.Dev	3.96	2.61	2.02	2.95	2.63	2.59	2.01	2.59	1.85	2.37	2.13
Goro	Min	0.81	0.73	3.51	0.76	2.33	1.30	4.21	0.59	2.96	2.25	3.83
Goro	Max	16.78	14.40	13.46	15.76	16.05	13.99	16.88	15.17	13.26	13.60	15.08
Goro	N. obs.	315.00	365.00	365.00	365.00	366.00	365.00	365.00	365.00	366.00	365.00	365.00
Marinetta	Average	NA	NA	7.63	7.49	NA	NA	7.37	NA	NA	7.48	7.74
Marinetta	St.Dev	NA	NA	1.71	1.91	NA	NA	1.40	NA	NA	1.60	2.01
Marinetta	Min	NA	NA	3.12	3.35	NA	NA	4.78	NA	NA	3.70	3.90
Marinetta	Max	NA	NA	10.99	11.33	NA	NA	11.94	NA	NA	10.94	12.71
Marinetta	N. obs.	NA	NA	365.00	315.00	NA	NA	311.00	NA	NA	327.00	357.00
Scardovari	Average	NA	NA	8.52	8.35	8.33	8.35	8.63	8.80	8.24	8.90	8.52
Scardovari	St.Dev	NA	NA	1.60	1.66	1.95	1.77	1.49	1.46	1.42	1.84	1.95
Scardovari	Min	NA	NA	4.86	4.29	3.70	3.91	5.24	4.37	3.98	4.81	3.23
Scardovari	Max	NA	NA	12.26	12.35	14.96	13.84	12.36	12.89	11.69	12.87	13.40
Scardovari	N. obs.	NA	NA	302.00	357.00	363.00	331.00	363.00	358.00	365.00	362.00	356.00
Vallona	Average	NA	NA	NA	NA	NA	NA	8.18	8.23	9.23	8.83	8.85
Vallona	St.Dev	NA	NA	NA	NA	NA	NA	2.54	2.67	1.78	2.47	2.31
Vallona	Min	NA	NA	NA	NA	NA	NA	1.37	2.49	4.75	2.71	3.55
Vallona	Max	NA	NA	NA	NA	NA	NA	13.90	17.00	13.86	15.92	15.13
Vallona	N. obs.	NA	NA	NA	NA	NA	NA	348.00	298.00	330.00	351.00	358.00

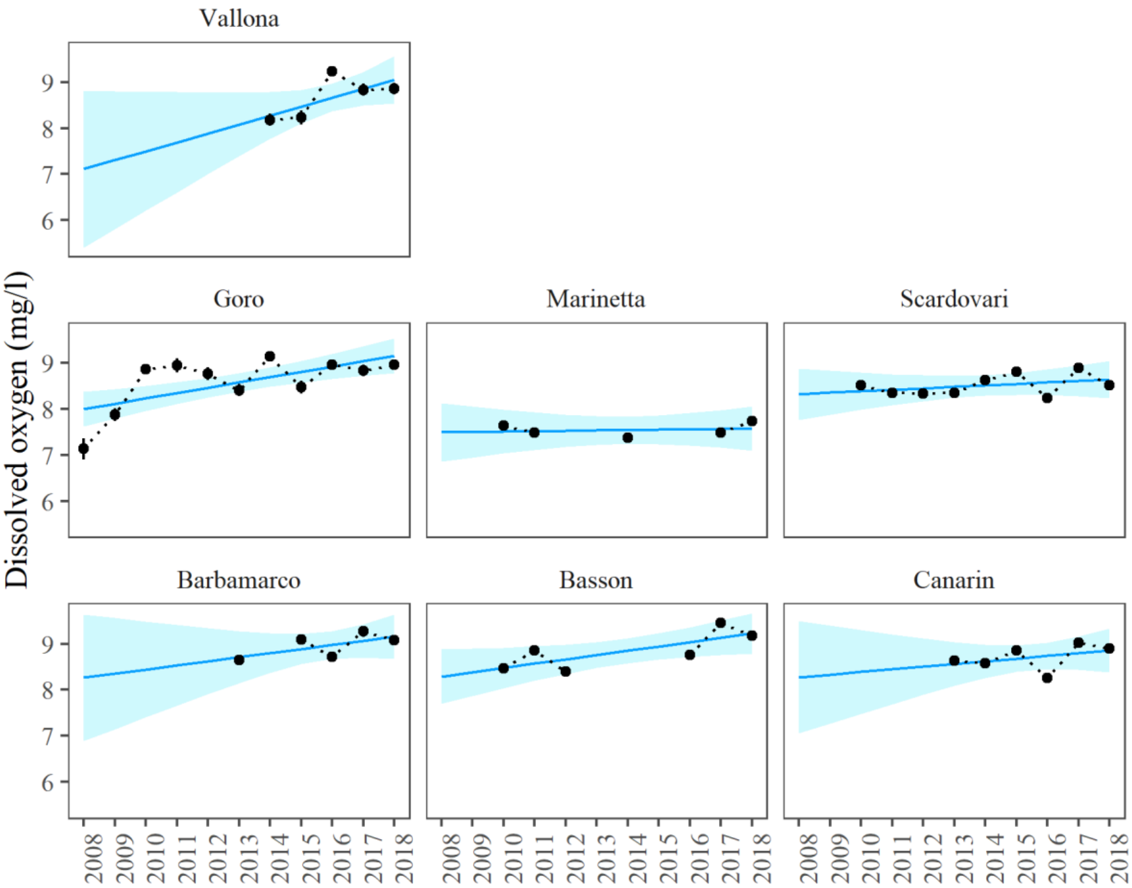


Figure 50. Dissolved oxygen trend evaluated on yearly average data (continuous data). Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I.; in this case the fitted is lagoon specific).

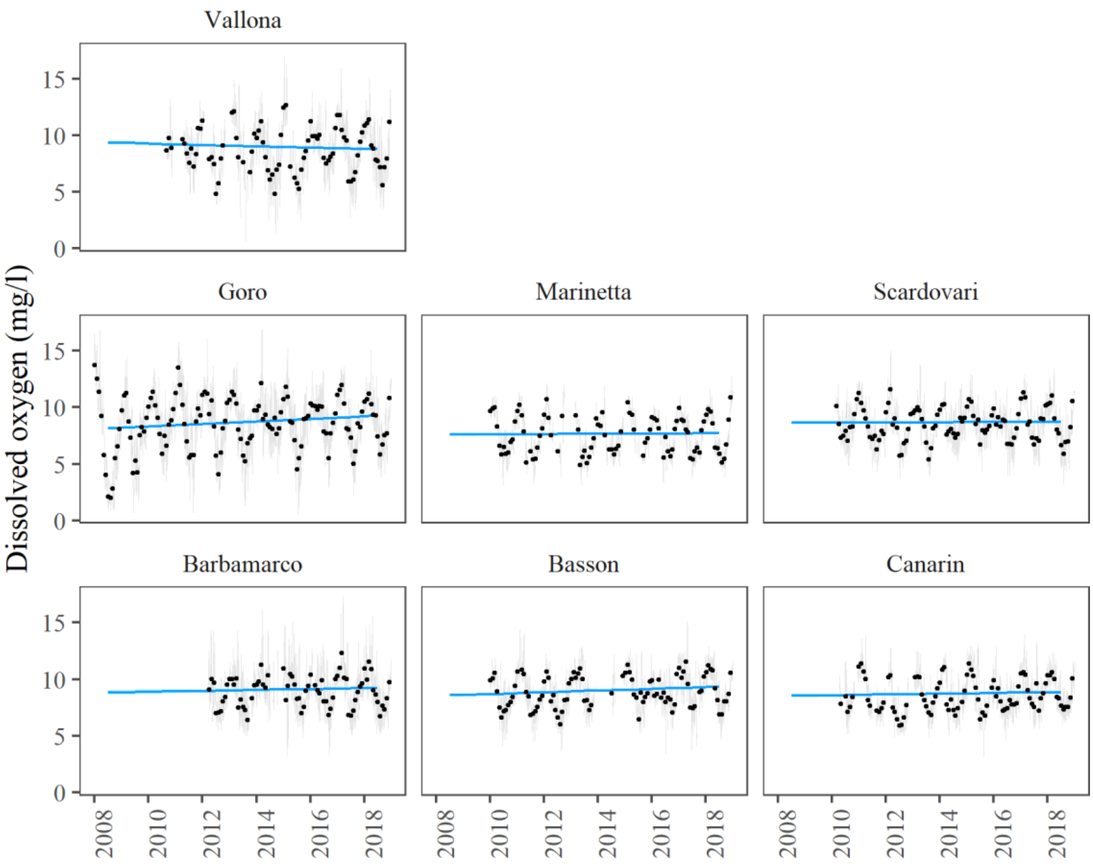


Figure 51. Dissolved oxygen trends (continuous data) evaluated on daily average data (light grey lines). Dots represent monthly averages; the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

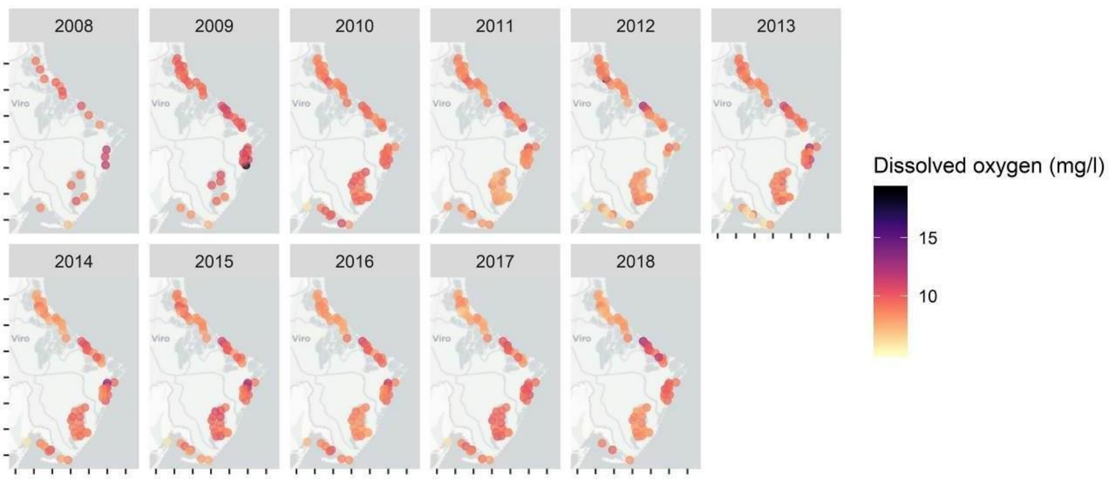


Figure 52. Yearly values (average) of dissolved oxygen for all collected data within the Po Delta case in the period 2008-2018

TOTAL SUSPENDED SOLIDS (Table 27, Figure 53, Figure 54, Figure 55)

TSS values recorded in the Po delta lagoon for the period 2009-2017 exhibited high variability, ranging from 0.5 to 205 mgL^{-1}. Each lagoon evidenced fluctuations among and within the years but the observed pattern resulted similar. Goro lagoon was characterized by the highest TSS content in each sampled years, with a mean value in the whole period which was more than three times higher with respect to what found in the other Po delta lagoons (36.3 mg L^{-1} *vs.* a mean value of 10.9 mg L^{-1}). The differences among Goro and the rest of the Po delta lagoon are evident also if the trend over the considered period is taken into account; in this case of Goro the inter-annual trend shows an increase of TSS content while in the rest of the Po delta lagoon the amount of TSS seems to decrease over the years. Considering the spatio-temporal evolution the highest values detected in 2012 and 2014, except for Goro (highest value in 2010), while any clear geographic pattern was observed over the years.

Marked lagoon specific trends have been detected at both yearly and seasonal temporal scale, with a positive tendencies (with varying slopes) for the lagoons of the Veneto Region and a negative trend for Goro. Higher TSS values are expected in spring in all lagoons.

Table 27. Summary statistics for the yearly total suspended solid (mg/L) values in the Delta Po lagoons (sampling data)

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Barbamarco	Average	3.62	3.74	4.50	15.31	14.14	17.15	19.12	17.81	10.44
Barbamarco	St.Dev	2.84	2.18	3.01	18.39	5.62	13.78	13.45	11.81	5.12
Barbamarco	Min	1.00	1.00	2.00	2.50	7.00	5.00	1.00	3.00	1.00
Barbamarco	Max	13.00	10.00	10.00	64.00	29.00	59.00	42.00	42.00	20.00
Barbamarco	N. obs.	21.00	23.00	16.00	18.00	21.00	20.00	16.00	32.00	16.00
Caleri	Average	3.71	3.71	3.94	18.08	13.78	10.19	16.85	8.53	9.22
Caleri	St.Dev	3.16	3.50	2.19	20.01	18.17	6.37	14.47	4.36	5.04
Caleri	Min	1.00	2.00	2.00	1.00	2.00	2.00	0.50	2.00	2.00
Caleri	Max	11.00	19.00	8.00	72.00	82.00	27.00	53.00	16.00	20.00
Caleri	N. obs.	21.00	24.00	17.00	18.00	18.00	21.00	17.00	30.00	18.00
Canarin	Average	3.90	4.67	7.61	35.41	18.33	18.33	23.76	14.92	9.67
Canarin	St.Dev	3.06	2.24	7.13	59.14	12.97	7.94	13.43	7.03	6.24
Canarin	Min	2.00	2.00	2.00	5.00	5.00	7.00	6.00	2.00	0.50
Canarin	Max	12.00	10.00	25.00	205.00	50.00	40.00	60.00	25.00	21.00
Canarin	N. obs.	21.00	24.00	18.00	17.00	21.00	21.00	21.00	24.00	15.00
Goro	Average	NA	65.00	21.69	41.56	27.06	55.75	27.84	28.25	23.12
Goro	St.Dev	NA	46.19	14.70	18.38	21.09	45.82	18.82	16.32	9.57
Goro	Min	NA	18.00	2.50	14.00	10.00	14.00	2.50	11.00	10.00
Goro	Max	NA	203.00	48.00	76.00	93.00	203.00	72.00	66.00	39.00
Goro	N. obs.	NA	13.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Marinetta	Average	4.00	4.39	4.00	9.27	16.40	9.10	21.57	15.70	6.56
Marinetta	St.Dev	3.21	3.16	2.00	5.39	8.87	4.25	22.77	13.40	3.57
Marinetta	Min	1.00	2.00	2.00	2.00	8.00	4.00	3.00	2.00	3.00
Marinetta	Max	12.00	15.00	8.00	20.00	37.00	16.00	80.00	51.00	13.00
Marinetta	N. obs.	14.00	18.00	11.00	11.00	10.00	10.00	14.00	20.00	9.00
Scardovari	Average	3.36	3.19	4.48	11.33	11.59	15.74	20.07	10.74	6.30
Scardovari	St.Dev	3.31	1.45	1.63	6.03	7.28	10.53	25.14	9.62	4.77
Scardovari	Min	1.00	1.00	2.00	2.00	3.00	6.00	1.00	0.50	0.50

Scardovari	Max	12.00	7.00	7.00	28.00	29.00	55.00	127.00	46.00	18.00

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Scardovari	N. obs.	28.00	32.00	21.00	27.00	27.00	27.00	28.00	42.00	20.00
Vallona	Average	3.64	3.69	4.17	11.50	13.00	10.64	24.39	10.90	7.78
Vallona	St.Dev	3.34	2.91	1.53	11.18	6.39	6.87	19.37	5.81	2.82
Vallona	Min	1.00	1.00	2.00	2.00	7.00	2.00	0.50	2.00	4.00
Vallona	Max	12.00	13.00	6.00	42.00	26.00	24.00	63.00	19.00	12.00
Vallona	N. obs.	14.00	16.00	12.00	12.00	10.00	14.00	14.00	20.00	9.00

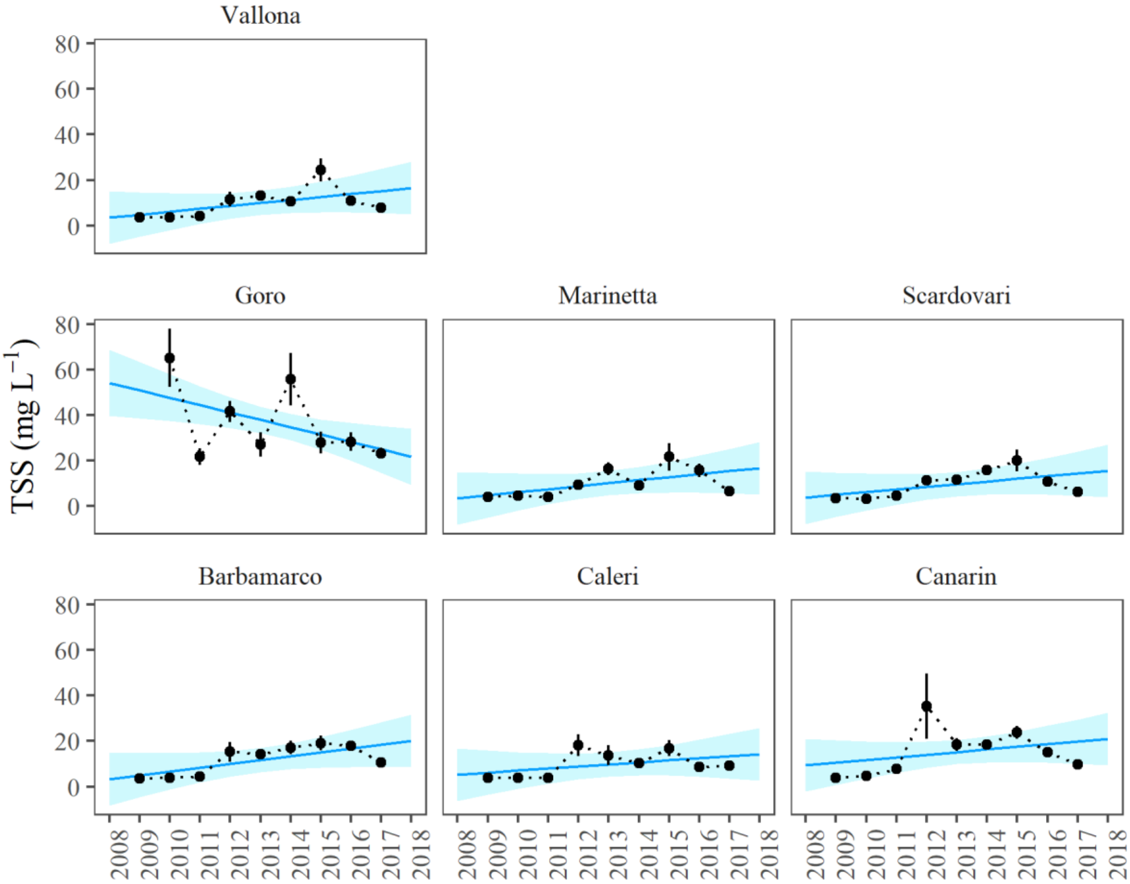


Figure 53. Total suspended solids trend evaluated on yearly average data (sampling data). Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific intercept).

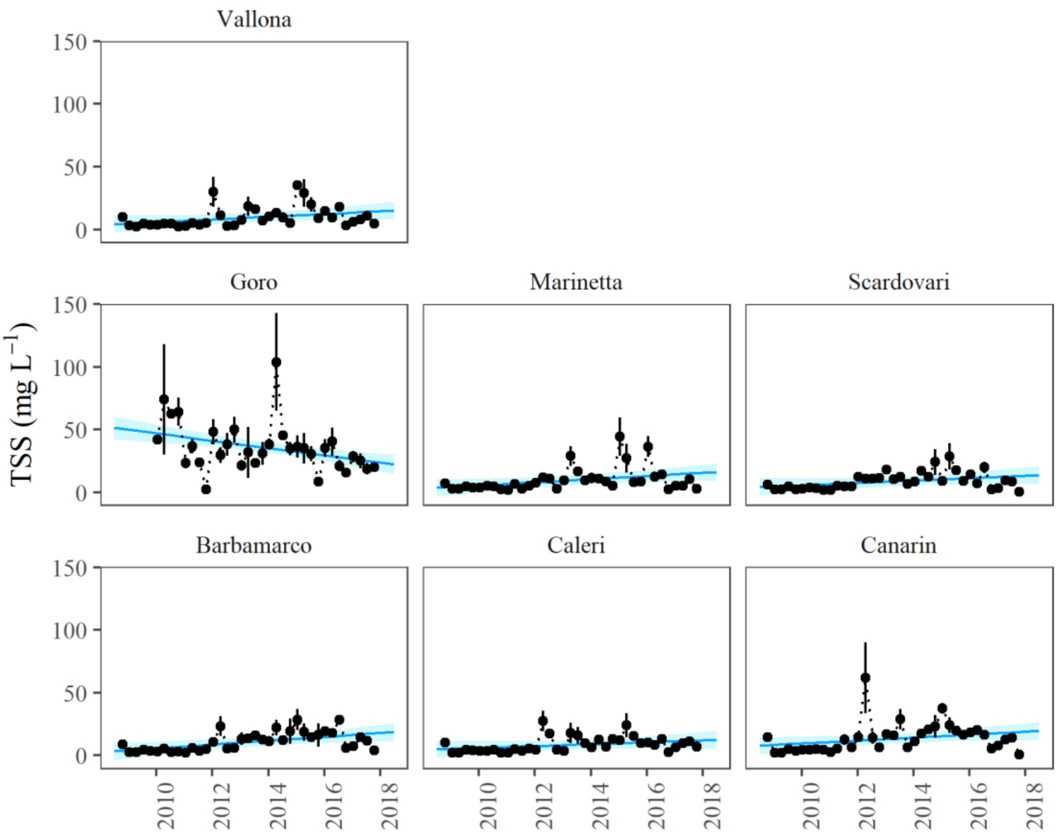


Figure 54. Total suspended solid trend evaluated quarterly averages (dots; sampling data); the blue line represents the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

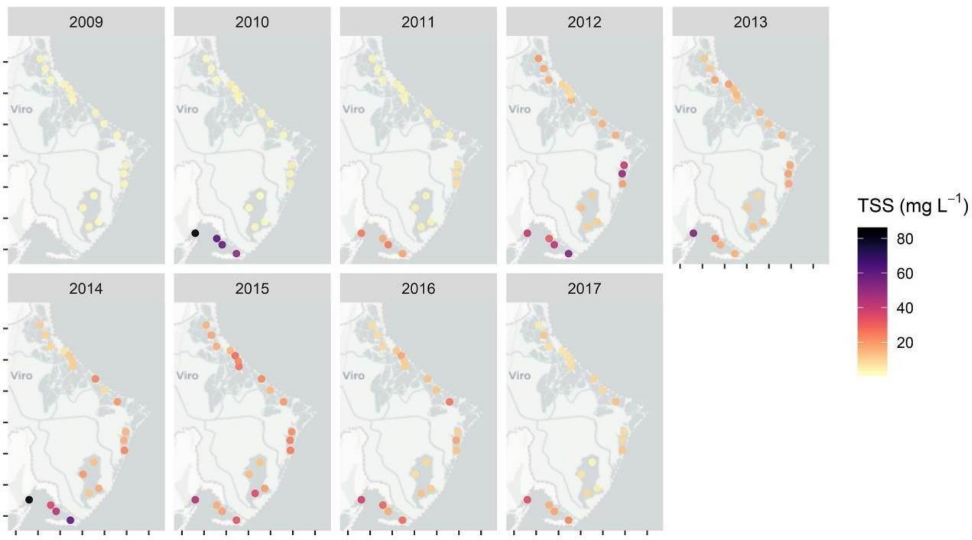


Figure 55. Yearly values (average) of sampled data for total suspended solids for sampling stations within the Po Delta case in the period 2009-2017

DISSOLVED INORGANIC NITROGEN (Table 28, Figure 56, Figure 57, Figure 58)

During the period 2009-2017 the DIN content in Delta Po lagoons exhibited some fluctuations both in spatial and in temporal terms. Goro, Marinetta and Vallona lagoons were characterized by the highest mean values (average value on the period > 1000 μgL^{-1}), while Caleri and Scardovari exhibited the lowest mean contents (average value on the period < 500 μgL^{-1}). In transitional water assessment methods under the Water Framework Directive (WFD), the supporting physic-chemical quality elements include DIN and its reference boundary assigned by the national legislation (DM 260/2010) to declass ecological status from “good” to “moderate” is fixed at 420 μgL^{-1} for WB’s with salinity < 30 and at 253 μgL^{-1} for WB’s with salinity > 30 (data considered as annual mean values). During the investigated period these values were always exceeded in Goro and regularly trespassed in Marinetta and Vallona. However, annual mean values higher than the boundary limits are found also in the rest of the Po delta lagoons.

Taking into account the spatio-temporal evolution, higher DIN content were found in 2008, 2013 (for all lagoons) and 2016 for Goro and Vallona lagoons, while any clear geographic pattern was detected.

A positive annual trend has been detected. The trend is lagoon-specific, even if the inter-lagoon differences are relatively small. The same can be observed with seasonal data, with a relevant contribution of the quarterly period variable in the model, with larger observed DIN values in winter andautumn and smaller in summer and spring.

Table 28. Summary statistics for the yearly dissolved inorganic nitrogen (µg/L) values in the Delta Po lagoons (sampling data)

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Barbamarco	Average	568.58	502.78	309.14	499.67	709.98	583.77	850.52	550.18	398.41
Barbamarco	St.Dev	513.16	246.06	216.18	464.68	475.11	565.20	1029.33	255.71	341.51
Barbamarco	Min	274.50	274.50	27.80	24.01	84.90	18.18	10.29	155.64	81.14
Barbamarco	Max	1843.50	878.20	705.60	1587.40	1610.60	1596.68	2848.42	863.43	1256.97
Barbamarco	N. obs.	12.00	12.00	12.00	12.00	12.00	13.00	12.00	24.00	12.00
Caleri	Average	374.97	343.65	241.39	149.92	511.55	175.95	306.12	214.51	171.31
Caleri	St.Dev	201.45	45.87	96.44	160.51	653.63	230.59	381.41	181.61	205.07
Caleri	Min	274.50	280.50	106.38	10.29	64.50	44.32	31.15	28.45	21.66
Caleri	Max	864.50	406.30	388.80	502.20	2533.90	869.07	1286.23	603.29	693.61
Caleri	N. obs.	12.00	12.00	12.00	12.00	12.00	12.00	12.00	24.00	12.00
Canarin	Average	406.93	784.57	345.91	569.60	975.83	693.78	1001.10	395.99	549.01
Canarin	St.Dev	366.21	788.34	60.20	438.41	555.26	648.59	890.24	243.27	386.42
Canarin	Min	274.50	274.50	261.20	10.29	194.10	70.08	54.13	49.05	111.96
Canarin	Max	1568.00	2517.80	449.80	1333.00	2299.30	2146.24	2646.95	767.00	1376.53
Canarin	N. obs.	12.00	12.00	9.00	12.00	12.00	13.00	12.00	24.00	12.00
Goro	Average	NA	1085.20	987.19	639.19	1816.75	805.39	716.86	1625.12	1123.83
Goro	St.Dev	NA	763.74	1358.22	516.71	2181.26	758.01	762.90	1105.08	710.80
Goro	Min	NA	62.00	168.00	35.00	110.00	15.00	184.00	224.00	167.36
Goro	Max	NA	2417.00	5739.00	1931.00	7716.00	2417.00	3156.40	5002.00	2524.00
Goro	N. obs.	NA	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00

Marinetta	Average	665.89	869.17	251.19	682.44	2284.39	793.25	1161.71	1622.44	492.63
Marinetta	St.Dev	522.62	536.23	268.80	863.17	2444.77	1200.65	1484.44	1667.53	540.91

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Marinetta	Min	274.50	282.50	9.88	13.15	84.30	46.47	76.33	36.54	78.06
Marinetta	Max	1759.10	1901.30	800.90	2244.00	6405.00	3611.20	4136.17	5482.34	1531.33
Marinetta	N. obs.	8.00	8.00	8.00	8.00	8.00	8.00	8.00	16.00	8.00
Scardovari	Average	279.39	439.46	193.32	308.45	693.82	276.92	341.19	167.93	267.13
Scardovari	St.Dev	6.40	137.44	126.92	339.41	535.23	291.39	297.83	135.48	238.66
Scardovari	Min	274.50	282.50	11.38	10.29	10.29	16.41	17.42	24.24	12.02
Scardovari	Max	293.80	645.10	387.88	1373.60	1940.10	987.60	836.10	600.53	846.07
Scardovari	N. obs.	16.00	14.00	16.00	16.00	16.00	16.00	16.00	32.00	16.00
Vallona	Average	417.09	1055.00	283.26	718.44	2093.60	1039.66	1354.12	1200.98	926.19
Vallona	St.Dev	128.35	344.94	227.09	517.82	1551.19	1000.95	1456.76	797.48	988.37
Vallona	Min	280.50	547.80	9.88	182.30	413.40	140.58	178.02	214.37	261.25
Vallona	Max	625.50	1473.10	736.00	1599.30	4537.90	2670.03	3930.32	2887.34	3066.46
Vallona	N. obs.	8.00	8.00	8.00	8.00	8.00	8.00	8.00	16.00	8.00

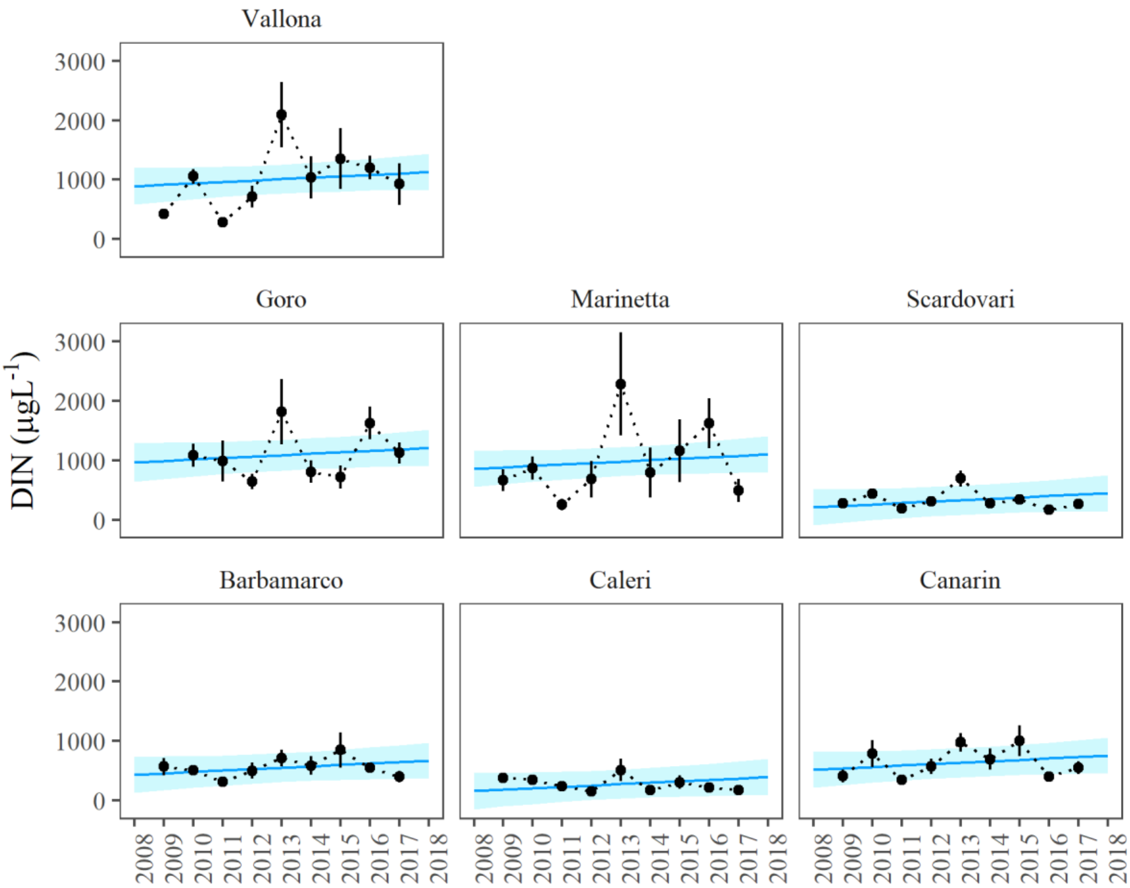


Figure 56. Dissolved inorganic nitrogen trends evaluated on yearly average data (sampling data). Dots represent yearly averages (± standard error); the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is common, with a lagoon specific intercept).

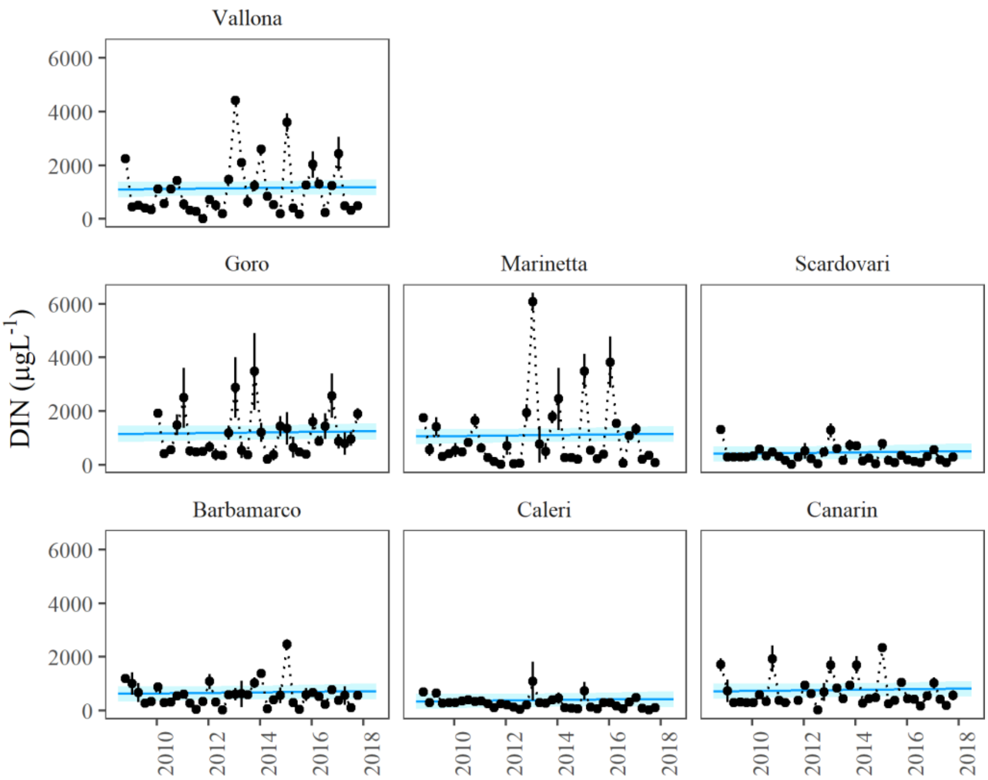


Figure 57. Dissolved inorganic nitrogen trends evaluated on quarterly averages (dots; sampling data); the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

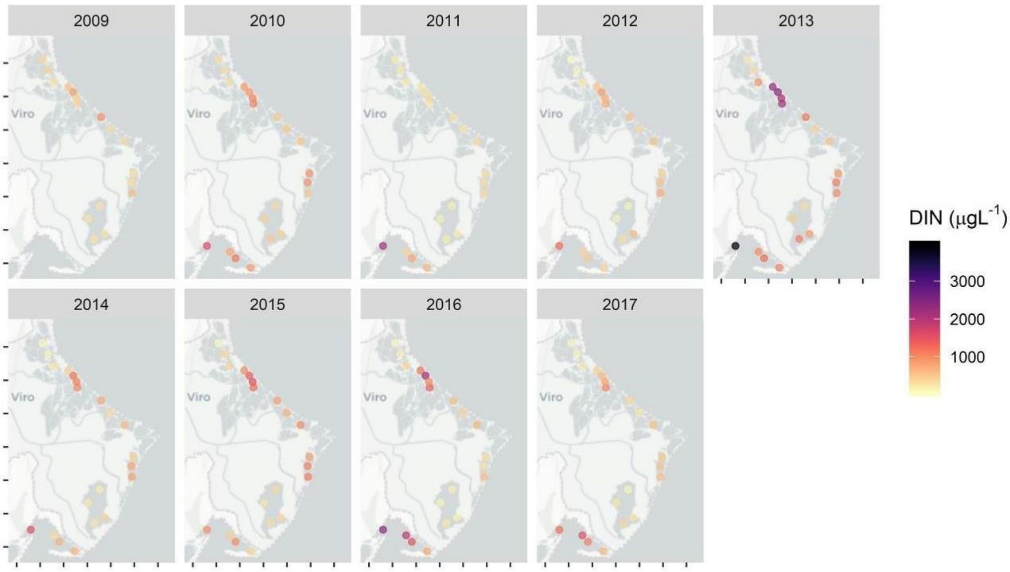


Figure 58. Yearly values (average) of sampled data for dissolved inorganic nitrogen for sampling stations within the Po Delta case in the period 2009-2017

ORTHOPHOSPHATE (Table 29, Figure 59, Figure 60, Figure 61)

During the period 2009-2017 the Orthophosphate content in Delta Po lagoons exhibited a common pattern among lagoons, with highest values recorded in 2009 and a consequent progressive decrease, with the exception of Goro lagoon where an opposite trend was observed. Marinetta, Barbamarco and Vallona were characterized by an higher mean PO_4 values (average value on the period > 20 μgL^{-1}), while Caleri and Scardovari exhibited the lower mean contents (average value on the period 9.6 and 12.1 μgL^{-1}, respectively). In transitional water assessment methods under the Water Framework Directive (WFD) the supporting physic-chemical quality elements includes PO_4 and its reference boundary assigned bythe national legislation (DM 260/2010) to declass ecological status from good to moderate is fixed at 15 μgL^{-1} for WB's with salinity > 30 (data considered as annual mean values, no boundary available for WB's <30). During the investigated period these values were frequently trespassed in Vallona and Marinetta (≥80% of the samples), regularly trespassed in Barbamarco, Goro and Canarin (= 70% of the samples) and occasionally trespassed in Caleri and Scardovari (≤ 20% of the samples).

The DIN and PO_4 data reflected a general condition of high trophic status in the waters of the Po delta lagoons.

Marked lagoon specific trends have been detected at both yearly and seasonal temporal scale, with a negative tendencies (with varying slopes) for the lagoons of the Veneto Region and a positive trend for Goro. Lower PO_4 values are expected in summer in all lagoons.

Table 29. Summary statistics for the yearly orthophosphate (µg/L) values in the Delta Po lagoons (sampling data)

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Barbamarco	Average	31.292	21.625	16.208	13.417	16.525	15.123	20.567	14.770	9.684
Barbamarco	St.Dev	23.228	15.613	12.982	10.816	14.473	11.516	21.947	11.128	9.688
Barbamarco	Min	5.000	5.000	2.000	5.000	4.300	3.900	3.130	2.500	2.500
Barbamarco	Max	68.500	60.000	37.500	36.000	42.200	43.000	64.290	38.820	29.270
Barbamarco	N. obs.	12.000	12.000	12.000	12.000	12.000	13.000	12.000	24.000	12.000
Caleri	Average	9.458	14.375	13.792	5.500	8.933	5.215	8.831	4.578	5.834
Caleri	St.Dev	9.277	13.274	20.369	1.834	7.546	1.775	5.706	2.851	2.219
Caleri	Min	5.000	5.000	2.000	3.000	1.000	3.070	2.790	2.500	2.500
Caleri	Max	33.500	46.500	68.500	9.000	25.000	10.000	17.570	11.250	10.460
Caleri	N. obs.	12.000	12.000	12.000	12.000	12.000	12.000	12.000	24.000	12.000
Canarin	Average	22.958	24.125	8.722	18.417	27.892	18.952	21.323	12.838	8.002
Canarin	St.Dev	19.406	17.355	7.965	11.098	15.308	15.724	20.257	11.689	8.689
Canarin	Min	5.000	5.000	2.000	5.000	7.700	4.720	1.830	2.500	2.500
Canarin	Max	57.500	53.500	22.000	44.000	67.300	50.000	50.250	42.360	32.570
Canarin	N. obs.	12.000	12.000	9.000	12.000	12.000	13.000	12.000	24.000	12.000
Goro	Average	NA	13.831	11.500	13.312	12.812	20.350	18.750	26.812	22.355
Goro	St.Dev	NA	13.419	7.882	12.611	9.005	14.504	13.324	17.065	16.768
Goro	Min	NA	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Goro	Max	NA	45.300	26.000	41.000	29.000	45.300	51.000	60.000	60.000
Goro	N. obs.	NA	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000
Marinetta	Average	30.750	22.625	7.688	19.625	32.337	16.100	20.747	19.775	11.839
Marinetta	St.Dev	23.201	16.503	10.769	19.242	17.945	10.867	14.251	8.705	11.340

Marinetta	Min	5.000	5.000	0.250	3.000	5.600	5.480	7.560	7.400	2.500
Marinetta	Max	67.000	48.500	25.000	59.000	54.100	37.000	45.670	31.000	37.920

Lagoon	Statistic	2009	2010	2011	2012	2013	2014	2015	2016	2017
Marinetta	N. obs.	8.000	8.000	8.000	8.000	8.000	8.000	8.000	16.000	8.000
Scardovari	Average	12.406	20.536	5.469	8.375	10.519	5.202	10.005	5.532	6.196
Scardovari	St.Dev	16.591	10.163	6.322	4.515	11.707	2.718	8.074	4.836	4.398
Scardovari	Min	5.000	5.000	1.250	3.000	1.300	1.850	1.380	2.500	2.500
Scardovari	Max	55.500	40.000	27.500	17.000	40.200	13.000	29.390	17.610	17.580
Scardovari	N. obs.	16.000	14.000	16.000	16.000	16.000	16.000	16.000	32.000	16.000
Vallona	Average	20.875	21.750	13.375	29.875	36.925	23.171	18.907	24.739	16.930
Vallona	St.Dev	8.275	11.732	15.970	18.954	13.918	13.461	9.512	7.645	6.018
Vallona	Min	5.000	5.000	0.250	7.000	17.500	7.710	7.590	11.980	8.600
Vallona	Max	35.000	36.000	45.000	57.000	56.000	46.860	31.360	35.890	26.460
Vallona	N. obs.	8.000	8.000	8.000	8.000	8.000	8.000	8.000	16.000	8.000

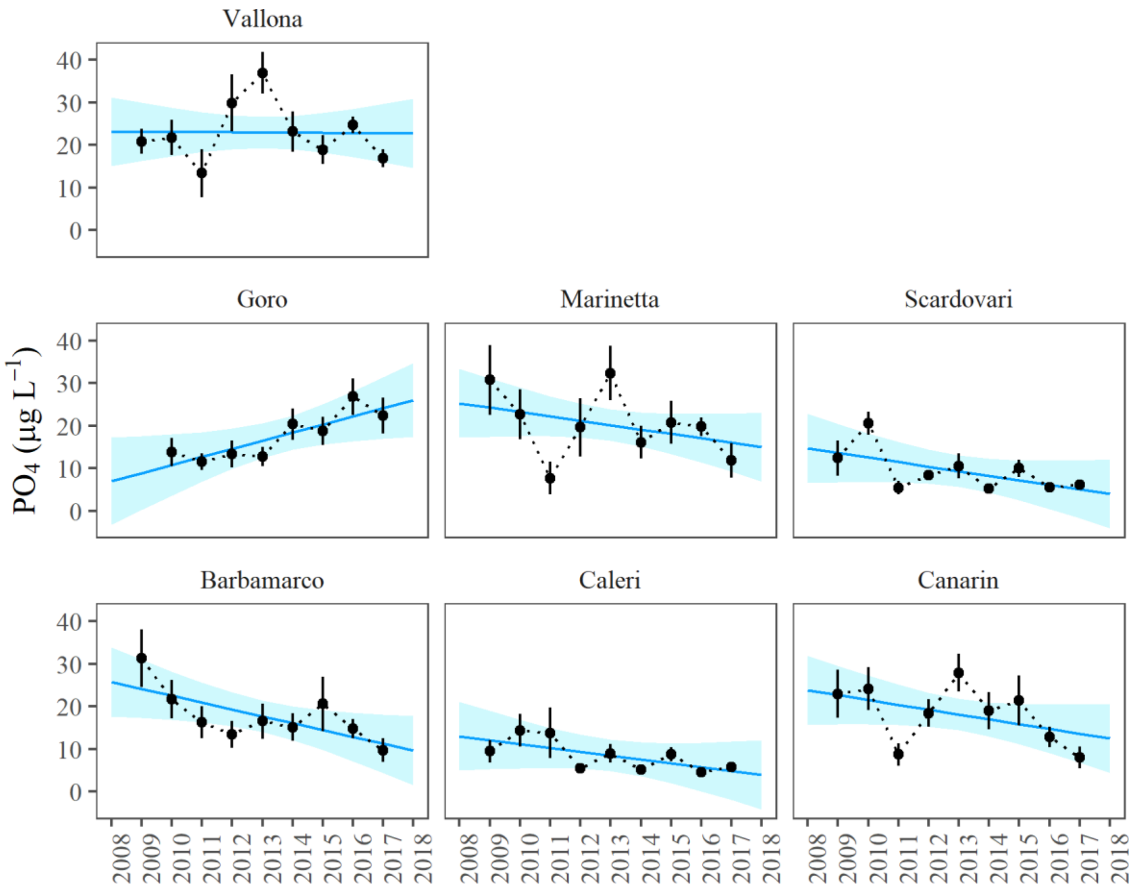


Figure 59. Orthophosphate trend evaluated on yearly average data (sampling data). Dots represent yearly averages (± standard error); the blue line represents the best fitted models (± 95% C.I.; in this case the fitted trend is common, with a lagoon specific intercept).

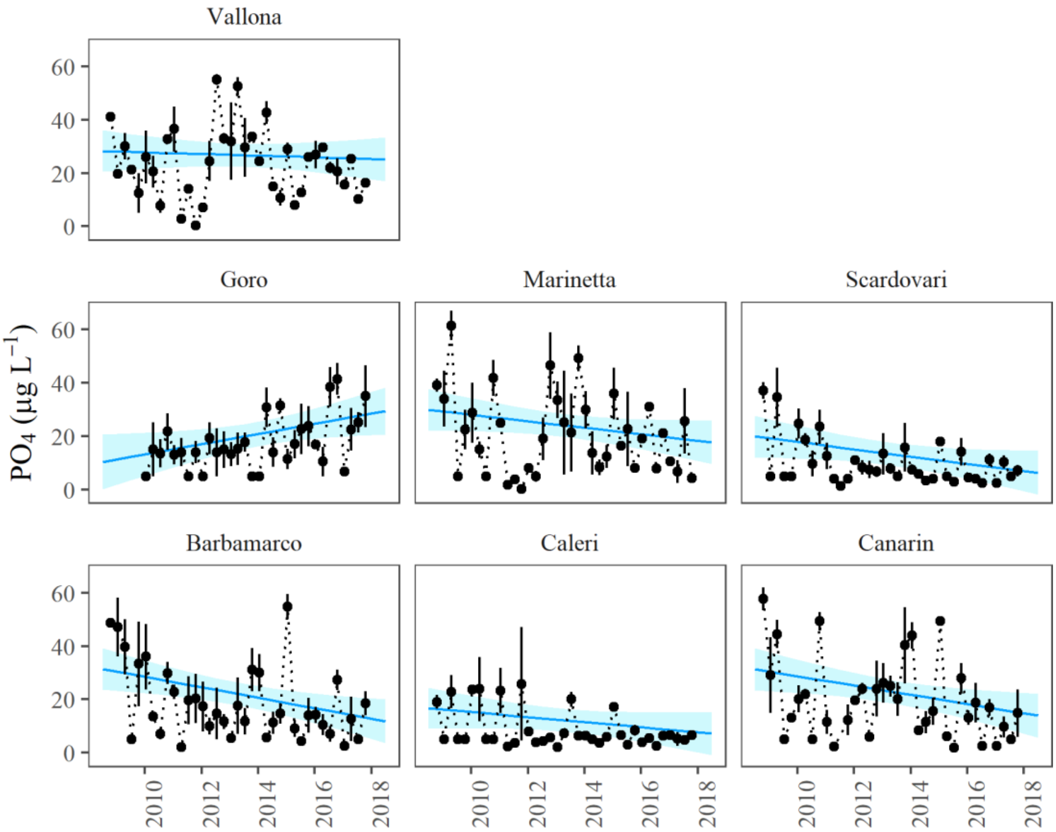


Figure 60. Orthophosphate trend evaluated on quarterly averages (dots; sampling data); the blue line represents the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

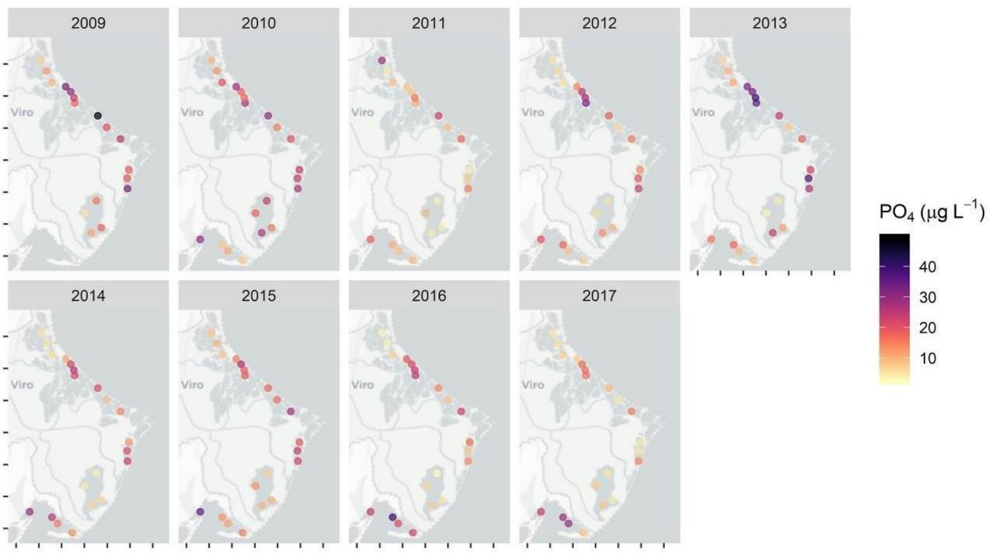


Figure 61. Yearly values (average) for sampled data of orthophosphate for sampling stations within the Po Delta case in the period 2009-2017

6.4. Biological parameters

6.4.1. Data availability

A resume of the data collected and considered for the assessment of the status and trend of biological parameters in the Po Delta lagoons is presented in

Table 30, while a more exhaustive table, including all the collected data and further information about its availability is reported in Annex 4.

Biological parameters considered for the study area are:

- phytoplankton: using Chlorophyll-a as proxy of phytoplankton biomass;
- macrozoobenthos: using MAMBI (Multivariate-AZTI's Marine Biotic Index) as index of ecological status of macrozoobenthos;
- macrophytes: using MaQI (Macrophyte Quality Index) as index of ecological status of macrophytes);
- Manila clams *Ruditapes philippinarum*
- Natura 2000 habitats;
- reedbeds.

Table 30. Resume table of the Biological parameters considered in the Po delta area

CATEGORY	TYPOLOGY	DESCRIPTION	REFERENCE AREA	DATA COLLECTED -	YEARS / REFERENCE PERIOD	AVAILABILITY	NOTES
Phytoplankton	pdf, spreadsheet Excel format	sampled stations at lagoon scale (n=4)	Sacca di Goro	measurement of Chla;	2009-2017 Quarterly data	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici ARPAE Public Report	Chla mostly instrumental
Phytoplankton	pdf; spreadsheet Excel format	1)_ CTD data on 6 Po Delta lagoons (62 st.).	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	measurement of Chla;	1)_ 2008-2018 monthly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici	1)_Chla instrumental
Macrozoobenthos	pdf; spreadsheet Excel format	sampled stations at lagoon scale (n=4)	Sacca di Goro	MAMBI	Data available for 2010, 2013, 2015, 2017	ARPAE Public Report EIONET	
Macrozoobenthos	csv, pdf	Data on 6 Po delta lagoons	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	MAMBI	Data available for 2008, 2009, 2012, 2014	ARPA VENETO Servizio dati ambientali	EQR scores for2012 and 2014

Macrophytes	Pdf, xls	sampled stations at lagoon scale (n=4)	Sacca di Goro	MAQI	Data available for 2010, 2013, 2015 2017	ARPAE Public Report ARPAE data shared in the	On Eionet/SOE data available also

						frameworks of other project	for 2017
Macrophytes	csv, pdf	Data on 6 Po delta lagoons (17 stations)	Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari	MAQI	Data available for 2008, 2009, 2010, 2014,	ARPA VENETO Servizio dati ambientali	Checklist, EQR for 2010 and 2014 coverage for 2014
Manila Clam	pdf	Articles, reports and technical documents	Sacca di Goro	Focus of the clam production in the area (distribution, production, techinques, licenced areas)		References cited in the text	
Manila Clam	1) pdf 2)shp	1) Articles, reports and technical documents 2)Maps of licenced mollusc farming areas for	1) Po delta veneto lagoons 4) Caleri, Marinetta, Barbamarco and Scardovari	1) producction data 2) Focus of the clam production in the area (distribution, production, techinques, licenced areas)	2)maps updated at September 2019	1 References cited in the text 2)Regiobe Veneto	2) some fishing cooperatives are not included in the map
Natura 2000 Habitat	shp	Habitat maps	Sacca di Goro		shapes available for 2007, 2010, 2014 Natura 2000 form upgraded in 2017	PARCO/UNIFE Data owned by the Park and fully available for the project	
Natura 2000 Habitat	pdf, shp	Natura 2000 form with map layers SIC IT3270017	SIC IT3270017		Maps available for 2008. Last available revisions in 2018	REGIONE VENETO	
Reedbeds	shp	Map of herbaceous vegetation on emerging parts of the Sacca di Goro	Sacca di Goro		1996	PARCO/UNIFE Data owned by the Park and fully available for the project	
Reedbeds	1) pdf 2) shp	1) Articles, reports and technical documents 2) Map of reedbeds (according to the Corine Land Cover Typology 4.1.1.1) in the SIC IT3270017	1) Po delta veneto lagoons 2) SIC IT3270017	Focus of th reedbeds in the Po delta area of Veneto Region	2)Maps available for 2008. Last available revisions in 2018	1) References cited in the text 2) REGIONE VENETO	

The maps including the spatial distribution of the available stations considered for Chlorophyll-a, MAMBI and MaQI are shown respectively in Figure 62, Figure 63 and Figure 64.

Habitats, monitored in the Po delta lagoons, include Natura 2000 habitats and reedbed Habitats. Data on biological communities were collected by the Regional Environmental Agencies of Veneto and Emilia Romagna Regions (ARPAV and ARPAE, respectively) in the period 2009-2018, while the Natura 2000

Habitat mapping of Site of Community Interest (SCI) and Special Protection Areas (SPA) are the responsibility of the respective regional and provincial Offices. The distribution of reedbed was analyzed considering for the lagoons of Regione Veneto the regional habitat maps (which include the Corine land cover codes, in which Reedbed habitat is listed) and the document "Atlante lagunare costiero del Delta del Po" (Parco Regionale Veneto *del Delta del Po*, 2015); for Sacca di Goro, a map of the vegetation for 1996 (information owned by the Po Park and available in GIS format) was considered.

Further information collected, resumed in Annex 4 and included in D3.4.2, consist in:

- Macrozoobenthos data collected in the period 1998-2002 (Goro).
- Data from the Life AGREE project (LIFE13 NAT/IT/000115) coordinated by Provincia di Ferrara during the ex ante (2014-2016) and ex post (2018-2019) phases. Data include chlorophyll-a, macrozoobenthos and pluriennal data on bird fauna nesting on the Goro sandbank.
- Atlas of nesting birds in the years 2004-06

Figure 62 Chlorophyll-a. Delta Po available data in the period 2008-2018

Figure 63 MAMBI. Delta Po stations sampled in the period 2008-2017

Figure 64 MaQI. Delta Po stations sampled in the period 2008-2017

6.4.2. *Reviewing the status and trend of biological parameters*

Data collected in the period 2008-2018 are presented and analyzed under different modalities.

In particular, the status and trend of Clorophyll-a, MAMBI, MaQI, Manila clam, habitats and reedbeds are reported.

CLOROPHYLL-a

Clorophyll-a content, used as proxy of the phytoplankton biomass, was estimated instrumentally using CTD probes during sampling surveys carried out in the period 2008-2018. The frequency of measurement was monthly except for Goro lagoon (quarterly).

Clorophyll-a results are presented as:

- a resume table (Table 31), including the summary statistics (Average, S.D., Min, Max, N. obs.) of data collected in each lagoon on annual basis;
- a graphical representation of the trend, observed in each lagoon, on annual basis (Figure 65);
- a graphical representation of the trend, observed in each lagoon, taking into account seasonality, on a quarterly (sampling data) or monthly (continuous data) basis (Figure 66);
- a map showing the spatio-temporal evolution of all data (sampling and continuous data) collected, evaluated on annual basis (Figure 67).

Annual mean values ranged from 1.0 μg L^{-1} to 9.6 μg L^{-1}, with the exception of Goro Lagoon where a mean value of 27.1 μg L^{-1} was observed in 2014. In the period 2010- 2014, Goro lagoon was characterized by the highest chl-a content, with a mean value three times higher than what found in the others Po delta lagoons (15.4 μg L^{-1} vs. a mean value of the remaining lagoons of 4.6 μg L^{-1}). After that period the differences detected among the Po delta lagoons decreased. Considering the whole period, the highest chl-a content were found in Goro and Canarin lagoons (11.8 μg L^{-1} and 8.5 μg L^{-1},respectively), while the lowest content were found in Scardovari and Caleri lagoons (2.8 μg L^{-1} and 3.5 μg L^{-1},respectively).

Considering the spatio-temporal evolution no clear geographical or temporal patterns resulted evident.

In particular, no temporal trend can be highlighted in the yearly data, while a weak negative (lagoon-specific) pattern can be associated to the periodic sampling data, after taking into account the periodic term (lower values in autumn).

Table 31. Summary statistics for the yearly chlorophyll-*a* concentration values (µg/L) in the Delta Po lagoons (sampling data)

Lagoon	Statistic	2010	2011	2012	2013	2014	2015	2016	2017	2018
Barbamarco	Average	5.567	6.975	7.963	6.330	8.589	6.246	7.453	4.676	9.686
Barbamarco	St.Dev	5.320	6.484	17.135	10.630	8.516	5.982	9.326	3.645	10.614
Barbamarco	Min	0.317	0.588	0.300	0.500	0.600	0.973	0.600	0.700	0.455
Barbamarco	Max	28.250	26.300	119.725	75.718	47.155	27.347	50.288	16.055	51.050
Barbamarco	N. obs.	91.000	61.000	66.000	59.000	60.000	70.000	68.000	69.000	70.000
Caleri	Average	2.500	5.740	2.280	2.765	3.776	5.286	2.865	3.293	3.375
Caleri	St.Dev	1.759	3.671	2.114	2.372	3.309	4.259	1.850	3.379	3.033
Caleri	Min	0.446	0.461	0.270	0.445	0.600	0.768	0.878	0.493	0.245
Caleri	Max	10.500	11.475	12.206	11.926	21.450	24.825	8.843	20.253	13.980
Caleri	N. obs.	107.000	52.000	83.000	72.000	84.000	84.000	84.000	84.000	92.000
Canarin	Average	6.390	6.047	4.547	7.016	8.588	9.567	7.637	9.380	8.059
Canarin	St.Dev	5.891	3.891	4.190	7.063	7.627	6.867	7.483	12.755	5.782
Canarin	Min	0.200	0.413	0.650	0.440	0.500	1.000	1.017	1.418	0.600
Canarin	Max	27.167	15.900	21.356	36.271	31.382	25.340	31.812	81.925	22.575
Canarin	N. obs.	99.000	66.000	75.000	52.000	65.000	76.000	77.000	69.000	70.000
Goro	Average	19.100	7.156	14.050	9.488	27.113	8.319	4.188	5.119	NA
Goro	St.Dev	21.972	7.160	13.895	8.937	32.504	9.442	3.537	3.791	NA
Goro	Min	1.100	0.700	1.200	1.500	1.200	0.700	1.400	0.800	NA
Goro	Max	89.600	23.000	50.400	32.400	90.100	26.700	15.000	14.200	NA
Goro	N. obs.	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	NA
Marinetta	Average	2.576	2.476	1.639	3.689	3.433	3.552	3.247	1.774	3.162
Marinetta	St.Dev	1.590	1.996	0.995	2.189	2.845	3.052	1.899	1.115	4.179
Marinetta	Min	0.540	0.443	0.523	1.030	0.791	0.900	0.912	0.600	0.400
Marinetta	Max	7.050	8.946	4.625	8.831	15.467	13.552	6.671	6.019	19.146
Marinetta	N. obs.	36.000	27.000	26.000	28.000	29.000	28.000	28.000	28.000	27.000
Scardovari	Average	6.069	3.911	3.840	8.612	6.891	3.838	4.964	3.470	5.107
Scardovari	St.Dev	5.168	2.571	4.848	7.187	4.077	4.800	4.949	3.143	4.688
Scardovari	Min	0.270	0.600	0.373	0.790	1.000	0.400	0.500	0.615	0.682
Scardovari	Max	23.386	13.592	23.540	32.215	20.444	24.418	23.009	20.919	27.646
Scardovari	N. obs.	103.000	72.000	84.000	78.000	78.000	90.000	91.000	91.000	91.000
Vallona	Average	4.757	3.277	2.266	6.092	6.143	7.673	5.193	2.912	7.677
Vallona	St.Dev	3.946	2.156	1.318	4.589	5.369	8.312	3.991	1.726	12.392
Vallona	Min	1.189	0.900	0.800	2.056	1.880	1.000	1.483	1.482	0.900
Vallona	Max	14.858	9.300	5.381	17.617	21.969	24.780	13.828	6.610	38.000
Vallona	N. obs.	18.000	13.000	14.000	14.000	14.000	14.000	14.000	14.000	14.000

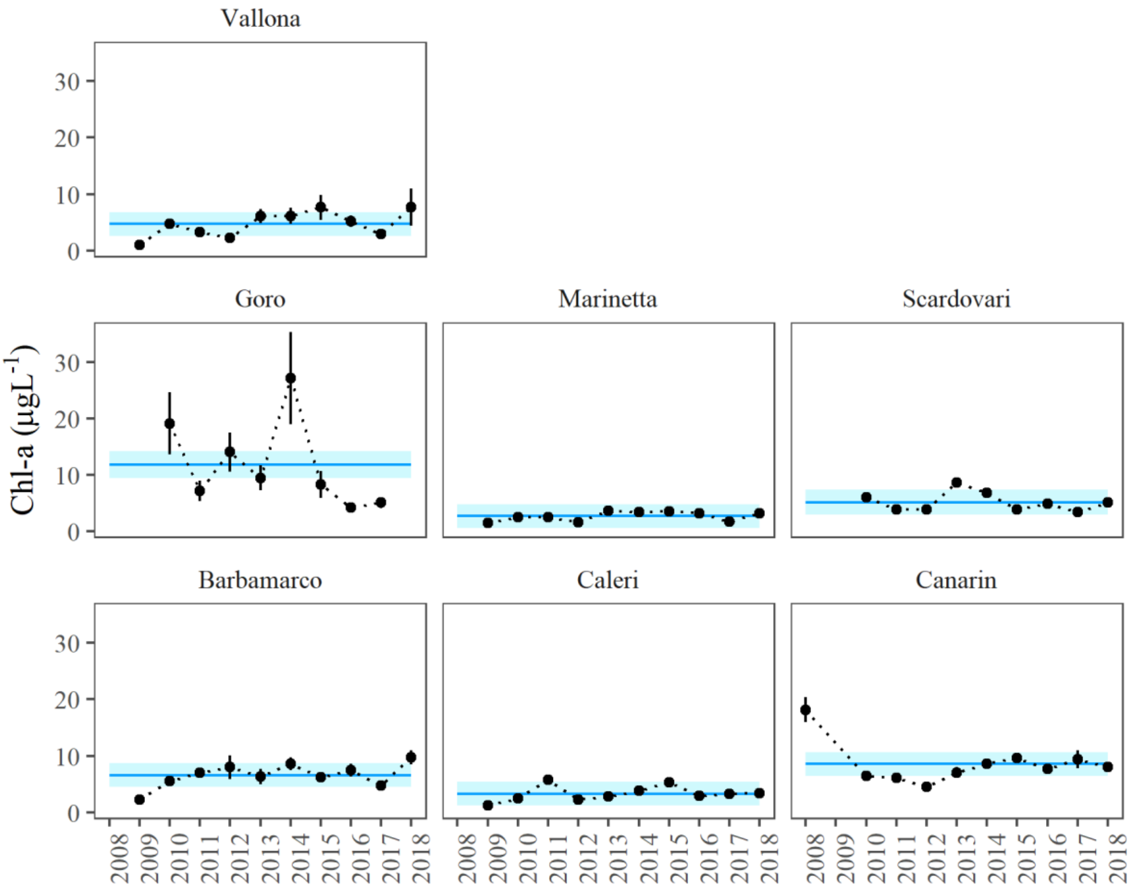


Figure 65. Chlorophyll-a trends evaluated on yearly average data (sampling data). Dots represent yearly averages (± standard error); the blue lines represent the best fitted models (± 95% C.I.; in this case no trend has been detected).

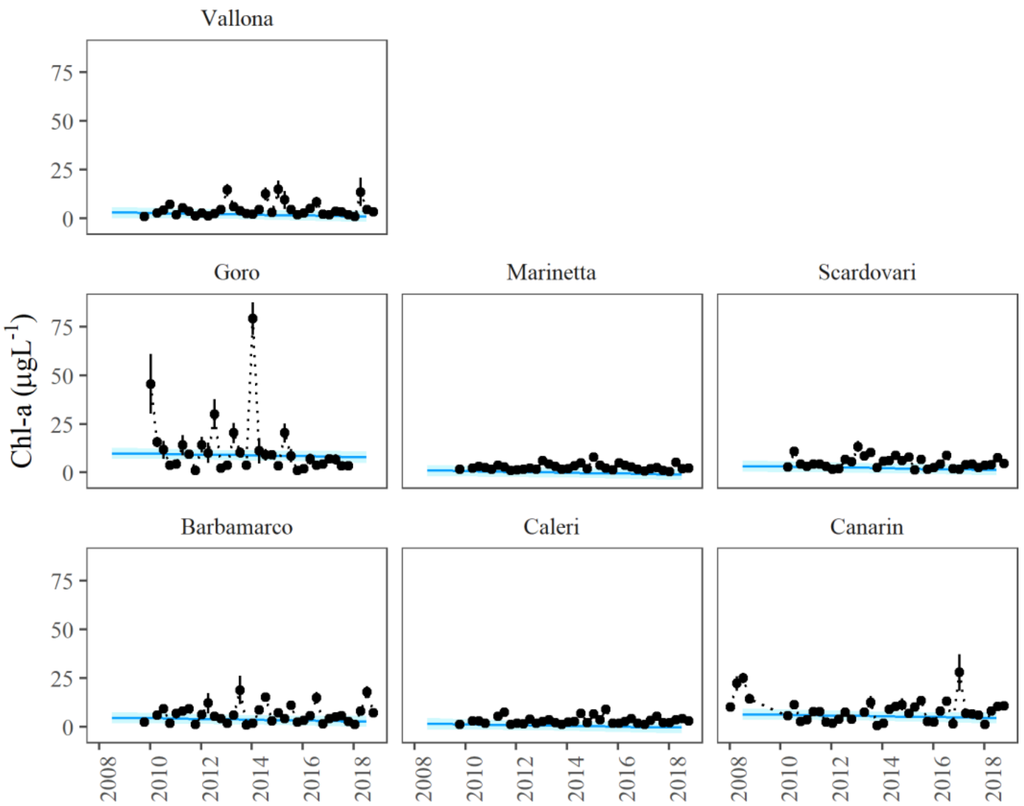


Figure 66. Chlorophyll *a* trends evaluated on quarterly averages (dots; sampling data); the blue lines represent the best fitted models (± 95% C.I.; in this case the fitted trend is lagoon specific).

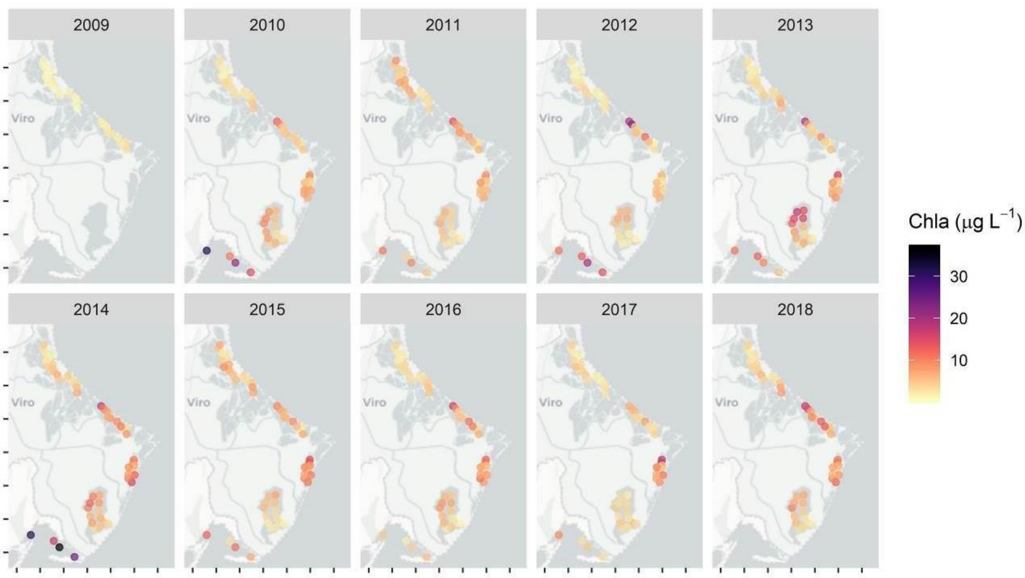


Figure 67. Yearly values (average) for sampled data of chlorophyll-*a* concentration for sampling stations within the Po Delta case in the period 2009-2017

MACROZOONBENTHOS ECOLOGICAL QUALITY INDEX: MAMBI

The ecological status of macrozoobenthic communities in the Po delta lagoon has been assessed using the MAMBI index (Multivariate-AZTI's Marine Biotic Index), which is a multimetric index for assessing the ecological quality status of marine and transitional waters adopted at national scale to assess the ecological quality status of benthic macroinvertebrate communities for transitional water, according to the European Water Framework. Regional data were collected and analyzed by the respective Regional Agencies of Veneto and Emilia Romagna Regions (ARPAV and ARPAE, respectively). For Goro lagoon data were available in 2010, 2013, 2015 and 2017 (four stations sampled each time) while for the Po delta lagoons belonging to Veneto region (Barbamarco, Caleri, Canarin, Marinetta, Scardovari, Vallona) available data include 2012 and 2014 (1 station sampled per lagoon). In consideration of such differences in the sampling year these two dataset are considered separately.

For the Goro lagoon, In 2010 MAMBI data indicated a “good” ecological status, with the exception of station 99100100 (“poor”). In the following years the decrease of MAMBI score was generally observed, with some fluctuations among stations and among years, indicating an overall “moderate” status which remained unchanged in 2014, 2015 and 2017. In the Po delta lagoons belonging to the Veneto Region differences over the two sampling years were detected, with some lagoons that increased their quality class (Barbamarco from “bad” to “good”, Canarin from “poor” to “moderate” and Scardovari from “bad” to “poor”), some others that decreased the quality class (Marinetta from “good” to “poor”, Vallona” from “moderate” to “poor”). No clear geographical trend is, however, observed. In any case the overall quality status of Po delta lagoons of Veneto region considered as a whole remained unchanged (moderate) among the two years. Results are reported in Figure 68.

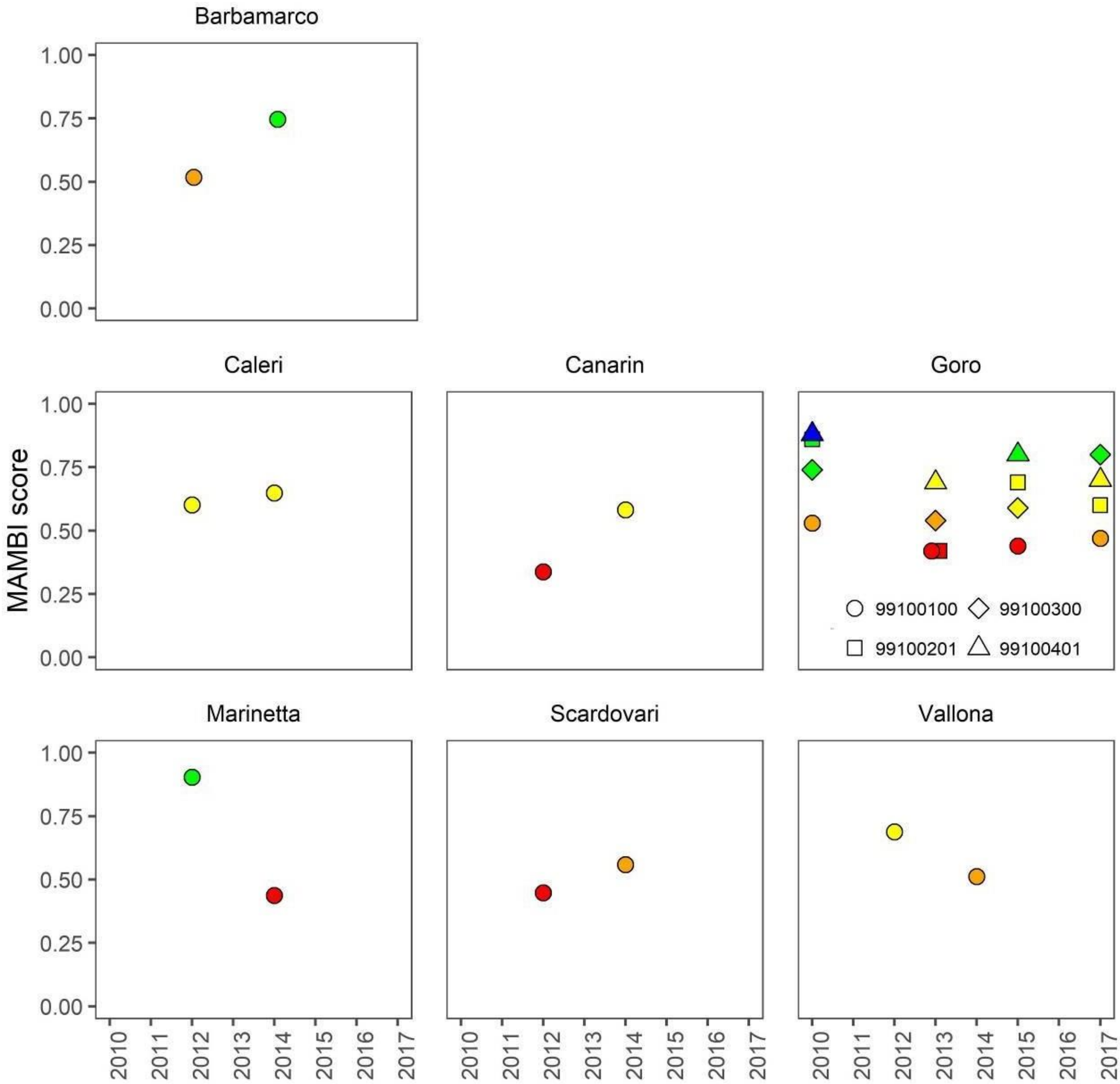


Figure 68. MAMBI values within the Po Delta case in the period 2010-2017. Colours indicate the ecological status according to the 2000/60/EC Directive: red= “bad”; orange= “poor”, yellow= “moderate”; green= “good”; blue= “high”

MACROPHYTES ECOLOGICAL QUALITY INDEX: MAQI (Figure 69)

The ecological status of macrophytic communities (macroalgae, aquatic angiosperms) in the Po delta lagoons has been assessed using the MaQI index (Macrophyte quality index) (MaQI) for macrophytic communities, which is adopted at national scale to assess the ecological quality status of macrophytes for transitional water, according to the European Water Framework. Regional data were collected and analyzed respectively by the Regional Agencies of Veneto (ARPAV) and Emilia Romagna Regions (ARPAE).

For Goro lagoon data were available in 2010, 2013, 2015 and 2017 (4 stations sampled each time) while for the Po delta lagoons belonging to Veneto region (Barbamarco, Caleri, Canarin, Marinetta, Scardovari, Vallona) data were available for 2010 and 2014 (17 stations covering 6 lagoons). In consideration of differences in the sampling year, these two dataset are considered separately.

For each sampling station in Goro Lagoon, data collected in different years indicated the same ecological class: “bad” for station 99100100 and “poor” for the rest of stations.

MAQI data collected in the Po Delta lagoons of Veneto in 2010 and 2014 indicated a generalized “poor”status except for the stations 433 (Canarin) and 413 (Marinetta) 4 sampled in 2010, whichindicated a “bad” quality status.

These MaQI values indicated a poor status of macrophytic communities in the whole Po delta area, with a very small presence of aquatic angiosperms, low macroalgal biodiversity and high occurrence of opportunistic macroalgal blooms (eg. *Ulva* sp.)

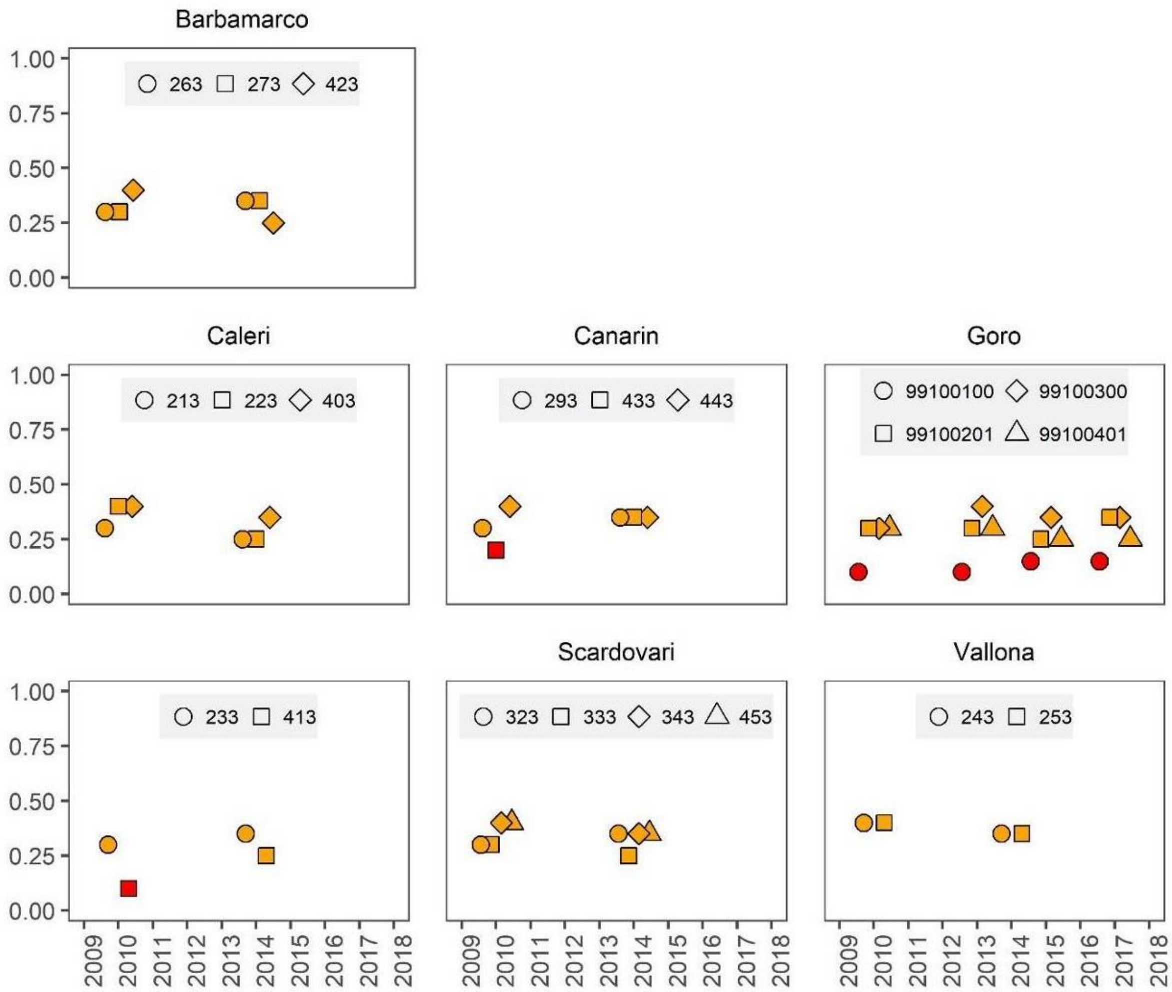


Figure 69. MAQI values within the Po Delta case in the period 2010-2017. Colours indicate the ecological status according to the 2000/60/EC Directive: red= "bad"; orange= "poor"

MANILA CLAMS

The Po delta represents an optimal environment for the farming of bivalves, due to the shallow waters, high freshwater inputs rich in nutrients and high natural productivity, mainly driven by phytoplankton. The main farmed species is Manila clam *(Ruditapes philippinarum),* an halloctonous species which was introduced in the area in the early eighties and that rapidly colonized the Po delta and Venice lagoons. The great suitability of these environments for Manila clam, both in terms of growth and natural reproduction, soon became evident, the species rapidly spread to all favorable sites, and Manila clam harvesting soon became the most economically important fishing activity. For the Po delta lagoons of Veneto Region, a study carried out on the period 1986-2008 (Mistri, 2009) shows that the production and harvest of *R. philippinarum* in this area underwent through various stages. In the first part of the period

(1986-1989) there was a rapid increase in the quantities, which was followed by a very strong increase in production (from 1800 tons in 1989 to 6100 in 1990). The production remained almost stable until 1997; after that phase a further subsequent increase (with a peak of 13600 tons in 1999) was observed, interrupted by a phase of production collapse in 2003 (4018 tons), then reabsorbed in the following years.

Successive studies carried out by the "Osservatorio Socio Economico della Pesca e dell'Acquacoltura" (OSEPA) of Veneto Region investigated the production of Manila clam in Po delta lagoons during the period 2008-2018 (OSEPA, 2019 a and b), as shown in Figure 70.

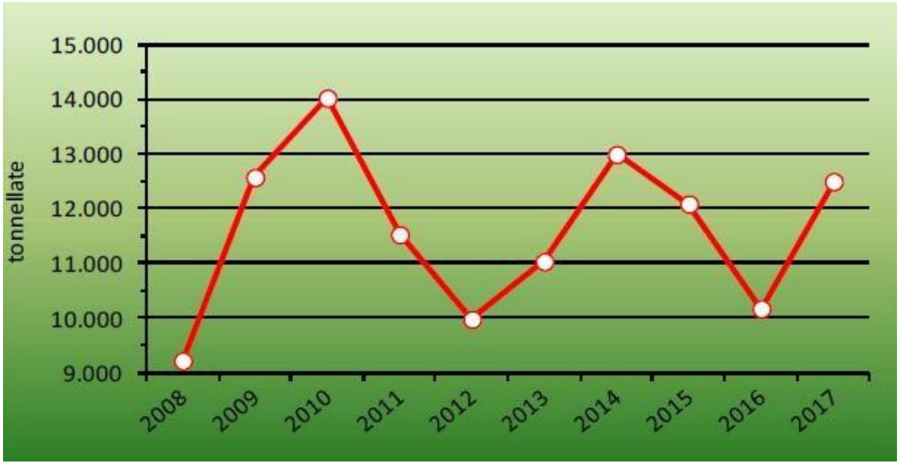


Figure 70. Production of Manila clam in the Po delta lagoons of the Veneto during the period 2008-2017. From Osservatorio Socio Economico della Pesca ed dell'Acquacoltura, 2019a.

During the ten-year comparison, a swinging production curve was observed, with maximum peaks of production observed in 2010 (approx. 14000 tons) and 2014 (approx 13000 tons) followed by decreases to values around 10000 tons in the years 2012 and 2016. The production of clams estimated in 2017 was about 12,498 tons, while for 2018 the production decreased at 8363 tons (data not shown in the graph).

The productive realities of the Po delta lagoons can be divided into two large areas: the northern lagoons of Caleri and Marinetta-Vallona, and the southern lagoons of Scardovari, Canarin, Basson and Barbamarco, between the Po di Maistra and the Po di Goro.

A study carried out in 2010 (AA.VV., 2013) estimated for the Po delta lagoons of Veneto Region an overall production area of 855 ha, mostly located in the lagoons of Caleri and Marinetta (44%) and Scardovari (34%) (Figure 71).

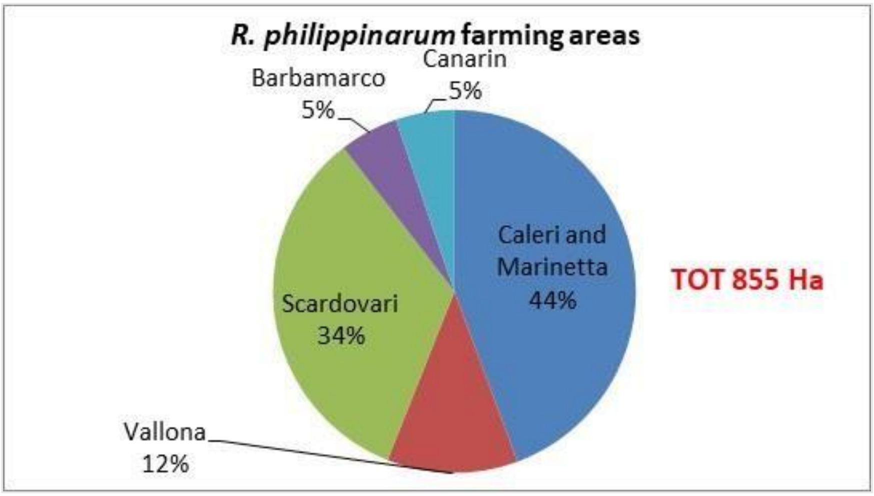


Figure 71. Farming areas for Manila clam production in 2010. Data expressed as percentage of the total extension. Elaboration from AA.VV, 2013

The same study indicates the clam production for each lagoon of the Po delta (Figure 72) and the harvest yield (Figure 73), estimated using data collected in the period 2006-2008.

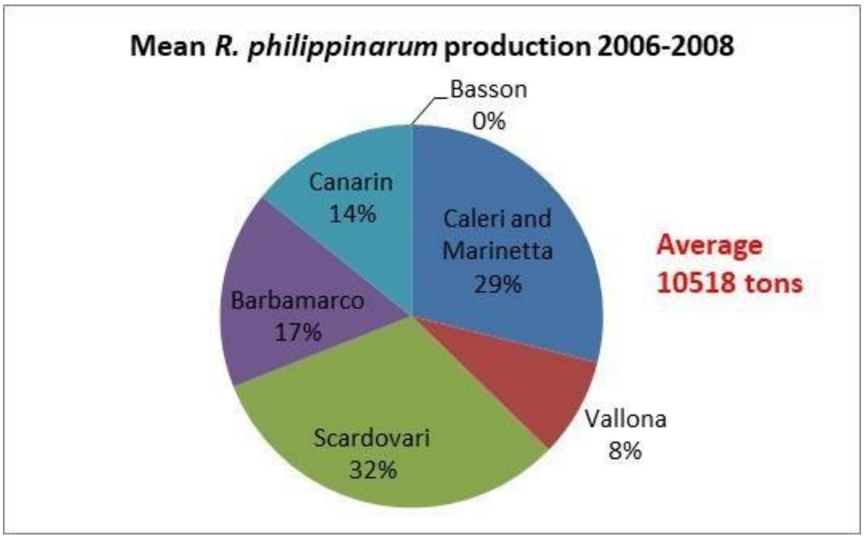


Figure 72. Mean Manila clam production in the period 2006-2008. Data expressed as percentage of the total production. Elaboration from AA.VV, 2013

The incidence of the production areas goes from zero in the Basson to a maximum of 32% in Scardovari and 29 % in northern areas (Caleri and Marinetta).

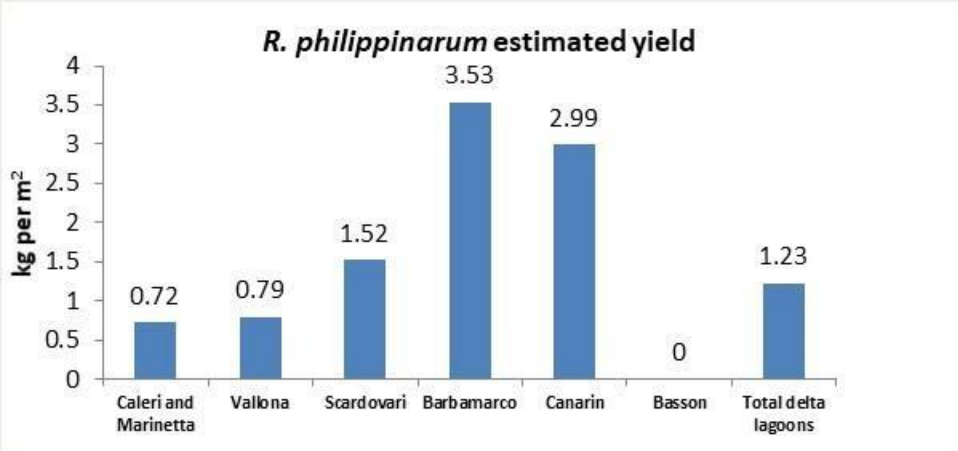


Figure 73. Mean Manila clam production in the period 2006-2008. Data expressed as percentage of the total production. Elaboration from AA.VV, 2013

The actual yield per square meter has a maximum value in the Laguna del Barbamarco (3.53 kg), followed by the Sacca del Canarin (2.99 kg), the Sacca degli Scardovari (1.52 kg); the Vallona (0.79 kg)and the Caleri and Marinetta 0.72 kg. In the Basson lagoon Ruditapes are fished only when there are no adequate operating conditions in the Canarin or Barbamarco.

The Clam Farming activity is sustained by Local Authorities for management purposes (Consorzio di Bonifica Delta del Po, Genio Civile), through systematic lagoon vivification interventions.

A map of the licenced areas in the Po delta lagoons of Regione Veneto is shown in Figure 74.

Looking at the Emilia Romagna side of The Po Delta, at present, the Sacca di Goro is one of the top European sites for clam rearing and the most productive lagoon in Italy. In the 2017 the production of the Sacca was estimated to be the 42% of the whole national production (approx.. 30000 tons) (Turolla, 2018).

Manila clam was introduced in the Sacca di Goro in 1986 and it rapidly colonizes wide areas of the Sacca. A study carried out on the period 1987-2008 (Zentilin et al., 2008) shows that the production and harvest of *R. philippinarum* in this area underwent through various stages. At the beginning production increased significantly, passing from 35 tons in 1987 to over 9000 in 1990. Except for decrease in 1993 and 1994, due to mass mortalities, the production then stabilized around these values until 2003. Subsequently, a new production increase was recorded up to the maximum value of around 18000 t in 2006 (Figure 75). Most recently the production slightly decreased and in 2017 a clam production for this lagoon was estimated to be of 12700 tons (Turolla, 2018).

Figure 74. Licenced areas for clam farming in the Po delta of the Veneto Region (Caleri, Marinetta, Barbamarco, Scardovari). Data (2019) from Regione Veneto do not include the whole areas managed by fishing cooperatives and by individuals.

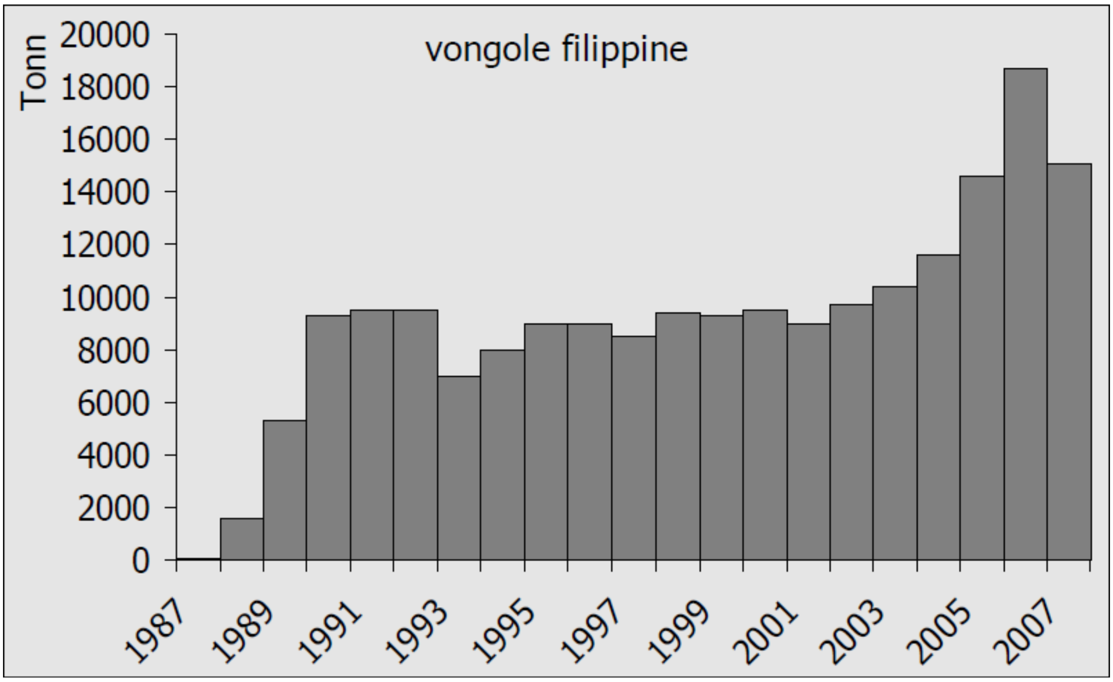


Figure 75. Production of *R. philippinarum* in Sacca di Goro in the period 1987-2008 (Zentilin et al., 2008).

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The farming area in Goro (1300 ha) covers almost half of the total surface and other 800 ha of surface, inside and outside of the Sacca, are used and collectively managed as nursery area to collect the wild spats necessary for the farming activity.

Clam farming is managed by cooperatives of fishermen that exploit licensed areas, under the control of regional and local authorities. Up to 1500 fishermen are associated in numerous cooperatives (43 in 2018,) and are primarily employed in clam farming in the Sacca di Goro and in mussel farming in the adjacent sea. Fishermen are also directly involved activities aimed at increasing the sustainability of the activities, such as the management of the nursery areas and the hydro-morphologic works, aimed at the vivification of the farming areas and at increasing the environmental quality of the lagoon (Turolla, 2018).

The Clam Farming activity is sustained by Local Authorities for management purposes, through systematic lagoon vivification interventions, contributed in improving the situation and ensuring adequate clam yields.

A map of the licenced areas in the Po delta lagoons of Emilia Romagna Region is shown in Figure 76.

Figure 76. Licenced areas for clam farming in the Sacca di Goro. Map (2012) from Local Health Authority of Ferrara.

Natura 2000 Habitats.

Delta Po area includes different Natura 2000: the Veneto Po delta region is covered by the SCI IT3270017 and by the SPA IT3270023 (Delta del Po Veneto); the Sacca di Goro is covered by SCI/SPA IT4060005 (Sacca di Goro. Po di Goro, Valle Dindona. Foce del Po di Volano).

The SCI IT3270017 covers an area of 25362 ha. The data form (compiled in 1996 and updated in 2017) indicates the presence of 20 Natura 2000 habitats, 5 of which of priority type (Coastal lagoons 1150*, Fixed coastal dunes with herbaceous vegetation 2130*, Coastal dunes with *Juniperus spp*. 2250*, Wooded dunes with *Pinus pinea* and/or *Pinus pinaster* 2270*, Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* 7210*, Alluvial forests with *Alnus glutinosa and Fraxinus excelsior* 91E0*). The global status of the habitat ranging from B (good) to C (average or bad). Thefloristic and faunal lists include 105 species of communitarian interest (4 of priority type).

The SCI IT4060005 covers an area of 4872 h. There are data by the Po Delta Park and covering not only the Sacca di Goro but the whole Park territory for the years 2007, 2010, 2014 and 2020 (to be completed). The data form (compiled in 1999 , last update in 2017) indicates the presence of 20 Natura 2000 habitats, 3 of which of priority type (Coastal lagoons 1150*, Fixed coastal dunes with herbaceous vegetation 2130*, Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*2270*). These latter cover approx 78% of the whole area. The global status of the habitat ranging from A (excellent) to B (good), with the exception of habitat 1310 (Salicornia and other annuals colonizing mud and sand) which was evaluated as C (average or bad). The floristic and faunal lists include 102 species of communitarian interest.

Reedbeds

The common reed (*Phragmites australis* (Cav.) Trin. Ex Steud.) is a cosmopolitan perennial halophyte that forms wide meadows in wetland environments. In transitional water ecosystems this plant plays a key role by supplying different ecosystem services (e.g. oxygenation of soils, erosion control, nutrients and chemicals removal from water and soils, ecosystem engineer and habitat for birds and fish of commercial and conservation interest). This species is well-adapted to a wide range of environmental conditions, it can be found also in areas were water surfaces are limited, but it tolerates only moderate salinity. In the Po delta area the *P. australis* forms different kinds of meadows (reedbeds):

- Valley reedbed. In some fishing valley characterized by low salinity there are wide reedbed meadows that are managed by the owner of the valleys to host and protect bird fauna target for hunting activities. Riverine reedbed: mainly found both in the riverbanks and in the slinky canals present in flood plain areas, where the flows is moderate. This kind of reedbed is mostly present in the Po di Maistra branch and in some sector of the Po di Tolle branch

- Reedbed of minor wetlands: it is located close to pond and ex mine areas or drainage canals. These reedbeds are generally of small dimensions but their role as nesting and foraging areas for bird fauna is relevant.

- Lagoon or estuarine reedbed: represents the main reedbed surface area in the Po delta, with a presence of *P. australis* almost monospecific. This kind of reedbed grows in intertidal area subjected to tidal cycle and, accordingly, it's growth is limited to the areas less affected by marine salinity. The presence of reedbed in the Po Delta lagoon is generally limited to the areas protected by marine influence by sandbank.

Historically, the reedbed habitat covered larger surfaces in the Po delta area but its presence has been greatly reduced by historic human interventions.

The reedbed meadows are mostly found in the sheltered areas of the lagoons located in proximity of the main Po branches (Barbamarco, Basson, Burcio and Canarin), along the riverbanks and in the wetlands more influenced by freshwater (Allagamento Bonelli, Bacucco).

The document "Atlante lagunare costiero del Delta del Po" (AA.VV., 2015) includes a multiannual study (1977-2011) on the extension of reedbeds in one of the most representative area of the Po delta (Bacucco) which is a wetland area included between the Po branches of Gnocca and Goro historically dominated by *P. australis* meadows.

In the period 1997-1999 the meadows extension in Bacucco remained almost unchanged, while during the 90's a reduction of approx 30% of the surface was observed; such reduction increased further in the next years. The meadow surface observed in 2011 was reduced by 48% with respect to the values found in 1997. The authors identify different causal factors which may have act separately or in a synergic mode leading to such drastic decrease

- the saline ingression could be one of the major causes of disintegration of the reed formations; this could be the consequence of subsidence and erosion of the benches, and for anthropogenic hydraulic interventions that aim to forcefully increase the salt rate for production reasons, or to speed up the outflow of river waters into the sea for reasons of hydraulic safety.
- water pollution: reedbeds, like many other plant formations, might suffering from changes in the quality of the water, especially river water; an important role could be played by theincrease in dissolved phosphorus and nitrogen contents.
- Moreover, this reduction could be related to the "reed decline" or "reed die-back" (Van der Putten,1997), an anomalous, mostly unknown, spontaneous and irreversible phenomenon of destruction or disappearance of a reed mature surfaces that has been observed in centralEurope and recently also in Italy.
- Well developed reed bed, dominated by *P. australis* and with a limited presence of halophytes are mostly present in the inner areas sheltered by the main sandbanks and most influenced by freshwater inputs. Other meadows containing *P. australis* in association with a moisaic of *Typha* sp. and *Claudium* sp. are found in the channels surrounding the Sacca and in the terminal tract of the Po di Goro branch.

The distribution of reedbeds in Sacca di Goro was evaluated considering a map of the emerging herbaceous vegetation owned by POPARK and dated fom 1996. Well developed reed bed, dominated by *P. australis* and with a limited presence of halophytes are mostly present in the inner areas sheltered by the main sandbanks and most influenced by freshwater inputs. Other meadows containing *P.australis* in association with a moisaic of *Typha* sp. and *Claudium* sp. are found in the channels surrounding the

Sacca and in the terminal tract of the Po di Goro branch.

6.4.3. *Maps of habitats trend*

Habitat Natura 2000

The most recent available GIS map of the SCI in the Po delta lagoons of the Regione Veneto are reported in Figure 77.

For the Emilia Romagna Region, there are GIS maps owned by the Po Delta Park covering not only the Sacca di Goro but the whole Park territory for the years 2007, 2010, 2014 and 2020 (to be completed). The most recent (2014) available habitat map for Sacca di Goro is shown in in Figure 78.

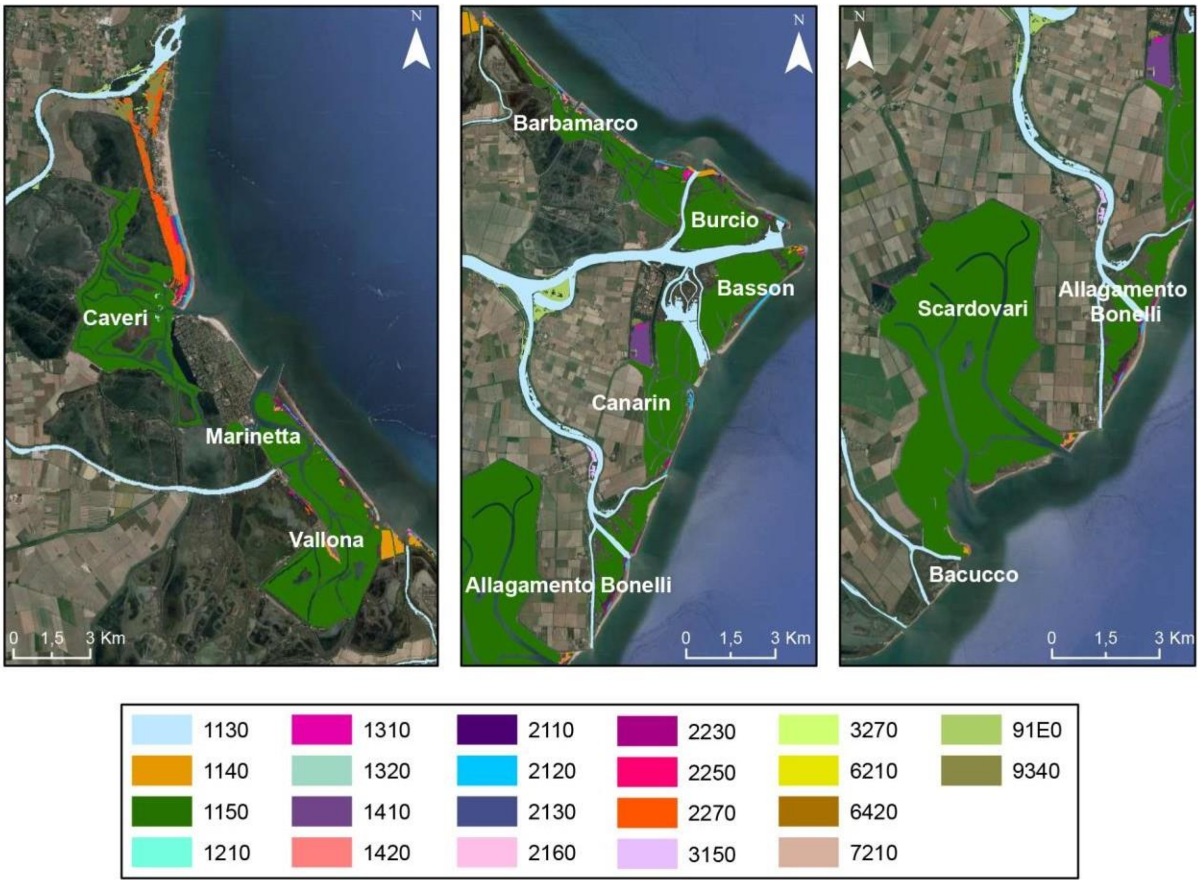

Figure 77 Maps of the Natura 2000 Habitats in the Po delta lagoons of the Regione Veneto. Data for 2006.

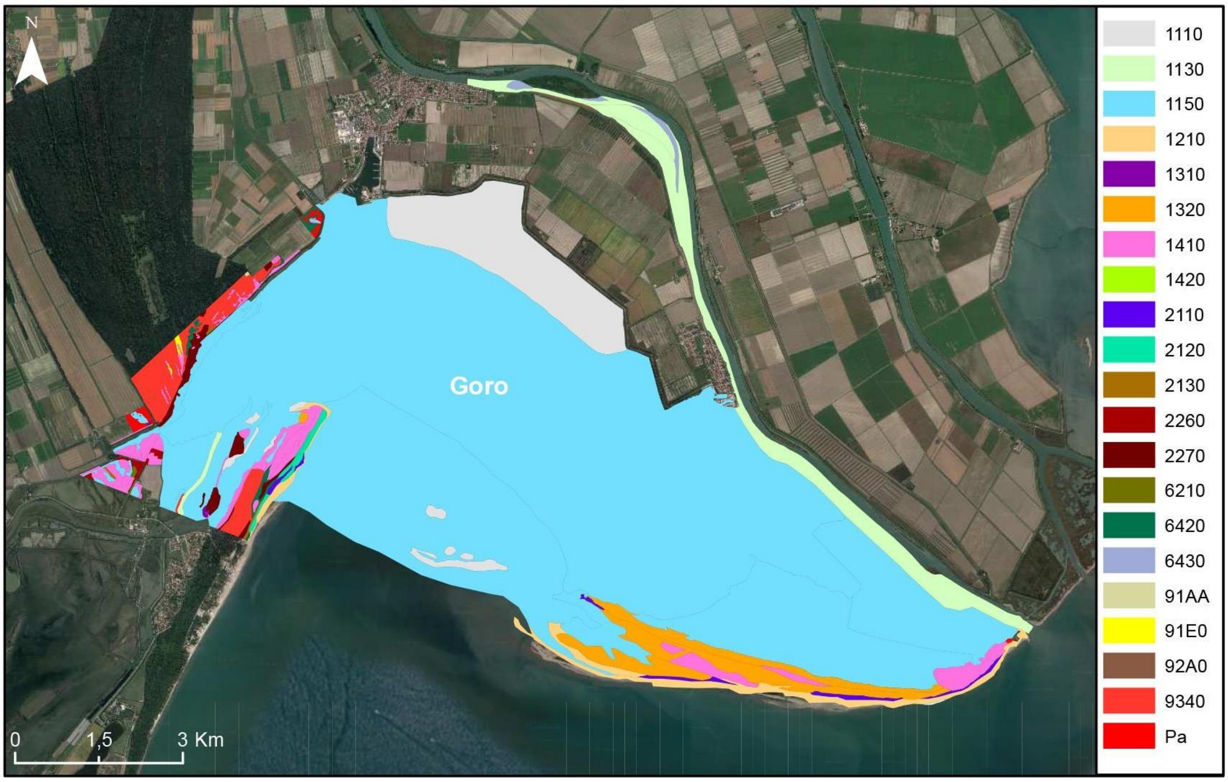

Figure 78 Maps of the Natura 2000 Habitats in Sacca di Goro. Data from 2014 (Habitat)

<u>Reedbeds</u>

The distribution of reedbeds in the Po delta area of Veneto Region is shown in Figure 79. This map considers data collected by Regione Veneto in 2006.

The distribution of reedbeds in Sacca di Goro is shown in figure Figure 80. This map considers data collected by POPARK in 1996.

Figure 79 Maps of the reedbeds in the Po delta lagoons of the Regione Veneto. Data from 2006 (Parco Regionale Veneto del Delta del Po, 2015).

Figure 80. Maps of reedbeds (in green) in Sacca di Goro. Data extracted by a map of emerging herbaceous

vegetational of 1996 (owned by POPARK)

6.5. Operational Plan of acquisition data in situ to complete the main uncertainties and knowledge gaps.

For the Sacca di Goro, to make comparisons between the already available maps and the present situation, the Park had taken the commitment of producing, ex novo, one GIS map for vegetation and one for nesting birds, updated to the present. Monitoring campaigns were planned to be performed in Spring 2020, and maps to be available for the project within the year.

However, this activity has not yet started due to the COVID-19 pandemic. At present, in Italy, there is a ban on circulation, in addition on access to the structures of the University of Ferrara, where the field gear is located. Therefore, as it is still not possible to foresee sampling success, the Park has started to manage to purchase data, already collected from third parties, on vegetation and birds, in order to be able to have a picture, as updated as possible to recent years.

For the whole delta area a remote sening-based approach will be adopted to explore the feasibility of updating the reedbeds maps, given the availability of suitable satellite products. In particular moderate resolution imagery (10-30 m pixel size) from different platforms will be considered.

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8. Annexes

Annex 1. Database of Pilot Site 1 Neretva River Delta

CATEGORY	TYPOLOGY	DESCRIPTION	2011	2012	2013	2014	2015	2016	2017	YEARS / REFERENCE PERIOD	AVAILABILITY of the data by institution (contact person, e-mail)	AVAILABILITY ON-LINE	note
			acquisition frequency										
PHYSICAL-CHEMICAL PARAMETERS													
Water temperature	.xls	Data on four stations in Neretva River Delta (40159, 40155, 40161, 40160)					4	4	4	2015-2017 Quaterly	Hrvattske vode, Katarina.Glavas-Ljubimir@voda.hr, +385 21 309 480		
oxygen saturation (%), inorganic nitogen (μmol/dm³), orthophosphates (μmol/dm³), total phosphorus (μmol/dm³), supporting physicochemical quality elements (status), coper (μg/L), zink (μg/L), specific pollutants (status), Ecological status	.xls	Data on three stations in Neretva River Delta (40159, 40160, 40161)			1	3	3			2013-2015	Hrvatske vode, Katarina.Glavas-Ljubimir@voda.hr, +385 21 309 480		
pH value, Electrical conductivity (μS/cm), Total suspended solids (mg/l), Total residual chlorine ($mgCl_2/l$), Alkalinity m-value ($mgCaCO_3/l$), Alkalinity p-value ($mgCaCO_3/l$), Total hardness ($mgCaCO_3/l$), Ca hardness ($mgCaCO_3/l$)	.xls	Data on four stations in Neretva River Delta (40159, 40155, 40161, 40160)					4	4	4	2015-2017 Quaterly	Hrvatske vode, Katarina.Glavas-Ljubimir@voda.hr, +385 21 309 481		
BPK5 (mgO2/L), KPK-Mn (mgO2/L), ammonia (mgN/L), nitrates (mgN/L), total nitrogen (mgN/L), orthophosphates (mgP/L), total phosphorus (mgP/L), supporting physical-chemical quality elements (status), arsenic (μg/L), copper (μg/L), zink (μg/L), chromium (μg/L), fluroides (PGKμg/L), fluorides MGK (μg/L), AOX (μg/L), specific pollutants (status), Ecological status	.xls	Data on one station in Neretva River Delta (40155)	1	1	1	1	1			2011-2015	Hrvatske vode, Katarina.Glavas-Ljubimir@voda.hr, +385 21 309 482		
BIOLOGICAL PARAMETERS													
Phytoplankton													
Macrozoobenthos													
Habitat	web portal	Bioportal is a web portal of Nature protection information system of Croatia								2019	Ministry of Environment and Energy, info@haop.hr, +385 (0)1 5502 900	http://www.bioportal.hr/gis/?lang=en&theme=neptune	Partially transleted in english

Annex 2. Database of Pilot Site 3 Vransko Lake

CATEGORY	TYPOLOGY	DESCRIPTION	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019r	YEARS / REFERENCE PERIOD	AVAILABILITY of the data by institution	AVAILABILITY ON-LINE
			acquisition frequency												
PHYSICAL-CHEMICAL PARAMETERS															
Water temperature	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
pH	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
Water salinity	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
Chlorides	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
Electrical conductivity	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9		12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
nitrogen compounds	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
Phosphorus compounds	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9		12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
organic carbon	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
Chlorofill a	.xls	measuring point Prosika, Crkvine, and mouth of the								6	6	12			

		Kotarka chanell													
Dissolved oxygen	.xls	measuring point Prosika, Crkvine, and mouth of the Kotarka chanell	12	7	6	6	8	12	11	9	6	12	2010-2019, irregurality in data aquisition and measuring points depending on the year	Croatian Waters (Hrvatske vode, Danko Biondic, danko.biondic@voda.hr	no
BIOLOGICAL PARAMETERS															
Macrophytes	.shp	Characeae. 41 sampling stations, distributed throughout the lake	1	1	1	1	1				1	1	2010-2019, gaps in certain years	Vransko lake Nature Park	no
Habitat															
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	shp.	Establishment of monitoring of occasional Mediterranean puddles and grassland habitats (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 2017. Natura 2000 habitats.								1			2017	Vransko lake Nature Park	no

Annex 3. Database of Pilot Site 4 Banco della Mula di Muggia

CATEGORY	TYPOLOGY	DESCRIPTION	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	YEARS / REFERENCE PERIOD	AVAILABILITY of the data	NOTES
PHYSICAL-CHEMICAL PARAMETERS																
Water temperature (°C)	.xls	CTD probe	12	12	12	12	12	12	12	11	12	6	3		ARPA FVG	
Water salinity (Cond mS/cm)	.xls	CTD probe	12	12	12	12	0	12	12	11	12	6	3		ARPA FVG	
salinity	.xls	CTD probe	12	12	12	12	12	12	12	11	12	6	3		ARPA FVG	
pressure (DBAR)	.xls	CTD probe	12	12	12	12	12	12	12	11	12	6	3		ARPA FVG	
pH	.xls	CTD probe	12	7	12	12	12	12	12	11	12	6	3		ARPA FVG	
PAR (μmoli/m²/s)	.xls	CTD probe	12	12	12	12	12	12	12	11	12	6	3		ARPA FVG	
clorofilla	.xls	CTD probe	12	12	12	12	12	12	12	11	12	6	3		ARPA FVG	
KPAR (1/m)	.xls	CTD probe						12	12	11	12	6	3		ARPA FVG	
REFPAR (μmoli/m2/s)	.xls	CTD probe						12	12	11	12	6	3		ARPA FVG	
PAR (%)	.xls	CTD probe						12	12	11	12	6	3		ARPA FVG	
torbidità (NTU)	.xls	CTD probe						12	12	11	12	6	3		ARPA FVG	
Chl a (μg/l)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
O_2 (%)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
N-NO_2 (μg/l)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
N-NH_4 (μg/l)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
N-NO_3 (μg/l)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
DIN	.xls	water samples				12	12	12							ARPA FVG	
P-PO_4 (μg/l)	.xls	water samples		12	12	12	12	12	11	6	6	6			ARPA FVG	
SiO_2 (μg/l)	.xls	water samples			11	9	10	12	12	6	6	6			ARPA FVG	
TN (μg/l)	.xls	water samples		12	12	12	12	12	12	6	6	6			ARPA FVG	
TP (μg/l)	.xls	water samples		12	11	12	12	12	12	6	6	6			ARPA FVG	
Oxygenation (ml/l)	.xls	Dissolved Oxygen in column water using CTD probe	12	12	12	12	12	12	12	11	12	6			ARPA FVG	

CATEGORY	TYPOLOGY	DESCRIPTION	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	YEARS / REFERENCE PERIOD	AVAILABILITY of the data	NOTES
BIOLOGICAL PARAMETERS																
Phytoplankton	.xls	phytoplankton quali-quantitative analysis	2	4	5	6	6	4	6						ARPA FVG	only CE131 sampling station
Benthos (MIB tot e per bennata)	.xls	macrobenthos quali-quantitative analysis	1	2			2			2					ARPA FVG	only CE132 samling station
Phanerogamae	.shp	Digitalization from: 1978 aerial photos CGR; 2006, 2014 and 2018 aerial photos AgEA.												1978, 2006, 2014, 2018	Change we care	Orthophotos analysis
Habitat	.shp .pdf	Delimitation of Natura 2000 site SCI/SPA IT3330006													https://www.minambiente.it/pagina/sic-zsc-e-zps-italia https://www.minambiente.it/pagina/schede-e-cartografie	
Habitat	.shp .pdf	Natura 2000 map												2011	FVG Region	
Habitat	.shp .pdf	Habitats map according to the Regional classification system												2008	FVG Region	
Habitat	.shp	Biocoenosis distribution map												2005	Cartografia delle principali biocenosi marine costiere, dei sedimenti, dello stato delle conoscenze e della naturalità - Habitat 2000 CDMinistero dell'Ambiente e della Tutela del Territorio – Direzione Protezione della Natura	

Annex 4. Database of Pilot Site 5 Po River Delta

CATEGORY	TYPOLOGY	DESCRIPTION	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	YEARS / REFERENCE PERIOD	AVAILABILITY of the data by institution	AVAILABILITY ON-LINE	note
PILOT SITE - PO DELTA - RV																	
PHYSICAL-CHEMICAL PARAMETERS																	
Water temperature	ODF	Continuous acquisiton data on 6 delta Po lagoons (7 buoys)			X	X	X	X	X	X	X	X	X	data 2010-2018 aquisition rate: 30'	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/acque-di-transizione-boe-delta-del-po	on line available only data 2016-2018
Water temperature	csv	CTD data on 9 lagoons (6 Po Delta) collected monthly. Multiple stations for each lagoon. Data also for 5 Po estuarine sampling stations	12	12	12	12	12	12	12	12	12	12	12	data 2008-2018	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-marino-costiere-e-acque-di-transizione/acque-marino-costiere-e-transizione-profili-sonda	CTD, includes depth
Water temperature	pdf	Annual report with resumed data and some elaboration.		X	X	X	X	X	X	X	X	X	X	data 2008-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	Public report
pH	ODF	Continuous acquisiton data on 6 delta Po lagoons (7 buoys)			X	X	X	X	X	X	X	X	X	data 2010-2018 aquisition rate: 30'	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/acque-di-transizione-boe-delta-del-po	on line available only data 2018-2018
pH	csv	CTD data on 9 lagoons (6 Po Delta) collected monthly. Multiple stations for each lagoon. Data also for 5 Po estuarine sampling stations	12	12	12	12	12	12	12	12	12	12	12	data 2008-2018	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-marino-costiere-e-acque-di-transizione/acque-marino-costiere-e-transizione-profili-sonda	CTD, includes depth
pH	pdf	Annual report with resumed data and some elaboration		X	X	X	X	X	X	X	X	X		data 2008-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	Public report
Water salinity	ODF	Continuous acquisiton data on 6 delta Po lagoons (7 buoys)			X	X	X	X	X	X	X	X	X	data 2010-2018 aquisition rate: 30'	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/acque-di-transizione-boe-delta-del-po	on line available only data 2016-2018
Water salinity	csv	CTD data on 9 lagoons (6 Po Delta) collected monthly. Multiple stations for each lagoon. Data also for 5 Po estuarine sampling stations	12	12	12	12	12	12	12	12	12	12	12	data 2008-2018	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-marino-costiere-e-acque-di-transizione/acque-marino-costiere-e-transizione-profili-sonda	CTD, includes depth

Water salinity	pdf	Annual report with resumed data and some elaboration		X	X	X	X	X	X	X	X	X	X	data 2008-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	Public report
Oxygen	ODF	Continuos aquisiton data on 6 delta Po lagoons (7 buoys)			X	X	X	X	X	X	X	X	X	data 2010-2018 aquisition rate: 30'	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/acque-di-transizione-boe-delta-del-po	(mg/L and %) on line available only data 2016-2018
Oxygen	csv	CTD data on 9 lagoons (6 Po Delta) collected monthly. Multiple stations for each lagoon. Data also for 5 Po estuarine sampling stations	12	12	12	12	12	12	12	12	12	12	12	data 2008-2018	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-marino-costiere-e-acque-di-transizione/acque-marino-costiere-e-transizione-profili-sonda	(mg/L and %) CTD, includes depth
Oxygen	pdf	Annual report with resumed data and some elaboration		X	X	X	X	X	X	X	X	X		data 2008-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	Public report
TSS	csv	Quarterly data on 6 Po Delta lagoons (22 stat.) Includes data also for 5 Po estuarine sampling stations.		4	4	4	4	4	4	4	4	4		data 2009-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/nutrienti-e-solidi-sospesi/transizione	data of 2009 only avaiable in 2 stations, 99100100 and 99100300
Concentration N, P, C: water	csv	Quarterly data on 6 Po Delta lagoons (22 stat.) Includes data also for 5 Po estuarine sampling stations		4	4	4	4	4	4	4	4	4		data 2009-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/nutrienti-e-solidi-sospesi/transizione	variable and extended list of analytes
Concentration N, P, C: water	pdf	Annual report with resumed data and some elaboration		X	X	X	X	X	X	X	X	X		data 2009-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	also chemical data available
Concentration N, P, C sediment: shallow waters and channels	csv	Annual data on a variable number of Delta Po stations (12, in general) covering 6 delta Po lagoons. Data also for 5 Po estuarine sampling stations		1	1	1	1	1	1	1	1	1		data 2009-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/dati-condizioni-morfologiche/transizione	granulometry and, since 2013, C and N
Concentration N, P, C sediment: shallow waters and channels	pdf	Annual report with resumed data and some elaboration		X	X	X	X	X	X	X	X	X		data 2009-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	only chemical data available
Water Physical-Chemical parameters	online interactive map	maps of PC quality (sensu WFD) at lagoon scale							X	X	X			2014-2016	Portale geografico dell'Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto	http://geomap.arpa.veneto.it/maps/313/view	

Oxygenation	csv	Data for 6 lagoons . AVS_Fe							2	3	3	3		data 2014-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione	

Oxygenation	pdf	Annual report with resumed data and some elaboration							X	X	X	X		data 2014-2017	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	
Granulometry	csv	Annual data on a variable number of Delta Po stations (12, in general) covering 6 delta Po lagoons. Data also for 5 Po estuarine		1	1	1	1	1	1	1	1	1	1	data 2008-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/dati-condizioni-morfologiche/transizione	granulometry and, since 2013, C and N
BIOLOGICAL PARAMETERS																	
Phytoplankton	csv	CTD data on 6 Po Delta lagoons collected monthly. Multiple stations for each lagoon. Data also for 5 Po estuarine	12	12	12	12	12	12	12	12	12	12	12	data 2008-2018	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-marino-costiere-e-acque-di-transizione/acque-marino-costiere-e-transizione-profili-sonda	Instrumental Chla, CTD includes depth
Phytoplankton	pdf	Annual report with resumed data and some elaboration			X	X	X	X	X	X	X	X	X	data 2010-2018	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	abundances, Analytic Chla, EQR since 2017
Phytoplankton	csv	Quarterly data on 6 Po Delta lagoons (17 st.). Data also for 5 Po estuarine		4	4	4	4	4	4	4	4	4		data 2008-2017	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/dati-fitoplancton-e-clorofilla-a/transizione	checklist, abundances, Analytic Chla
Macrozoobenthos	csv	Single data (3 replicates) on 6 Po Delta lagoons (12 stations) Data also for5 Po estuarines.		1			1		1					data 2008, 2009, 2012, 2014	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/file-e-allegati/soaml/dati-macrozoobenthos/transizione	checklist, abundances, indexes, no MAMBI no BITS
Macrozoobenthos	csv	Single data of Venice and delta Po lagoons			x	x	x		x	x	x			2010-2012, 2014-2016	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/eqb-elementi-di-qualita-biologica-delle-acque-di-transizione	EQB class (no score)
Macrozoobenthos	csv	Single data of delta Po lagoons					1		1					2012 and 2014	EIONET	files "BiologyTCwater" on EIONET	EQB score
Macrozoobenthos	pdf	Single data on 6 Po Delta lagoons					1		1					2012 and 2014	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	Statistics, ecological indexes, EQR for 2014
Macrophytes	csv	half-yearly data on 17 stations of Delta Po (6 lagoons)		2	2				2					2008, 2009, 2010, 2014	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/acque-di-transizione-macrofite	cheklist, coverage ONLY MACROALGAE except 2014
Macrophytes	csv	Single data of Venice and delta Po lagoons			x	x	x		x	x	x			2010-2012, 2014-2016	ARPAV	http://www.arpa.veneto.it/dati-ambientali/open-data/idrosfera/acque-di-transizione/eqb-elementi-di-qualita-biologica-delle-acque-di-transizione	EQB class (no score)

Macrophytes	pdf	Annual report with resumed EQR score and coverage			1				1					2010, 2014	ARPAV	http://www.arpa.veneto.it/temi-ambientali/acqua/file-e-allegati/documenti/acque-di-transizione/rapporti-finali-e-documenti-di-classificazione-altre-lagune	abundances, EQR Coverages fpr 2014
ECOLOGICAL STATUS (sensu WFD)	online interactive map	Maps of MAMBI and MaQI at lagoon scale							X	X	X			2014-2016	Portale geografico dell'Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto	http://geomap.arpa.veneto.it/maps/313/view	
Manila clam	shp	Maps of licenced mulluc farming areas												updated at September 2019 for Marinetta, Caleri, Barbamarco and Scardovari (data for Scardovari are not completed)	Regione Veneto		
Manila clam	pdf	Articles, reports and technical documents on clam production													see the following references cited in references section AA.VV., 2015; AA.VV, 2013; AA.VV., 2003; Barbieri, 2019;;OSEPA, 2019ab;		Focus of the clam production in the area (distribution, production, techinques)
Habitat	pdf; shp	Natura 2000 form with map layers SIC IT3270017	X									X	X	Maps available for 2008. Last available revisions in 2018. Natura 2000 form upgraded in 2017	Regione Veneto	https://www.regione.veneto.it/web/agricoltura-e-foreste/download#IT3270017 http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT3270017	
Habitat	shp	Natura 2000 sites in Delta Po of RV													Portale geografico dell'Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto	http://geomap.arpa.veneto.it/maps/313/view	
Naturalistic areas and Reserves	shp	Protected sites in Delta Po of RV													Portale geografico dell'Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto	http://geomap.arpa.veneto.it/maps/313/view	

Reedbeds	**shp**	**Map of reedbeds (according to the Corine Land Cover Typology 4.1.1.1) in the SIC IT3270017**												**Maps available for 2008. Last available revisions in 2018**	**Regione Veneto**	**https://www.regione.veneto.it/web/agricoltura-e-foreste/download#IT3270017**	

Reedbeds	pdf	Articles, reports and technical documents on clam production													see the following references cited in references section AA.VV, 2013; AA.VV., 2003;		Master Plan project. Includes reedbed distibution
PILOT SITE - PO DELTA - RER																	
PHYSICAL-CHEMICAL PARAMETERS																	
Water temperature	online, xls	Continuous acquisiton data on 4 buoys of Goro lagoon (3 available)	X	X	X	X	X	X	X	X	X	X	X	2008-2018 aquisition rate: 1 h	ARPAE -RER- Servizio Meteo e Clima	https://www.arpae.it/dettaglio_generale.asp?id=3981&idlivello=1625#	on line available data only for the last month.
Water temperature	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)		16	4	4	4	4	4	4	4	4		2009-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300
Water temperature	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Ex ante monitoring
pH	online, xls	Continuous acquisiton data on 4 buoys of Goro lagoon (3 available)	X	X	X	X	X	X	X	X	X	X	X	2008-2018 aquisition rate: 1 h	ARPAE -RER- Servizio Meteo e Clima	https://www.arpae.it/dettaglio_generale.asp?id=3981&idlivello=1625#	on line available data only for the last month
pH	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)		16	4	4	4	4	4	4	4	4		2009-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300
pH	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Ex ante monitoring
Water salinity	online, xls	Continuous acquisiton data on 4 buoys of Goro lagoon (3 available)	X	X	X	X	X	X	X	X	X	X	X	2008-2018 aquisition rate: 1 h	ARPAE -RER- Servizio Meteo e Clima	https://www.arpae.it/dettaglio_generale.asp?id=3981&idlivello=1625#	on line available data only for the last month
Water salinity	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)		16	4	4	4	4	4	4	4	4		2009-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300

Water salinity	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Ex ante monitoring

Oxygen	online, xls	Continuous acquisiton data on 4 buoys of Goro lagoon (3 available)	X	X	X	X	X	X	X	X	X	X	X	2008-2018 aquisition rate: 1 h	ARPAE -RER- Servizio Meteo e Clima	https://www.arpae.it/dettaglio_generale.asp?id=3981&idlivello=1625#	on line available data only for the last month
Oxygen	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)		16	4	4	4	4	4	4	4	4		2009-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300
Oxygen	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Ex ante monitoring
TSS	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			4	4	4	4	4	4	4	4		2010-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300
Concentration N, P, C: water	pdf, xls(transf)	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			4	4	4	4	4	4	4	4		2010-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		data of 2009 only avaiable in 2 stations, 99100100 and 99100300
Concentration N, P, C: water	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Ex ante monitoring
Oxygenation	pdf, xls(transf)	Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			2	2	2	3	3	3	3			2010-2016	ARPAE Daphne Public Report	https://www.arpae.it/elenchi_dinamici.asp?tipo=tec_mare&idlivello=1451	
Granulometry	pdf, xls(transf)	Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			1	1	1	1	1	1	1			2010-2016	ARPAE Daphne Public Report	https://www.arpae.it/elenchi_dinamici.asp?tipo=tec_mare&idlivello=1451	
BIOLOGICAL PARAMETERS																	
Phytoplankton	pdf	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)		16	4	4	4	4	4	4	4	4		2009-2017 Quarterly	ARPAE -RER- Servizio Tutela e Risanamento Acqua, Aria e Agenti fisici		Chla. Data of 2009 only avaiable in 2 stations, 99100100 and 99100300. Chla instrumental
Phytoplankton	pdf	Quarterly data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			4	4	4	4	4	4	4			2010-2016 Quarterly	ARPAE Daphne Public Report		Composition, abund., divers, indices NO MPI

Phytoplankton	shp, xlm	Sampled stations in the Valle di Gorino within the Life AGREE project (n=8)							7	21				variable sampling frequency from 08/2014 to 09/2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Chla. Ex ante monitoring
Macrozoobenthos	pdf	Data on 6 stations of Goro lagoon												1998, 2002	PARCO/UNIFE	Master Plan project	Diversity indexes
Macrozoobenthos	pdf	Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			X			X		X				2010, 2013, 2015	ARPAE Daphne Public Report		Composition, abund., MAMBI, BITS
Macrozoobenthos		Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)						1		1		1		2013, 2015, 2017		files "BiologyTCwater" on EIONET	MAMBI
Macrozoobenthos	shp. pdf	Sampled stations in the Valle di Gorino within the Life AGREE project (n=10)								1				2015	Project coordinated by Province of Ferrara	https://lifeagree.eu/	Composition, abund., MAMBI, BITS
Macrophytes	pdf	Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)			X			X		X				2010, 2013, 2015	ARPAE Public Report		Composition, abund., MAQI, NO COVERAGES
Macrophytes		Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)						1		1		1		2013, 2015, 2017		files "BiologyTCwater" on EIONET	MAQI
Macrophytes	xls	Data on 4 stations of Goro lagoon (99100100, 99100201, 99100300, 99100401)								X				2015	ARPAE data shared in the frameworks of other project		MAQI and COVERAGES
Manila clam	pdf	Articles, reports and technical documents on clam production													see the following references cited in references section Turolla, 2018; Zentilin et al., 2008		Focus of the clam production in the area (distribution, production, techinques)
Manila clam	pdf	map of licenced areas for Manila clam farming in Sacca di Goro					X							2012	Ferrara Health Autority	https://www.ausl.fe.it/azienda/dipartimenti/sanita-pubblica/servizio-veterinario/u-o-d-igiene-degli-alimenti-di-origine-animale-area-b/mappa-sacca-di-goro-con-punti-di-campionamento	
Habitat	pdf	Natura 2000 dataform SIC IT4060005												LAST AVAILABLE UPGRADE 2017	Regione Veneto	https://www.regione.veneto.it/web/agricoltura-e-foreste/download#IT3270017	
Habitat	shp	Natura 2000 map in the whole Po Park territory			X				X					maps available for 2007, 2010, 2014	PARCO/UNIFE		data collected in 2006, 2010 and 2013 Last available revisions in 2018

Parks and Reserves	shp	Protected sites in Po delta of RER													Geographic portal of Regione Emilia Romagna	https://geoportale.regione.emilia-romagna.it/it/download	

Vegetation	shp	Map of herbaceous vegetation on emerging parts of the Sacca di Goro												1996	PARCO/UNIFE Data owned by the Park and fully available for the project		Master Plan project. Includes reedbed distibution
Bird Fauna	shp, xlm	Bird nesting on the Goro sandbank								X				2015 ex ante monitoring	Project coordinated by Province of Ferrara	https://lifeagree.eu/	
Bird Fauna	shp	Atlas of nesting birds												period 2004-2006	PARCO/UNIFE		