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PROGRAMME 2021 – 2027

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Deliverable 1.3.1
Pilot regions marine ecosystems analysis

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Editor:	Simone Libralato (PP2- OGS)		
Contributors:	Simone Libralato, Davide Agnetta, Damiano Baldan, Vinko Bandelj, Sophie Burton Pogledic, Fabrizio Gianni, Diego Panzeri, Ivano Vascotto (PP2-OGS)		
	Revision by all PPs		

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Project website: <https://www.italy-croatia.eu/web/beyond>



Content

1. Introduction	5
1.1 Water ecological characteristics.....	6
1.2 Bottom habitats	6
1.3 Seagrass habitats	10
1.4 Benthic biodiversity	11
1.5 Demersal species biomass and richness.....	12
1.6 Demersal species biodiversity and trophic level	15
1.7 Marine mammal distribution.....	17
1.8 Seabird migration routes	20
1.9 Sensitive & protected areas.....	21
2. Istria Region	23
2.1 Water ecological characteristics.....	23
2.2 Bottom habitats	24
2.3 Seagrass habitats	26
2.4 Benthic biodiversity	27
2.5 Demersal species biomass and richness.....	28
2.7 Marine mammal distribution.....	31
2.8 Seabird migration routes	32
2.9 Sensitive & protected areas.....	33
3. Split-Dalmatia Region	35
3.1 Water ecological characteristics.....	35
3.2 Bottom habitats	36
3.3 Seagrass habitats	38
3.4 Benthic biodiversity	39
3.5 Demersal species biomass and richness.....	40
3.6 Demersal species biodiversity and trophic level	41
3.7 Marine mammal distribution.....	43
3.8 Seabird migration routes	44
3.9 Sensitive & protected areas.....	45



4.	Veneto Region	47
4.1	Water ecological characteristics.....	47
4.2	Bottom habitats.....	48
4.3	Seagrass habitats	50
4.4	Benthic biodiversity	51
4.5	Demersal species biomass and richness.....	52
4.6	Demersal species biodiversity and trophic level	54
4.7	Marine mammal distribution.....	55
4.8	Seabird migration routes	57
4.9	Sensitive & protected areas.....	57
5.	Apulia Region.....	59
5.1	Water ecological characteristics.....	59
5.2	Bottom habitats.....	60
5.3	Seagrass habitats	62
5.4	Benthic biodiversity	63
5.5	Demersal species biomass and richness.....	64
5.6	Demersal species biodiversity and trophic level	66
5.7	Marine mammal distribution.....	67
5.8	Seabird migration routes	68
5.9	Sensitive & protected areas.....	69
6.	Concluding remarks and discussion.....	71
7.	Acknowledgements	71
8.	References and cited literature	72



1. Introduction

This deliverable contains the analysis of marine ecosystem components in pilot regions using the most detailed and complete information available to the project partners. The deliverable is composed of four sections, each one dedicated to each of the four regions under investigation and are preceded by a general chapter describing the variables and materials used for the whole Adriatic Sea. The deliverable was developed by PP2 with the assistance off PPs from the pilot regions. The four regions are:

1. Istria Region
2. Split-Dalmatia County
3. Veneto Region
4. Apulia Region

These regions surround the four areas identified as possible sites for Offshore Wind Farms (OWF).

The analysis has been carried out with the use of existing data in the highest possible resolution and will be used to determine suitable (in terms of environmental impact) OWF position and shape.

The analyses are divided into main ecosystem components in order to facilitate comprehension of original data, analyses performed and the resolution specific for each component. Ecological themes identified during the first project phase and shared with all the partners of BEYOND constitute the ecosystem components that are considered most important in the future analyses of OWF effects:

1. Water ecological characteristics
2. Bottom habitats
3. Seagrass habitats
4. Benthic biodiversity
5. Demersal species biomass and richness
6. Demersal species biodiversity and trophic level
7. Marine mammal distribution
8. Seabird migration routes
9. Sensitive & protected areas

These ecosystem components are described briefly for the whole Adriatic Sea in this introductory section, for delineating data and methods used, which are common in the four regions. Thereafter, the four sections are dedicated to exploring in detail the ecosystem components by region.



1.1 Water ecological characteristics

The ecological characteristics of the waters considered useful for the scope of the project BEYOND are those that might be potentially influenced by the activities for developing, running and dismissing OWF and that are crucial for marine ecosystems. The main ecological water column characteristic considered is chlorophyll-a, which is measured experimentally and, by coupling physical and biogeochemical models and data, is modelled with continuity in time and space in the whole Mediterranean Sea. The data are derived from the Copernicus Marine Service (<https://marine.copernicus.eu/it>), in particular from the reanalysis covering the years from 2011 to 2022, inside and outside the region of interest, in order to evaluate possible differences between the point of interest and the nearby area. Data consist of mg/m^2 of chlorophyll for the whole Adriatic basin, and has been detailed for the four areas concerned by the project (Veneto, Istra, Split-Croatia and Apulia). Data from reanalysis represent the best blend between historical observations (from satellite, buoys and other measures) and modelling, and have the advantage of bearing no gaps in space and time, and a daily resolution in time and a $1/24$ -degree (approximately 6 km) grid resolution in horizontal space. Reanalysis is the result of 3D modelling, also having vertical layers that were downloaded from CMS website and were vertically integrated to represent the characteristic of the water column in the whole Adriatic Sea, and therefore the high intra-annual variability average by season is reported. Resulting chlorophyll climatological seasonal averages are then overlapped with the defined OWF areas and the average within these areas and outside the foreseen OWF calculated, in order to understand the role of the selected placing with respect to the surroundings for each region.

1.2 Bottom habitats

Bottom habitats are crucial for understanding not only technical feasibility, but also the ecological effects of the establishment of OWF. Therefore, the more useful characteristics of benthic habitats were investigated, such as: sediment grain size and habitats definition.

The sediment grain size reported as phi-scale (ϕ), was obtained from a detailed sedimentological map produced by interpolating the raw data (3-metric IDW) with a grid resolution of 1 km in 2020 and kindly provided by Dr Jenkins of the University of Colorado (USA). The interpolation distance metrics used were the geographic distances and water depth difference (Bostock et al. 2018). The phi diameter, introduced by Krumbein (1938, 1934) as a practical means of visualizing and analysing sediment grain size, is calculated as the negative logarithm to the base 2 ($\phi = -\log_2 d$) of the particle diameter (in millimeters), thus higher values indicate finer sediments (i.e., silt and clay). For more details see also the project website:

<https://instaar.colorado.edu/~jenkinsc/dbseabed/coverage/adriaticsea/adriatico.htm>

The full map of the sediment grain size for the Adriatic Sea is reported in Fig. 1.2.1: from this map were extracted the sub areas of interest for the four regions.



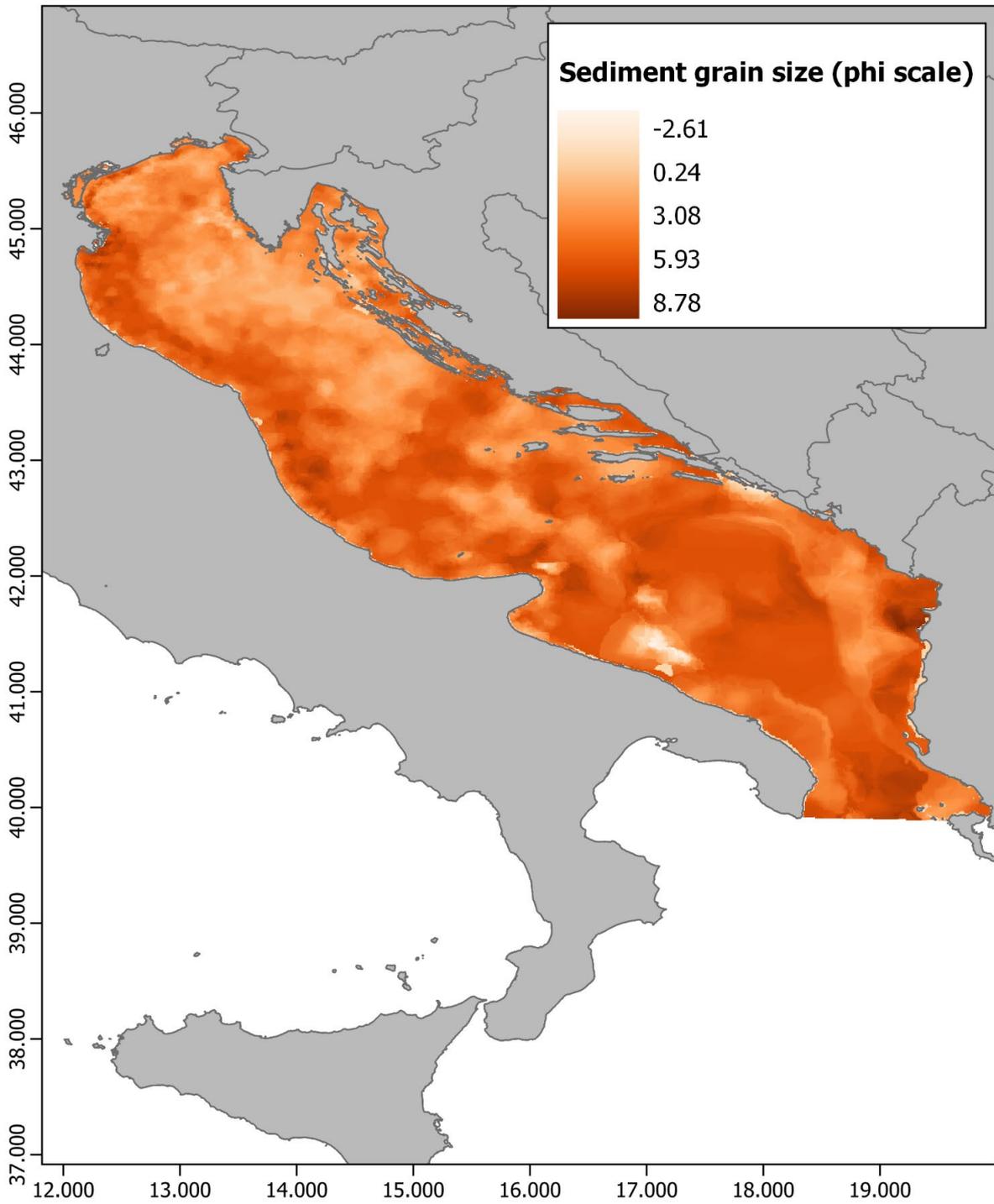


Figure 1.2.1. - Map of sediment grain size in the Adriatic Sea. Kindly provided by Dr Jenkins, University of Colorado (USA).



Moreover, EUNIS benthic habitats were extracted from the EuSeaMap (Vasquez et al., 2023) in EMODNET (https://emodnet.ec.europa.eu/en/about_emodnet) for the whole Adriatic Sea and the regions of interest. The map classifies benthic habitats based on depth, sediment texture, and the presence of biogenic substrates. The habitats are classified according to the EUNIS standard (Montefalcone et al., 2021).

The EUNIS habitats mapped in the Adriatic region are the following (habitats within the proposed area are marked with three asterisks ***):

- MB55: Mediterranean infralittoral sand***
- MC35: Mediterranean circalittoral coarse sediment***
- MD451: Biocenosis of Mediterranean open-sea detritic bottoms on shelf-edge***
- ME55: Mediterranean upper bathyal sand
- MB35: Mediterranean infralittoral coarse sediment***
- ME35: Mediterranean upper bathyal coarse sediment
- ME45: Mediterranean upper bathyal mixed sediment
- MC45: Mediterranean circalittoral mixed sediment***
- MB15: Mediterranean infralittoral rock***
- ME15: Mediterranean upper bathyal rock
- MF15: Mediterranean lower bathyal rock
- MD151: Biocenosis of Mediterranean shelf-edge rock***
- **MC151: Coralligenous biocenosis*****
- MD651: Biocenosis of Mediterranean offshore circalittoral coastal terrigenous muds***
- MC651: Biocenosis of Mediterranean circalittoral coastal terrigenous muds***
- MG65: Mediterranean abyssal mud
- MC451: Biocenosis of Mediterranean muddy detritic bottoms***
- MB65: Mediterranean infralittoral mud***
- ME65: Mediterranean upper bathyal mud***
- MF65: Mediterranean lower bathyal mud***
- **MB252: Biocenosis of [Posidonia oceanica]*****
- **MB2523: Facies of dead "mattes" of [Posidonia oceanica] without much epiflora*****
- **MB554: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand*****
- MB652: Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud
- MC55: Mediterranean Circalittoral sand***
- MF55: Mediterranean lower bathyal sand
- **MB2531: Facies with [Ficopomatus enigmaticus]*****
- **MB554 or MB652: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand or Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud**
- **MB152: Biocoenosis of the Mediterranean euryhaline and/or eurythermal lagoon on rock**



Please note, the highly sensitive habitats that might be considered with care if falling within the area of OWF are those underlined and in bold.

The habitat types falling within the proposed area were extracted (Fig. 1.2.2).

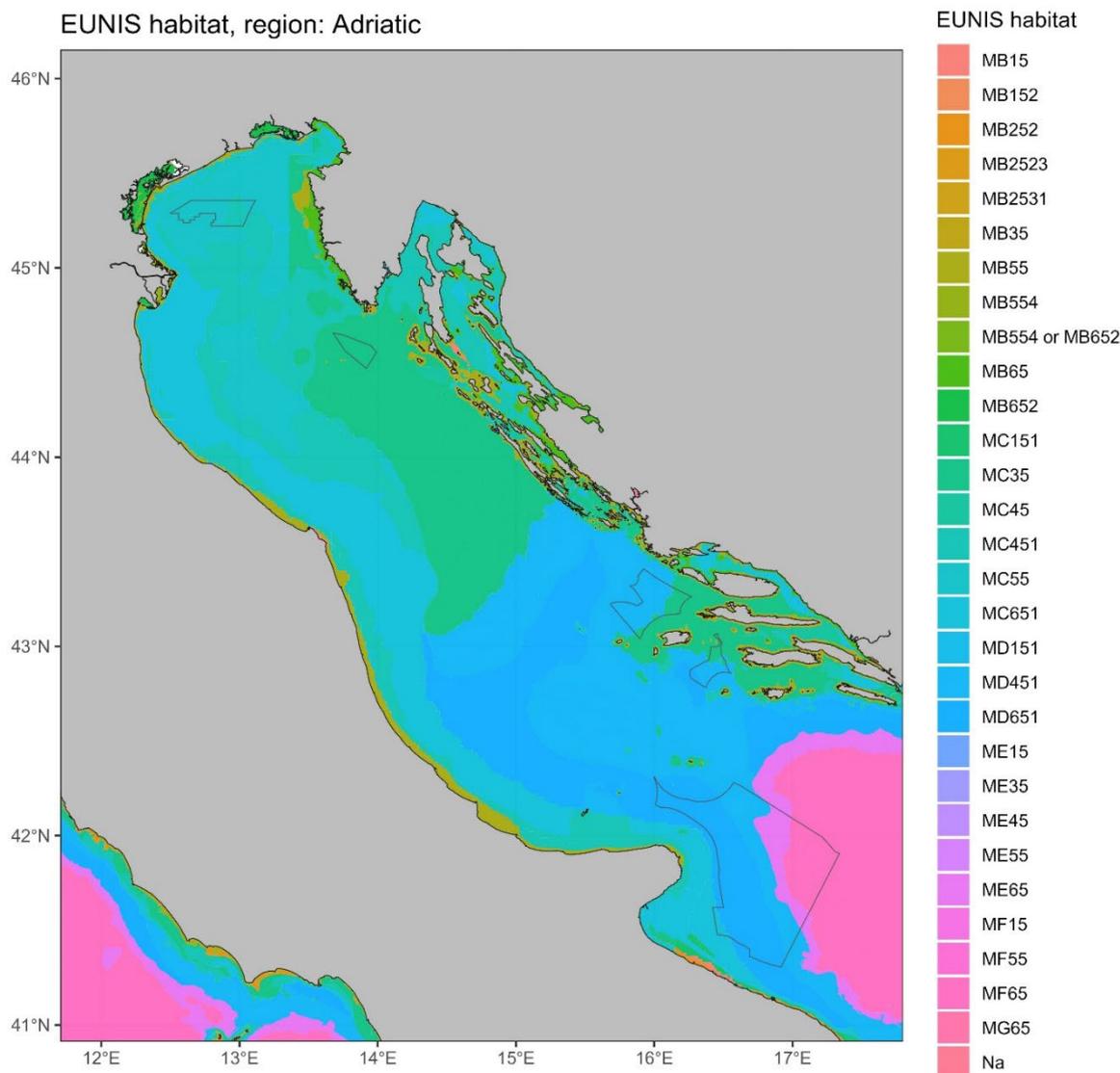


Figure 1.2.2 - EuSeaMap classification of bottom habitats in the whole Adriatic region. See below for the full names of the habitats



1.3 Seagrass habitats

Seagrasses are benthic marine plants that live on the seafloor and create meadows of great importance for marine biodiversity, because they represent an important nursery and living habitat for many species.

Seagrass maps are available for *Posidonia oceanica* and *Cymodocea nodosa* that are two important species of coastal habitats typical of the Mediterranean Sea. The maps obtained for these two species are the output of a statistical model described in detail elsewhere (Baldan et al., 2024). The best models were used to relate species occurrences with environmental predictors using machine learning ensemble approaches and trained with environmental predictors climatology for the years 2000-2020 (Baldan et al., 2024). The models were used to predict suitable and unsuitable sites for *P. oceanica* and *C. nodosa* within the 0-40 m bathymetric range, which is the potentially available habitat due to light availability constraints. Results are presented in Fig. 1.3.1.

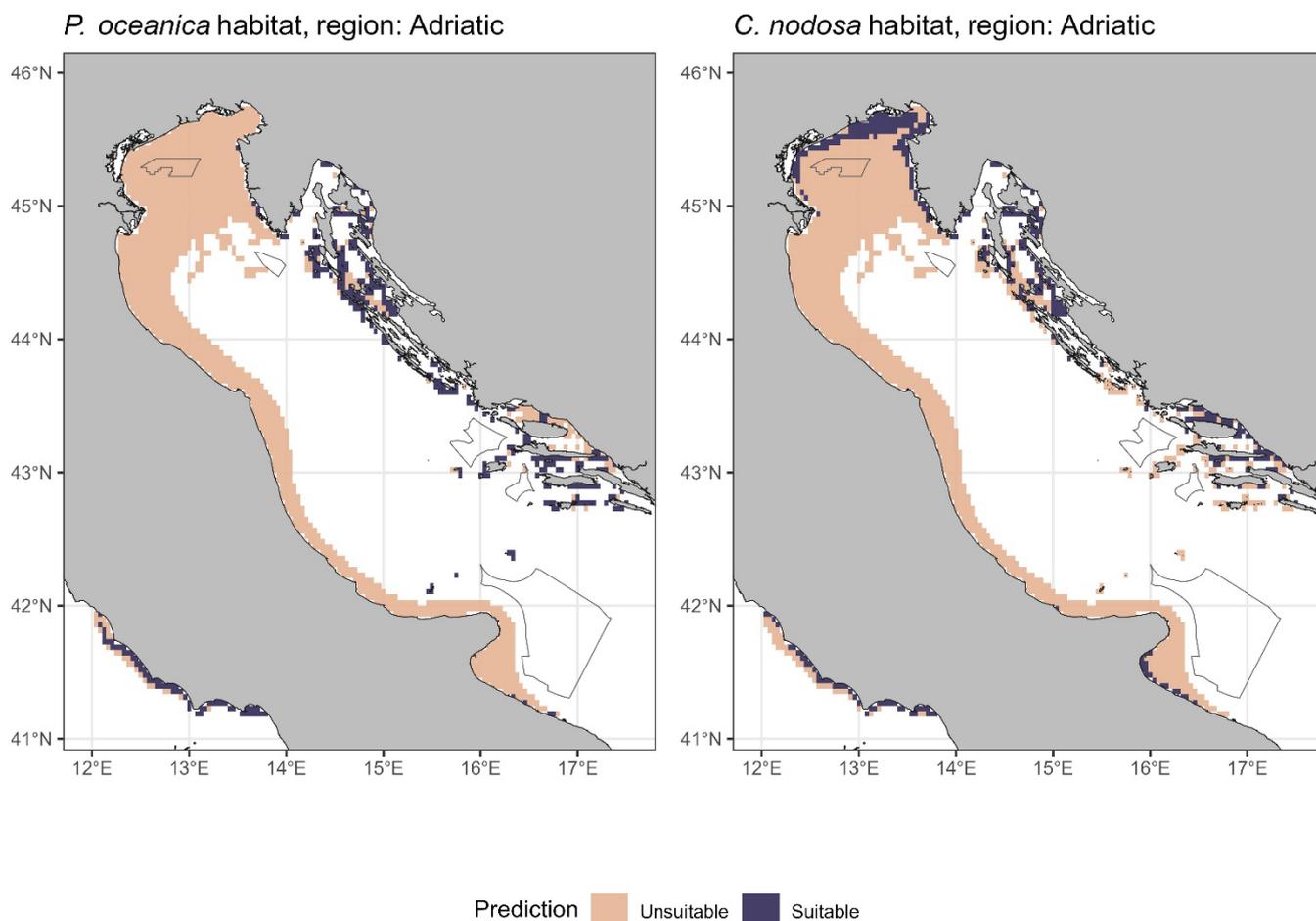


Figure 1.3.1 – Modelled distribution of *P. oceanica* and *C. nodosa*.



1.4 Benthic biodiversity

Since limited data are available on benthic macrozoobenthic biodiversity, data were collected from the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information Facility (GBIF) using the R packages 'robis' and 'rgbif', respectively. The data were queried using a polygon encircling the Adriatic Sea, and only occurrence data for 2000-2024 were retained. Data were discarded when:

- The date record was incorrect or incomplete
- The data point was located on land
- The data point coordinates were deemed to be too uncertain

Next, the 'worms' package was used to perform a fuzzy match between the reported species names and the taxonomy from the World Register of Marine Species (WoRMS), a database based on the Darwin Core Standards. For each taxon that matched, a unique WoRMS identifier (i.e., *aphiaID*) – favouring accepted names when multiple matches were found. Finally, data points belonging to the same species and falling in the same grid cell were merged in a unique data point. For each grid cell, the total number of species occurrences was counted and is reported in the map.



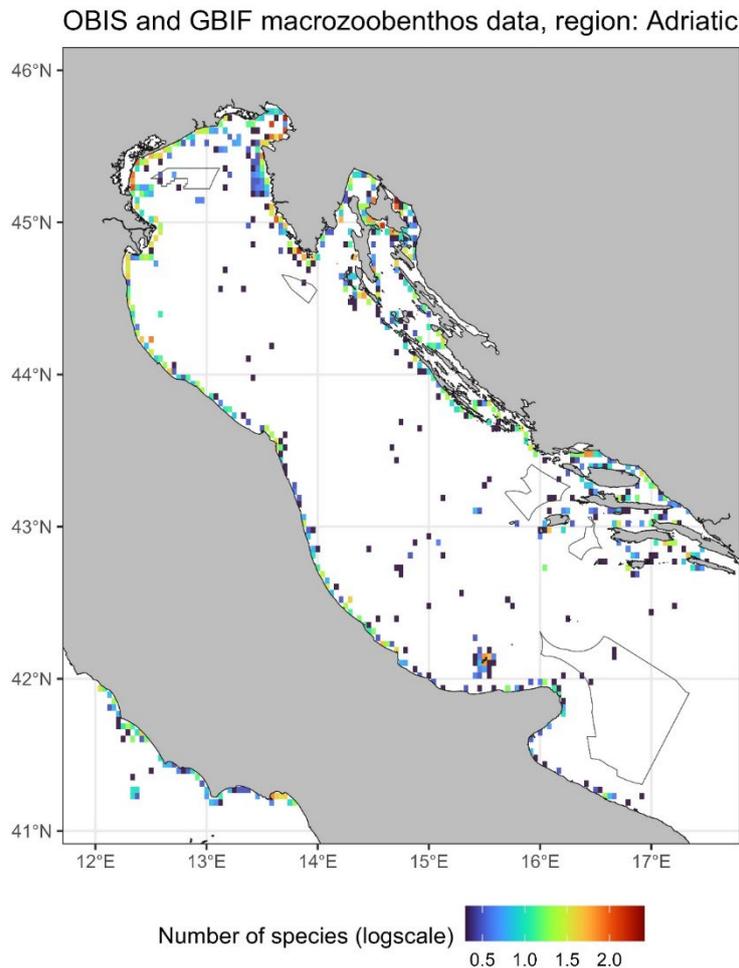


Figure 1.4.1 – Macrozoobenthos data from OBIS and GBIF for the entire Adriatic Sea. Data coverage is very scattered, and sampling are reported in terms of richness (number of species).

1.5 Demersal species biomass and richness

The Demersal species richness in the Adriatic Sea, i.e., the number of species, was quantified using the data collected by the Mediterranean International Trawl Survey (MEDITS program). The MEDITS is a standardized scientific survey carried out with bottom trawling using a standardized net with coded stretched mesh size of 20 mm. This survey is conducted generally in the summer months, across more than 100 sites in the Adriatic and the number of species sampled is more than 400 in total (Spedicato et al., 2019). Although this sampling is aimed at supporting the assessment of some important commercial target species (such as *Merluccius merluccius* and *Nephrops norvegicus*), this sampling permits the reconstruction of patterns of the demersal community.

The total biomass (Kg Km⁻²) was calculated as the sum of the biomass of each species for each haul. The total number of species (N) was also calculated for each haul. Raw MEDITS data can be found at



the Joint Research Centre Data Catalogue (<https://data.jrc.ec.europa.eu/dataset/f25092c4-3f0f-449f-ba60-5fbfe385defc>).

The data of species biomass and richness by hauls (> 100 hauls per year in the whole Adriatic Sea) were integrated and extrapolated in the whole Adriatic Sea using the Generalized Additive Mixed Model (GAMM) that links richness with environmental variables (predictors). A series of factors were used as predictors, such as the marine biotope classification map (EUSeaMap 2023 Broad-Scale Predictive Habitat Map for Europe) provided by EMODnet service (<https://emodnet.ec.europa.eu/en; Montefalcone et al. 2021>), bottom temperature (tmp_bot in °C), bottom dissolved oxygen (oxy in mmol m⁻³), bottom salinity (sal_bottom in PSU), integrated chlorophyll-a 0-200 m (chl in mg m⁻³), bottom particulate organic carbon (poc_bot in mg m⁻³), and integrated net primary production in the water column 0-200 m (npp in mg m⁻³) extracted from the Copernicus Marine Service (CMS, <https://data.marine.copernicus.eu/products>). These predictors were used to obtain the best GAMM model that was applied to map the species biomass and richness over the entire Adriatic Sea with a horizontal resolution of 1/24 of degree (approximately 6km) (see also Agnetta et al., 2025) For the biomass, the GAMM model accounted for 62% of the total variance (Fig. 1.5.1). For richness, the GAMM model accounted for 56% of the total variance (Fig. 1.5.2).



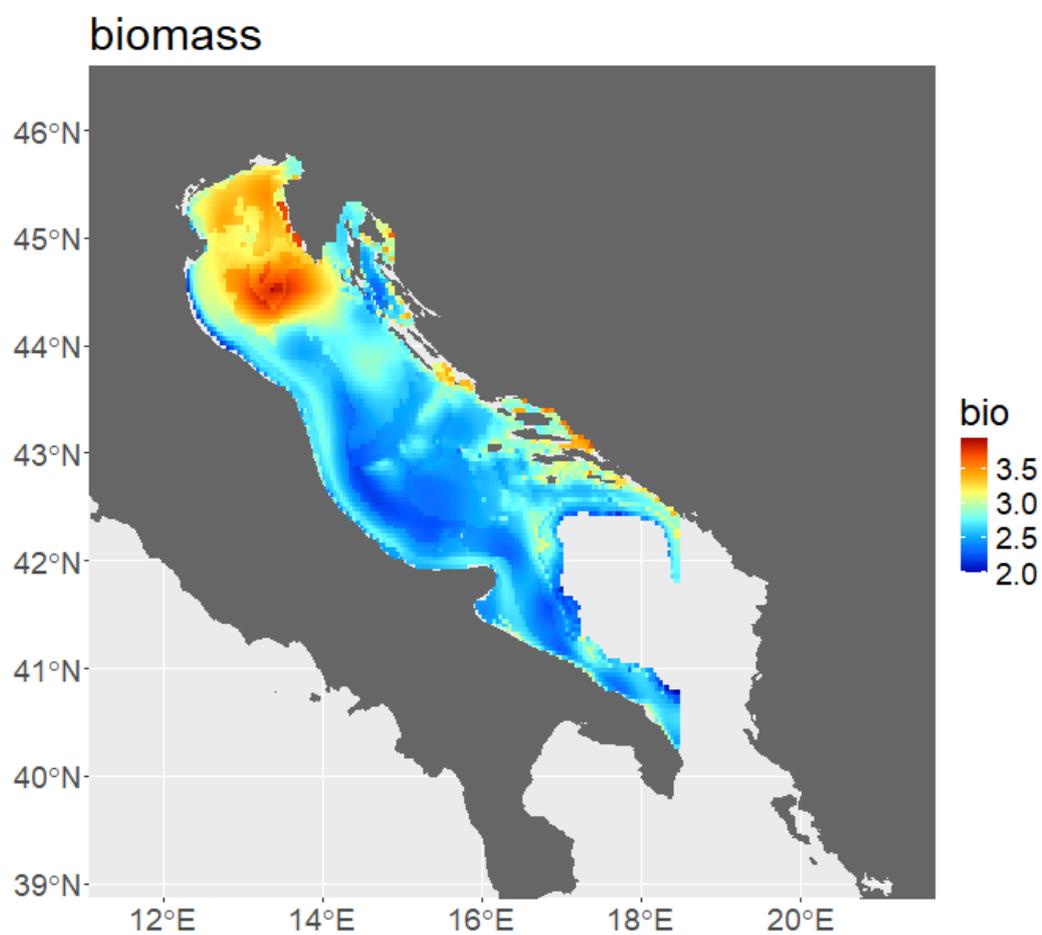


Figure 1.5.1 biomass projections are obtained from the GAMM model. The scale is logarithmic.



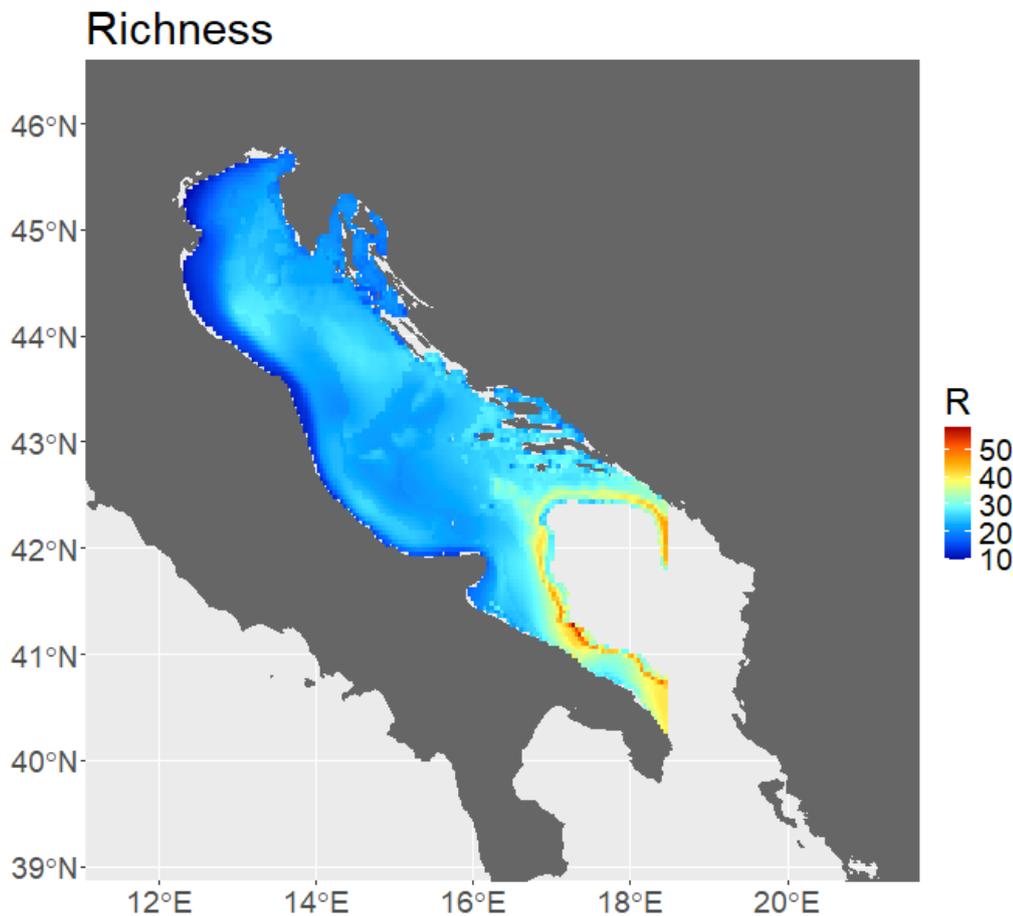


Figure 1.5.2 Richness projections are obtained from the GAMM model.

1.6 Demersal species biodiversity and trophic level

To explore the pattern of diversity, an index of variability of composition, called β -diversity, was used. This index has the property to link composition and variability and is based on a regional approach for diversity. The method adopted is proposed by Legendre and De Caceres (2013), where the biomass data were transformed calculating the composition π_i , before considering the square root of these proportions (Hellinger transformation). The β -diversity is then obtained by calculating the Euclidean distance from the average community profile used as a reference. The advantage of this approach is that i) there is an “average community composition,” which is used as a reference; ii) the values calculated for the whole basin can be disaggregated easily over time and include space contributions.

Biomass indices from MEDITS program (Spedicato et al. 2019) were used to estimate the β -diversity by each haul. Then a Generalized Additive Mixed Model (GAMM) based on environmental predictors (see Biomass and Richness) were used to map species richness over the entire Adriatic Sea with a



horizontal resolution of 1/24 of degree (approximately 6km; for the approach see also Agnetta et al., 2025). The GAMM model accounted for 70% of the variance (Fig. 1.6.1).

beta-diversity

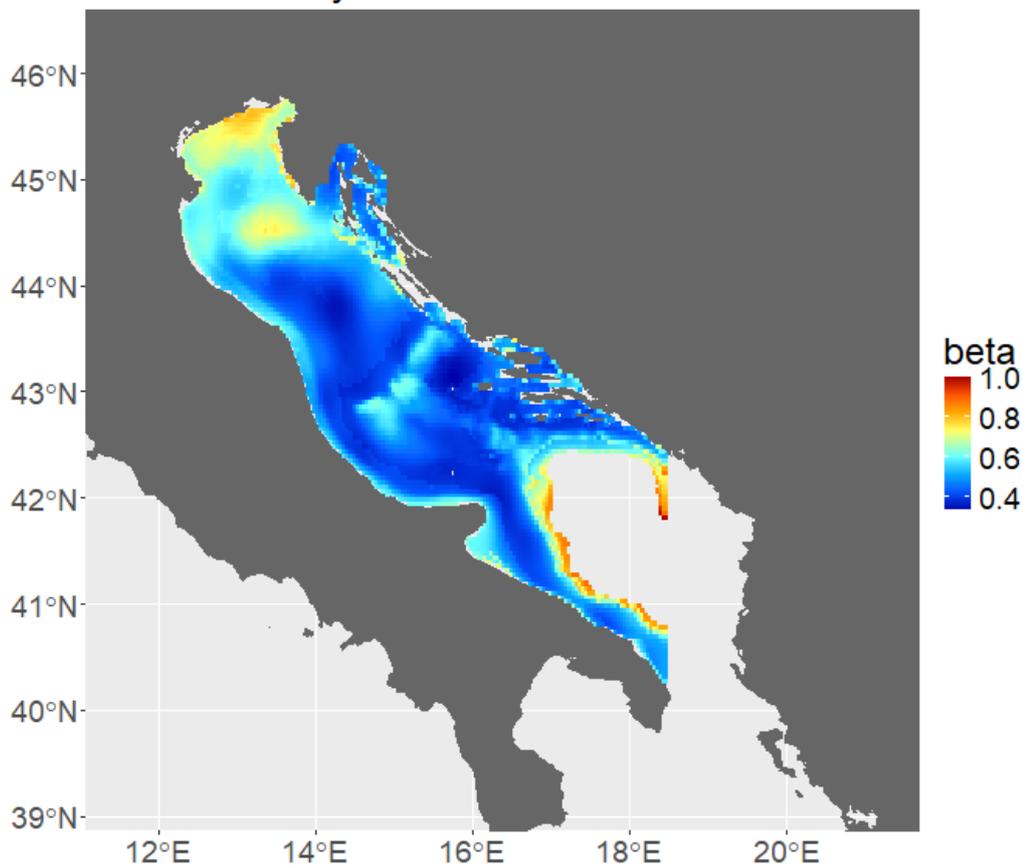


Figure 1.6.1 Beta-diversity projection obtained from the GAMM model.

To interpret the patterns in biomass, richness and diversity, an index of trophism - the mean trophic level (MTL) - was calculated for each haul (sensu Pauly et al., 1998; Libralato et al., 2004). A trophic level was assigned to each species according to literature and or available sources. The assignment was obtained, when possible, from the online database Fishbase (www.fishbase.org). For the remaining species, the trophic level assigned corresponds to the average of the closest taxonomic level known to the authors of this deliverable (genus, family etc.). Biomass indices from MEDITS program (Spedicato et al. 2019) were used to estimate the MTL by each haul. The MTL is the average trophic level of the species present in a haul weighted by their corresponding biomass in the haul. Then a Generalized Additive Mixed Model (GAMM) based on environmental (see Biomass and Richness) was used to map species richness across the entire Adriatic Sea with a horizontal resolution of 1/24-degree (approximately 6km). The GAMM model accounted for 56% of the variance (Fig. 1.6.2). High values of MTL indicate a prevalence of organisms high in the trophic chain (predators).



Conversely, low MTL indicates the prevalence of organisms of low trophic levels, such as herbivores and detritivores.

Trophism

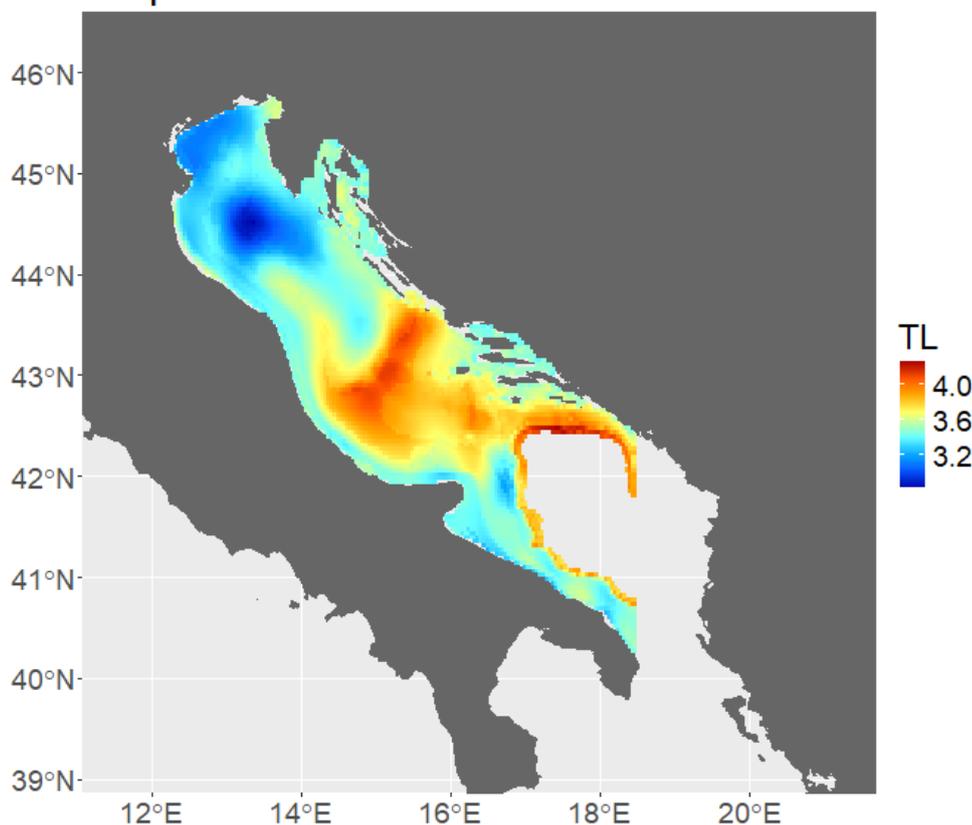


Figure 1.6.2 Trophic level projections are obtained from the GAMM model.

1.7 Marine mammal distribution

Among the iconic species, marine mammals have a special role, being sensitive to human disturbances (noise, pollution and habitat degradation) as well as have several interactions (both positive and negative) with marine activities (fisheries, tourism, navigation). Although the Monk seal (*Monachus monachus*) is an emblematic example of a species on the brink of extinction, there are few observations for supporting its presence. Conversely, the most dominant marine mammal in the central-northern Adriatic Sea is the bottlenose dolphin (*Tursiops truncatus*), which lives in an area with significant anthropogenic disturbance. The Mediterranean bottlenose dolphin subpopulation is has been assigned 'Least Concern' status on the IUCN Red List (Natoli et al. 2021). This species is amongst the best-known cetaceans when modern field studies started in the late 1980s. Observations of bottlenose dolphin were retrieved from GBIF (Global Biodiversity Information Facility; www.gbif.org) in March 2025 for the whole Adriatic Sea (Fig. 1.7.1).



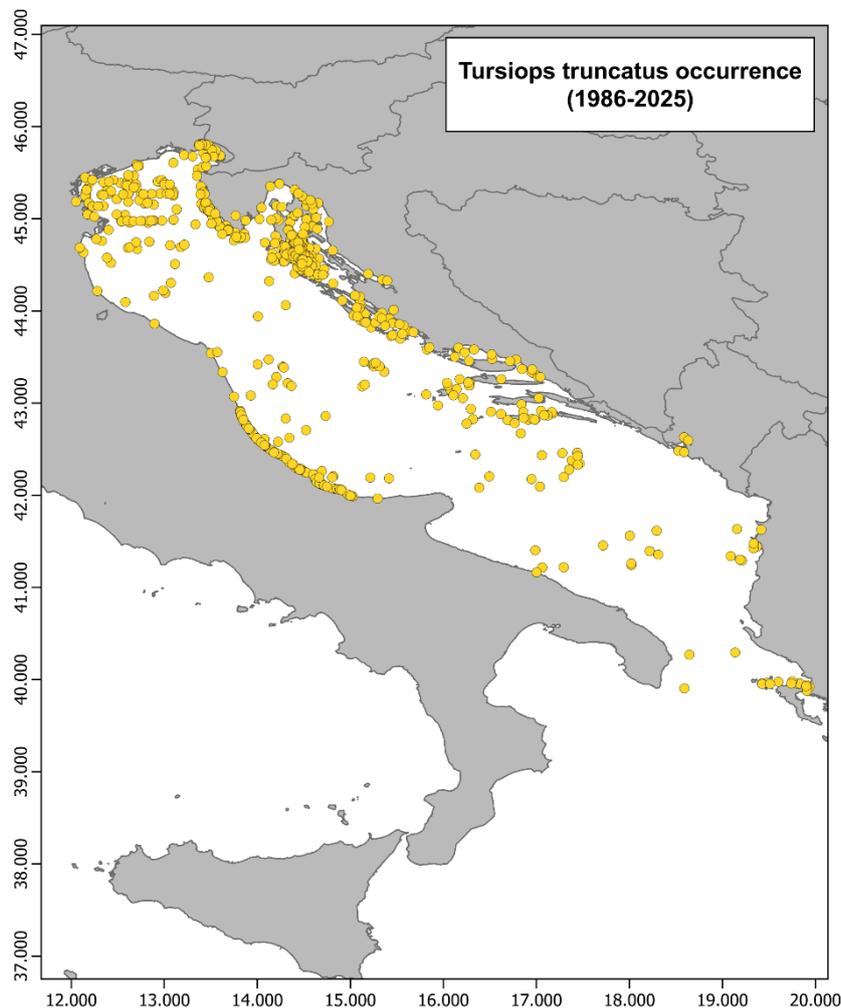


Figure 1.7.1 - *Tursiops truncatus* occurrence points from 1986 to 2025 in the Adriatic Sea. The presence points were downloaded from GBIF (March 2025).

More systematic data on the distribution and abundance of cetaceans and sea turtles throughout the Adriatic were collected during two aerial surveys carried out in the summers of 2010 and 2013 (Fortuna et al., 2018). The aerial survey observations (on standardized and parallel transects) enabled predictions of animal density over the Adriatic Sea (Figure 1.7.2). The data density was used to propose key areas for the bottlenose dolphin that are identified by yellow dotted (within 12 nm), dashed (over 12 nm), and dot-dashed shapes (areas within and over 12 nm) in Fig. 1.7.2. Key areas are also reported in Table 1.7.3.

Although the work on understanding the key areas for bottlenose dolphin is very useful and relevant (Fortuna et al., 2018), the sources provide dated information (last sampling used 2013), thus for the purposes of the analysis for BEYOND, only recent data from GBIF, although scant, were used for describing the regions.



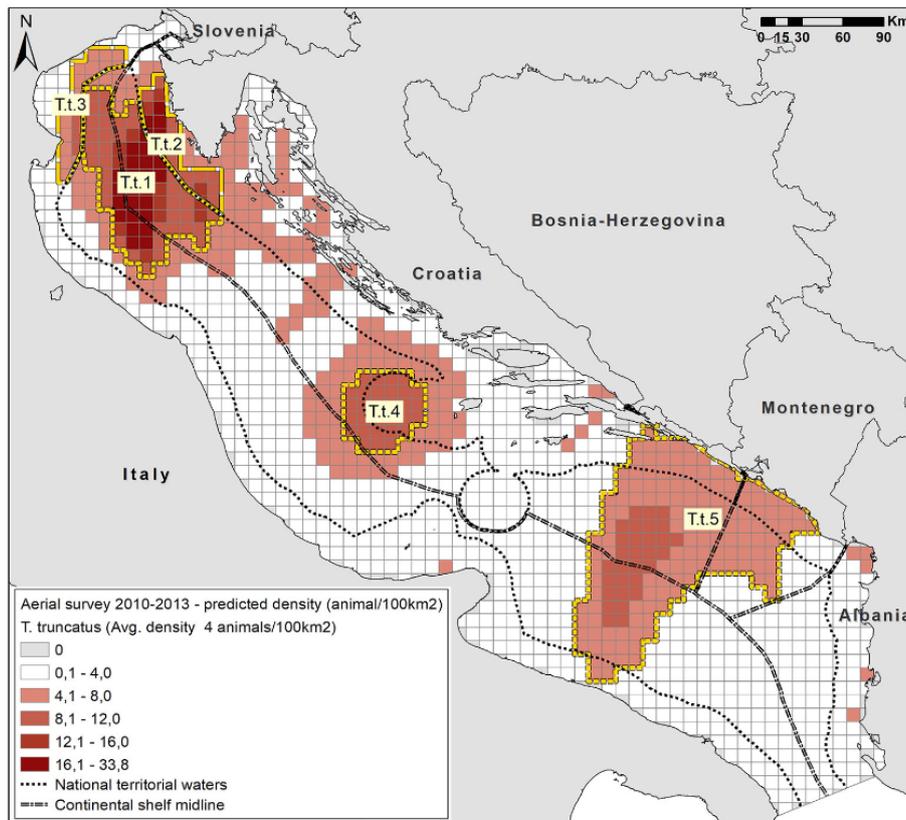


Figure 1.7.2. Density surface predicted distribution of the bottlenose dolphin in the Adriatic Sea based on 2010 and 2013 aerial survey data. Source: Fortuna et al 2018.

Table 1.7.3 - Key areas for bottlenose dolphins in the Adriatic Sea upon 2010-2013 datasets. See Figure 1.7.2 for the key areas. Densities categories: low density (densities below the Adriatic average, LD); low to medium densities (between the average and twice, L-MD); medium to high densities (two to three times the average, M-HD); high to highest (three to four times the average, H-HHD); maximum densities (over four times the average, MAXD). Source: Fortuna et al 2018.

Description	Relevance to existing Natura 2000 sites
Tt. 1 North Adriatic offshore waters (includes areas from H-HHD to MAXD)	–
Tt. 2 North-eastern Adriatic (includes areas from H-HHD to MAXD)	Overlapping sites HR5000032, HR3000161 and HR3000419 and adjacent to HR4000001
Tt. 3 North/north-western coastal waters off the Po delta and offshore waters off Veneto and Emilia-Romagna (Italy) (includes areas from L-MD to M-HD)	Overlapping sites IT3250047 and IT3250048, and adjacent to IT3320037; also overlaps or is adjacent to IT4060005, IT4060003, IT4060005, which do not list the bottlenose dolphin
Tt. 4 Pelagic habitat around Jabuka/Pomo island, including waters over 12 nm (includes areas with H-HHD)	Adjacent to site HR3000469
Tt. 5 Southern Adriatic, offshore waters off the of Dubrovnik, Croatia and Montenegro (includes areas with H-HHD)	Adjacent to site HR3000426



1.8 Seabird migration routes

Potential seabird site maps in the Adriatic were developed by UNEP-MAP-RAC/SPA (2010), which considered the pelagic distribution of the Mediterranean seabird under conservation concern. The map has a 10x10 cell resolution and was built on seven pelagic Mediterranean endemic and near-endemic seabird species (listed in Table 1.8.1) known to: a) occur regularly in offshore waters and therefore, are more representative of pelagic habitats; b) have higher levels of endemism, at species or subspecies level, and in most cases represent taxa that evolved in isolation in the Mediterranean and do not occur anywhere else in the world; c) endure higher levels of threat, according to international standards (IUCN, BirdLife International). The map (Fig. 1.8.2) was built by integrating all species' known distribution (both breeding and wintering areas) while ranges were obtained from a wide variety of internationally recognized sources: consultation with experts, published references, data from censuses at sea and satellite telemetry, and own data. However, there are several gaps in the knowledge concerning, among other aspects, their distribution at sea: for instance, feeding areas (they feed mainly from pelagic fish) or migratory movements. Moreover, their breeding colonies are scattered mainly on small isolated rocky islands, islets and cliffs. For more information on methodology, see UNEP-MAP-RAC/SPA (2010), report presenting a georeferenced compilation on important bird areas in the Mediterranean open seas.

Table 1.8.1 - Seabirds considered in the analysis by UNEP-MAP-RAC/SPA (2010).

Scientific name	Protected (1)	In decline (2)	Endemic or near-endemic	EC Birds Directive (3)	AEWA (4)
<i>Calonectris diomedea diomedea</i>	•	•	•	•	
<i>Puffinus yelkouan</i>	•	•	•	•	
<i>Puffinus mauretanicus</i>	•	•	•	•	
<i>Hydrobates pelagicus melitensis</i>	•		•	•	
<i>Phalacrocorax aristotelis desmarestii</i>	•	•	•	•	
<i>Larus melanocephalus</i>	•		•		
<i>Larus audouinii</i>	•		•	•	•

(1). Barcelona Convention. Protocol concerning specially protected areas and biological diversity in the Mediterranean. Annex II: List of Endangered or Threatened Species.

IUCN. IUCN Red List of Threatened Species. IUCN. 2008.

(2). BirdLife International. (2009). Species factsheets. <http://www.birdlife.org>

UNEP-MAP-RAC/SPA. (2006). Proceedings of the first symposium on the Mediterranean Action Plan for the conservation of marine and coastal birds. Vilanova i la Geltrú, Spain.

(3). EC Birds Directive. Council Directive 79/409/EEC on the conservation of wild birds. Annex I. Species subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution.

(4). AEWA. Agreement on the Conservation of African-Eurasian Migratory Waterbirds. Annex 2: Waterbird species to which the Agreement applies.



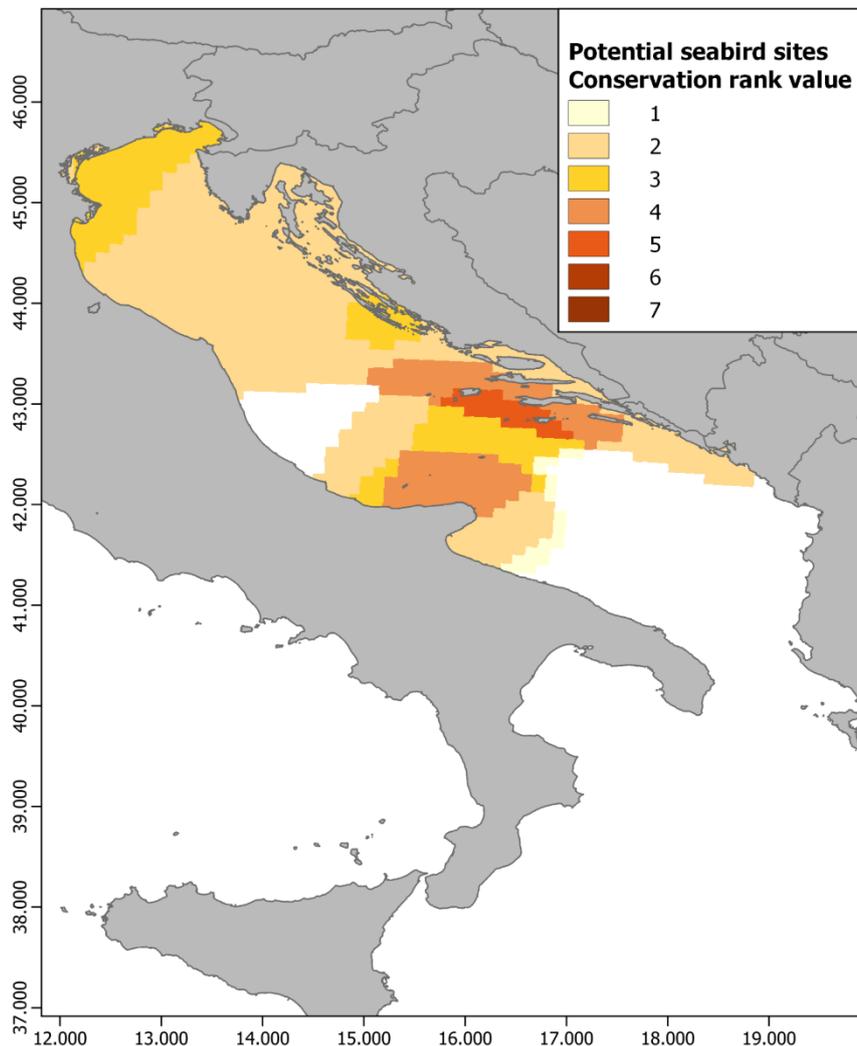


Figure 1.8.2. - Potential seabird sites in the Adriatic Sea. The map was downloaded from <https://www.portodimare.eu/> and rescaled according to the map reported by UNEP-MAP (2010).

1.9 Sensitive & protected areas

Although the description of the ecosystem provided in previous sections represents a quite comprehensive analysis of all the factors that contribute to shape the complexity and sensitivity of the Adriatic ecosystem, sensitive areas have been also declared through a series of protection efforts. Basically, several portions of the Adriatic Sea have been declared sensitive under different degrees of protection and were collected from Mapamed (2019). The various sensitive and protected areas vary in the intensity of the protection and in the sectors restricted, according to protected area definition (see Figure 1.9.1). Several different levels of protection are present in the Adriatic Sea, such as Ecologically or Biologically Significant Areas (EBSA), Fisheries Restricted Areas (FRA), Specially



Protected Areas of Mediterranean Importance (SPAMI), Natura 2000 sites, and Essential Fish Habitats (EFH) (See Fig. 1.9.1). Notably, EBSA and large FRAS, such as Pomo Pit Fra and deep sea (defined as areas with a depth greater than 1000m and where trawling is forbidden; FAO, 2020) cover large areas of the Adriatic Sea.

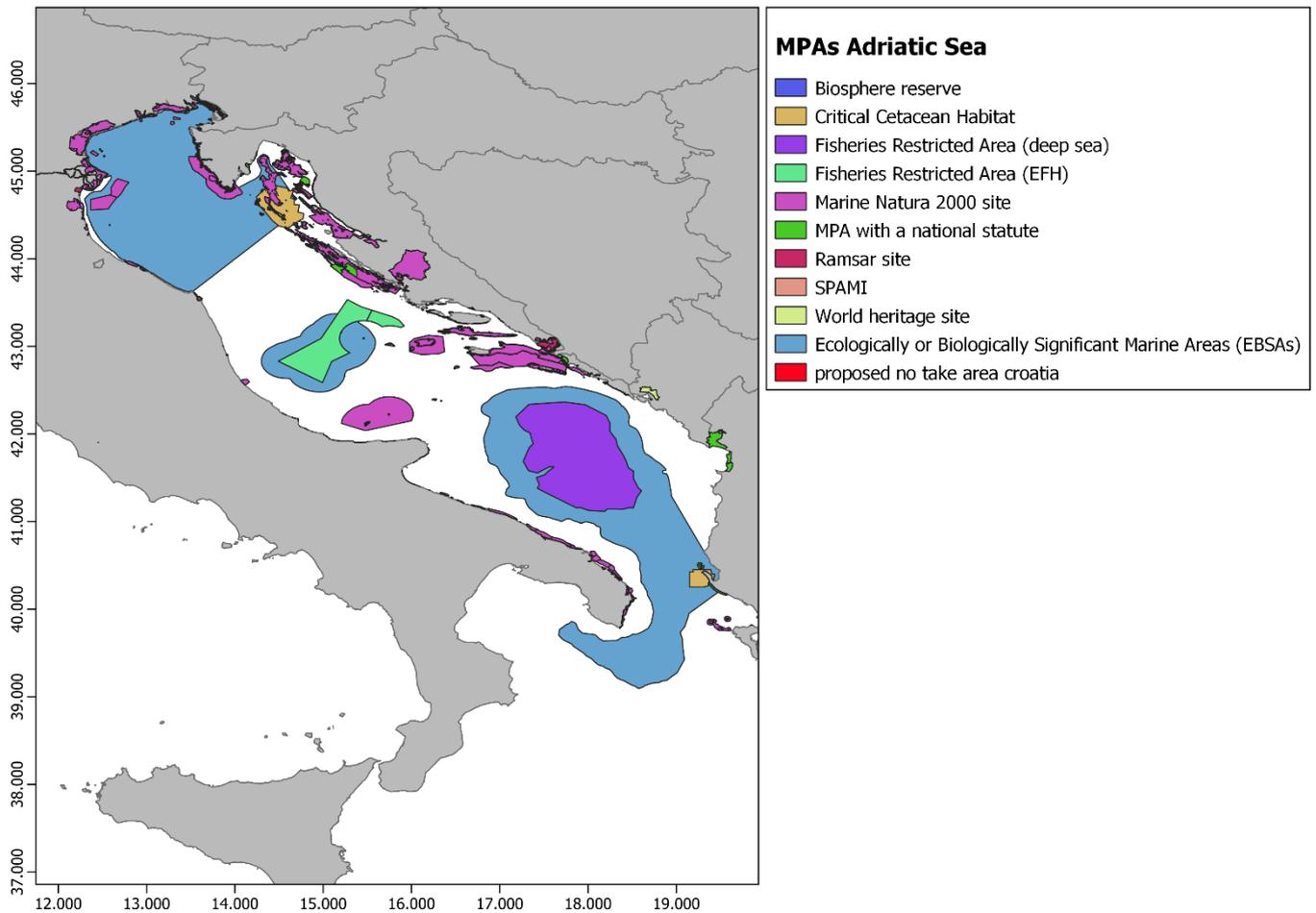


Figure 1.9.1 -. Sensitive and marine protected areas in the Adriatic Sea. Data source: mapamed.org, 2019 edition. The layer of the new proposed no take area in Istria (Ližnjan-Lisignano Sv. Stipan-Cuf) was provided by Doris Pajkovic of IRENA - Istrian Regional Energy Agency. Some marine Natura 2000 sites were integrated with data from protectedplanet.net (2024).



2. Istria Region

2.1 Water ecological characteristics

Chlorophyll is the best product of Copernicus as it is the result of satellite data assimilation of biogeochemical models (Cossarini et al., 2021). The chlorophyll-a concentration in the region has quite a strong seasonal signal (see colour scale and box plots in Fig. 2.1.1) with higher values in winter (JFM; average 10 mg Chl-a/m²) and spring (AMJ, average 8 mg Chl-a/m²). The area identified for the OWF is characterized by lower concentrations of chlorophyll with respect to the surrounding region with a maximum of approximately 8 mg Chl-a/m² in winter, although the overall average is approximately 5 mg Chl-a/m².

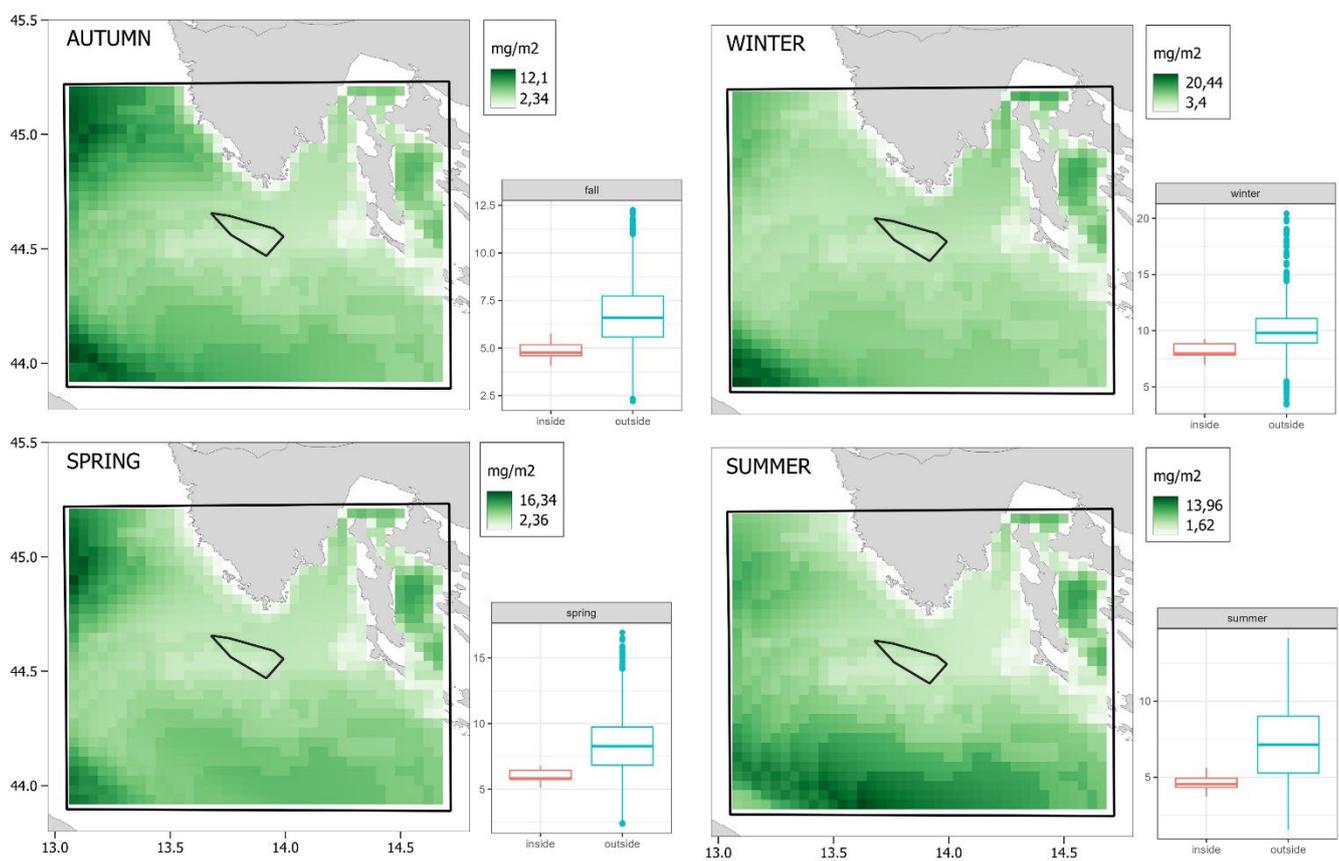


Fig. 2.1.1. Map of chlorophyll in Istria for each season in mg/m², inside and outside the region of interest. On the right side of each map is a whisker boxplot of the value inside and outside the area.



2.2 Bottom habitats

Sediment grain size in the Istria Region vary from $\phi = -2.61$ to $\phi = 8.78$ with the average for the whole region being approximately $\phi = 3$ (Fig. 2.2.1). Notably the grain size in the area defined for OWF is in the lower part of the regional range, i.e. $\phi = 2$, indicating grain sizes coarser in the OWF zone than across the region (on average).

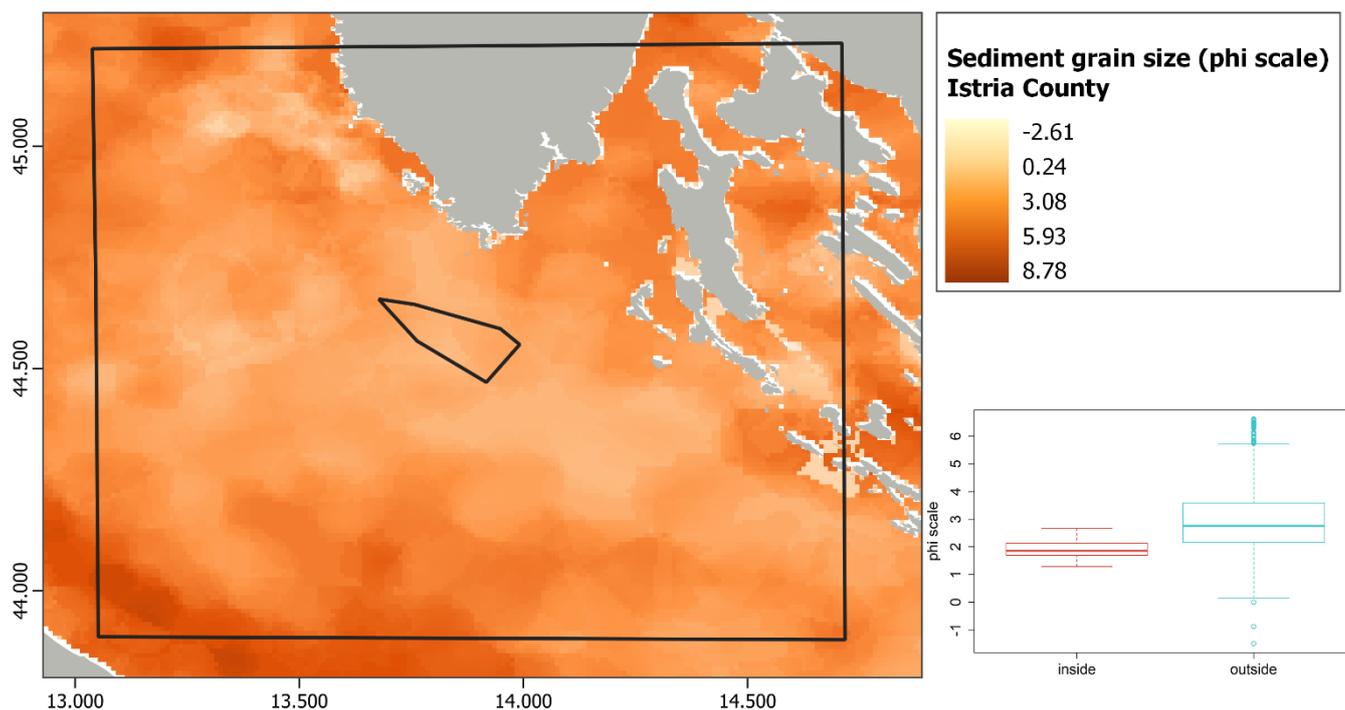


Figure 2.2.1 - Map of sediment grain size in the Istria Region. Kindly provided by Dr Jenkins, University of Colorado (USA).

The EUNIS habitats mapped in the Istria Region are the following and the habitats within the proposed OWF area are marked with three asterisks (***):

- MB55: Mediterranean infralittoral sand***
- MB554: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand
- MB652: Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud
- MC55: Mediterranean Circalittoral sand
- MC35: Mediterranean circalittoral coarse sediment***
- MB35: Mediterranean infralittoral coarse sediment
- MB15: Mediterranean infralittoral rock
- MC151: Coralligenous biocenosis



- MC651: Biocenosis of Mediterranean circalittoral coastal terrigenous muds
- MB65: Mediterranean infralittoral mud
- MC451: Biocenosis of Mediterranean muddy detritic bottoms
- MD451: Biocenosis of Mediterranean open-sea detritic bottoms on shelf-edge
- MC45: Mediterranean circalittoral mixed sediment
- MB252: Biocenosis of [*Posidonia oceanica*]
- MD651: Biocenosis of Mediterranean offshore circalittoral coastal terrigenous muds
- MD151: Biocenosis of Mediterranean shelf-edge rock
- MB554 or MB652: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand or Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud
- MB152: Biocoenosis of the Mediterranean euryhaline and/or eurythermal lagoon on rock

Overall, the bottom habitat information suggests that the OWF defined area will be between infralittoral sand and coarse sediment.

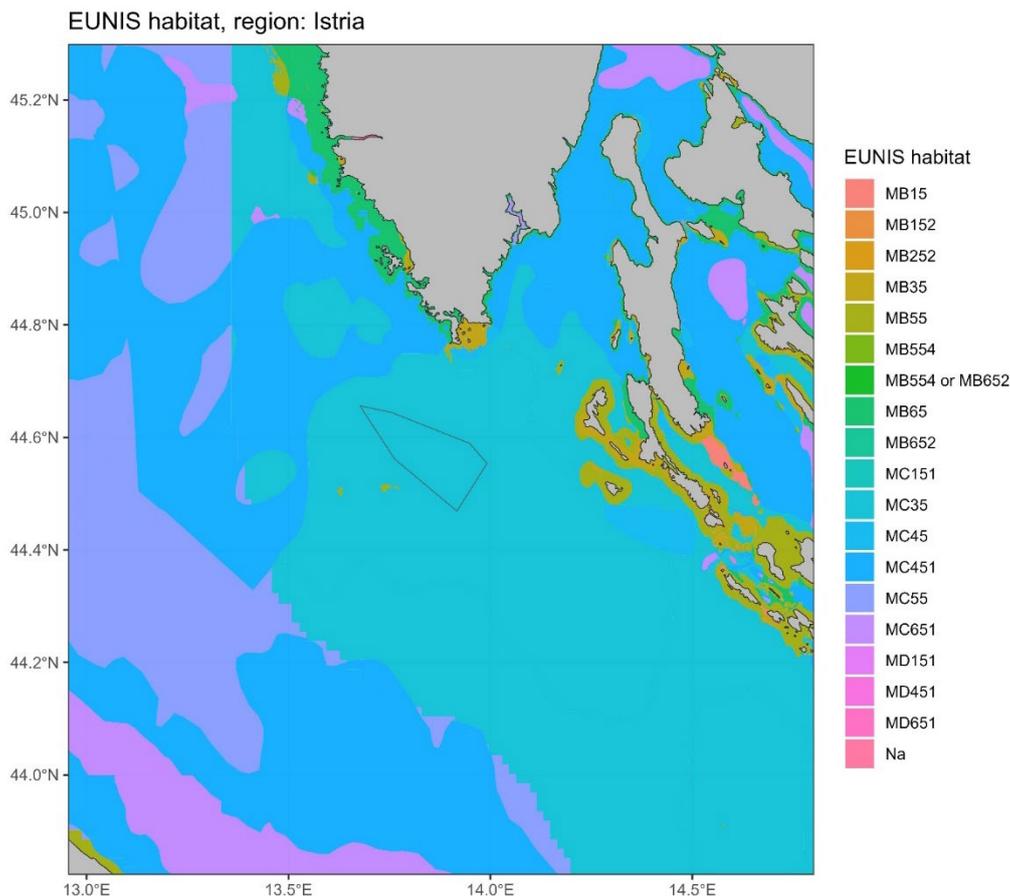


Figure 2.2.2 - EuSeaMap classification of bottom habitats in the Istria Region.



2.3 Seagrass habitats

Seagrass habitats for *Posidonia oceanica* and *Cymodocea nodosa* for the Istria Region (Fig. 2.3.1) show several coastal areas around the island of Losinj, Cres and the Istra peninsula where both *P. oceanica* and *C. nodosa* are present. Notably the two species have a prominent overlapping suitable area. It is worth noting that the area chosen for the OWF installation does not include any point on which these benthic species are or are possibly established in the region.

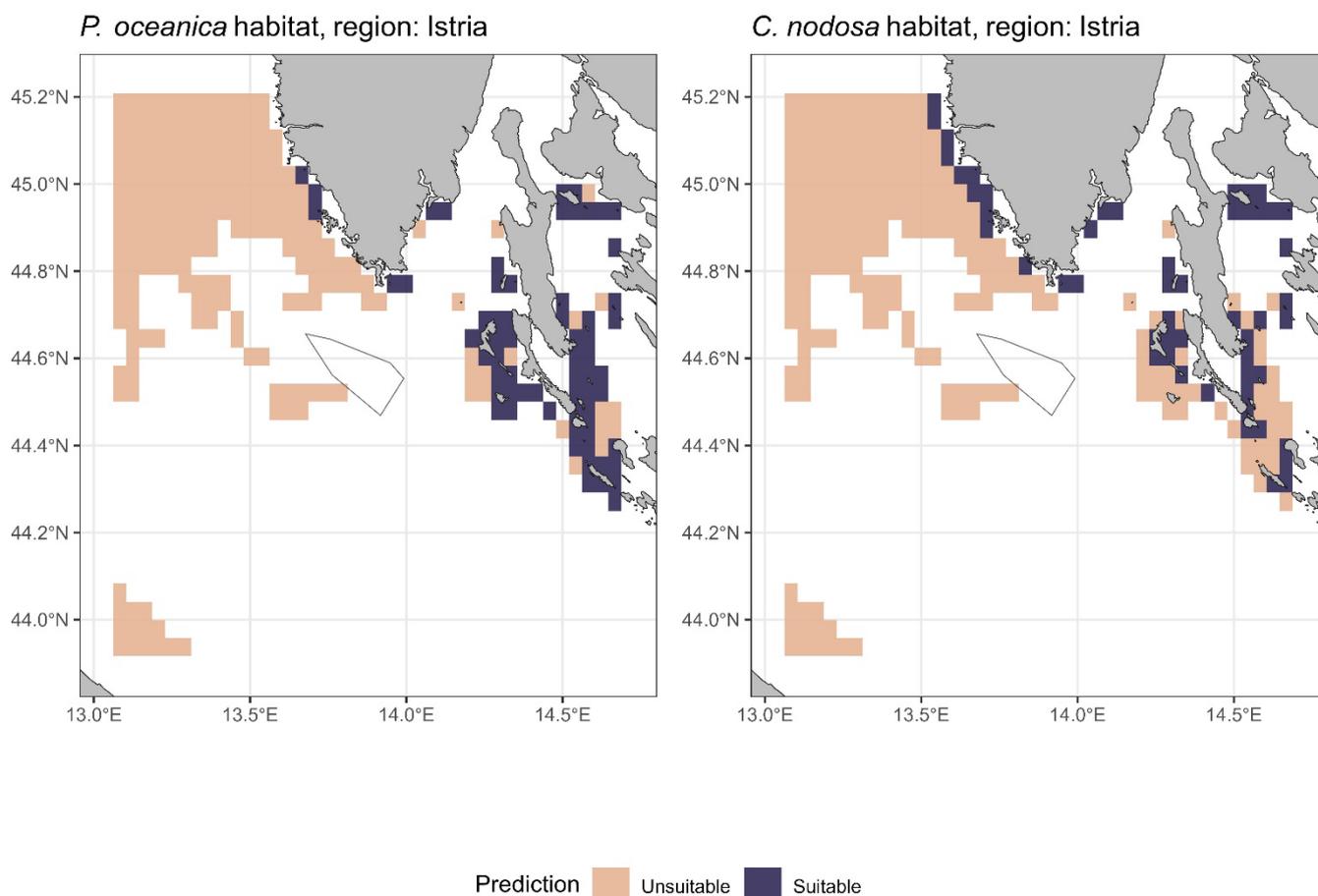


Figure 2.3.1 – Modelled distribution of *P. oceanica* and *C. nodosa* regarding unsuitable and suitable areas.



2.4 Benthic biodiversity

Unfortunately, benthic data for carrying a comprehensive analysis of benthic biodiversity are missing and OBIS and GBIF data regarding the presence/absence show scattered data points with generally a very low number of species ($\log N < 1$), especially offshore with data points as high as $\log N > 2$ inshore. In the area defined for future OWF, there is only one data point with a very low number of species ($\log N < 1$).

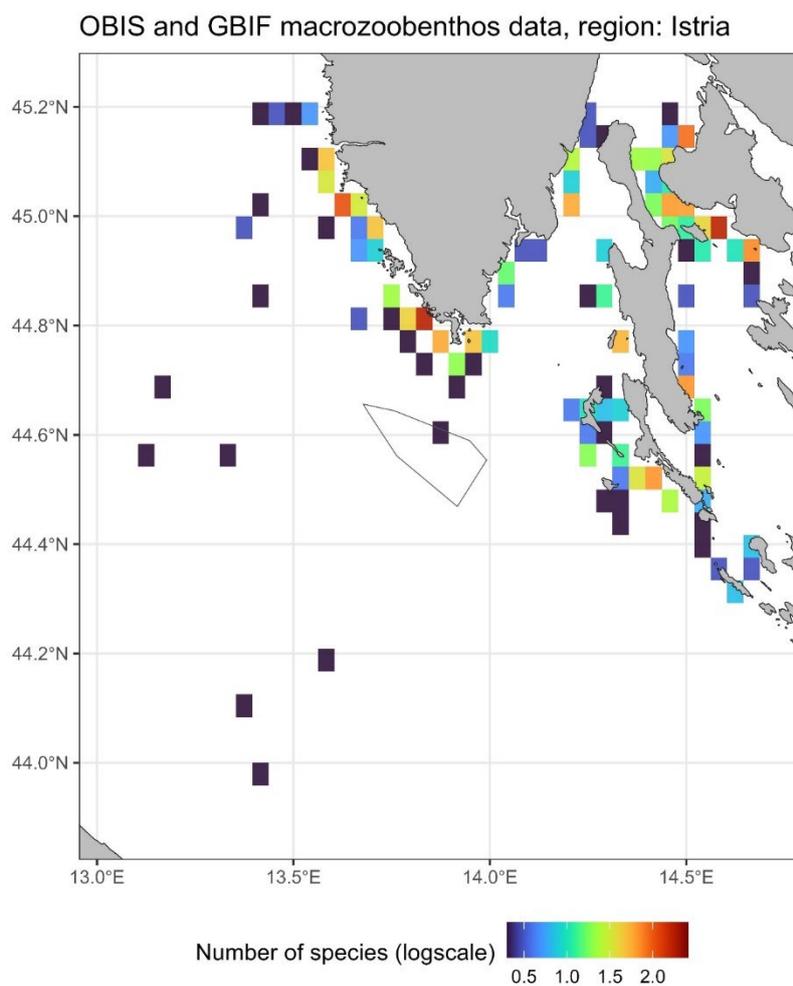


Figure 2.4.1 – Macrozoobenthos data from OBIS and GBIF for the Istria Region. Data coverage is very scattered, and sampling are reported in terms of richness (number of species).



2.5 Demersal species biomass and richness

Demersal species biomass in Istria shows a very high biomass hot spot in the central part of the Adriatic Sea in front of the region (Fig. 2.5.1). Peak biomass is in the order of 10^4 kg/km² (note the figure is in log scale). Biomass inside the OWF is on average 3.5 log kg/km² while the average across the region is 3 log kg/km² (Fig. 2.5.1). Richness in Istria displays a pattern with high values toward the centre of the Adriatic and lower values between the islands and close to the coast (Fig. 2.5.2). This pattern can have a relationship with the production pattern seen using chlorophyll-a as an indicator. The average number of species in the region numbers at approximately 24 while the OWF area shows a lower richness (22 species, see Fig. 2.5.2, boxplot). Overall, the OWF is placed in an area of intermediate-low richness value compared to the surroundings.

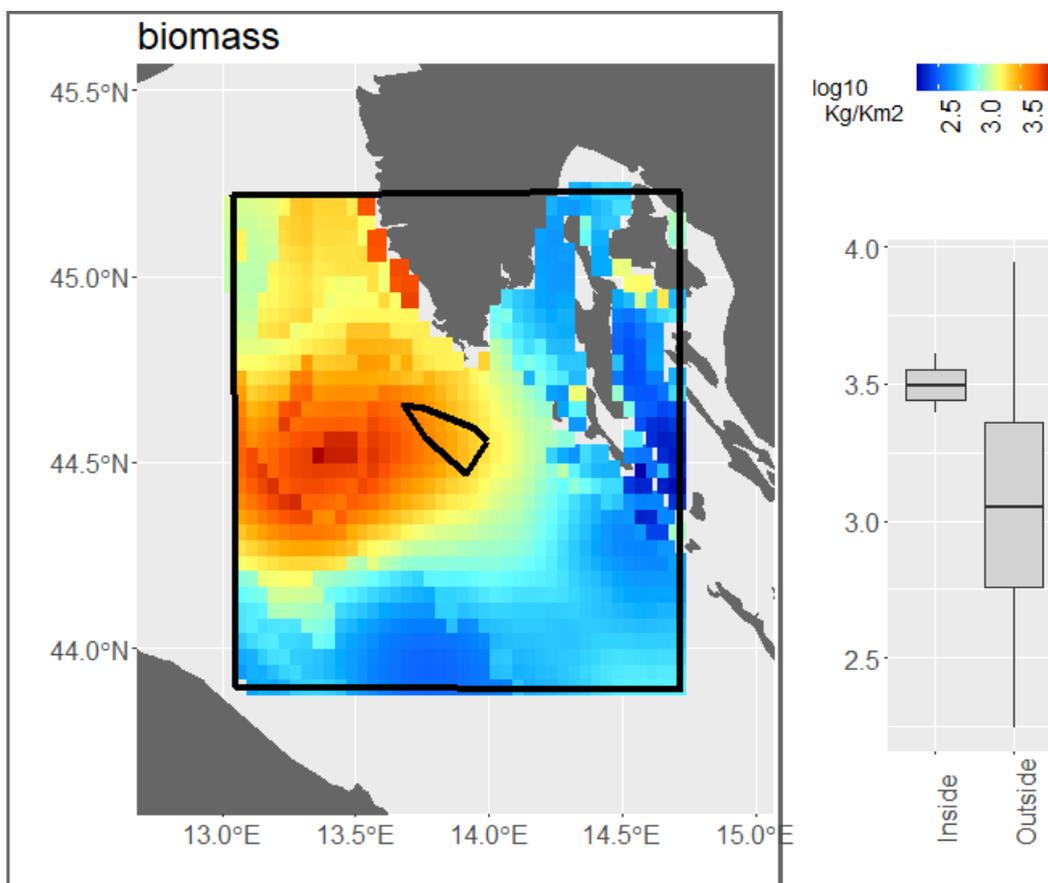


Figure 2.5.1 –Demersal species biomass for the Istria Region obtained from the GAMM model using the Medits trawl survey data. The scale is logarithmic.



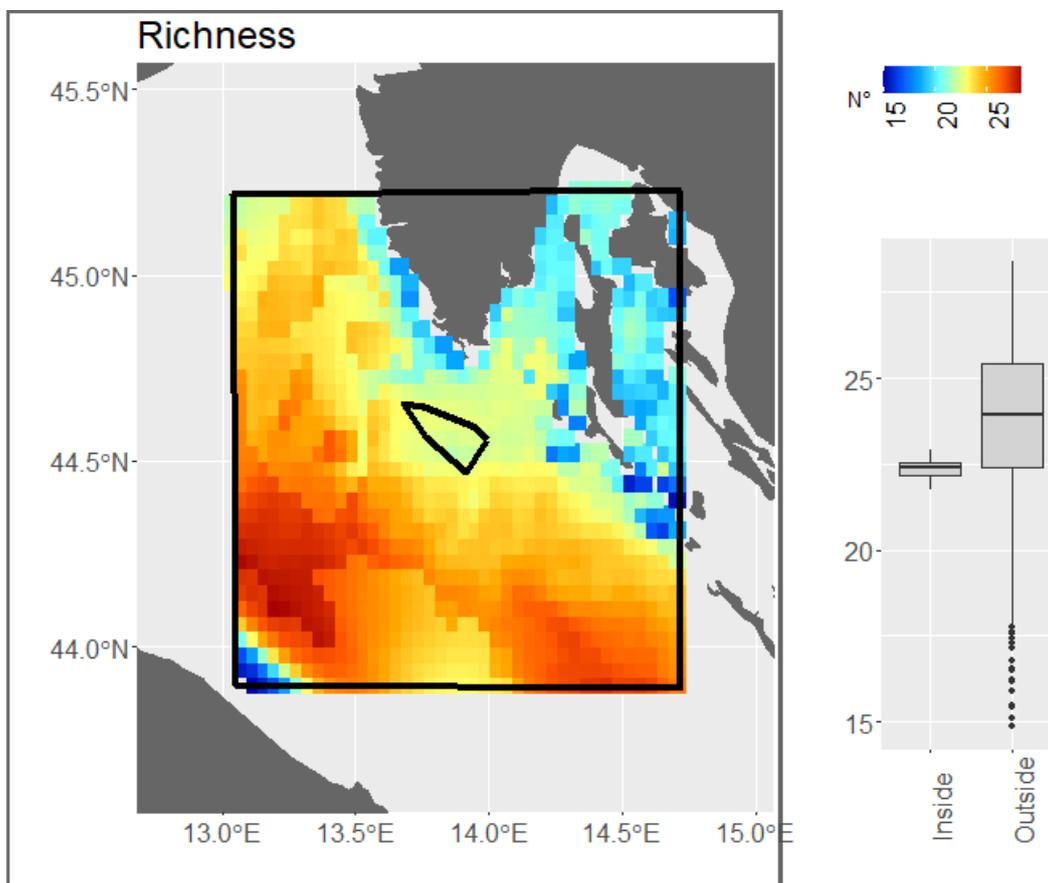


Figure 2.5.2 –Demersal species richness (number of species) for the Istria Region obtained from the GAMM model using the Medits trawl survey data.

2.6 Demersal species biodiversity and trophic level

Fish biodiversity considers both the number of species and their biomass (or abundance). Beta-diversity further use species and biomass considering also their degree of variability at the regional scale (here considering the Adriatic Sea). Results for the Istria Region indicate a clear pattern with high beta-diversity towards the centre of the Adriatic and few data with high beta-diversity along the coastline (Fig. 2.6.1). The average value of beta-diversity in the region is 0.55 while the OWF area is situated close to the area of high beta-diversity and accounts for 0.65 of beta-diversity. It is evident that the OWF is placed in an area partially overlapping with a rich biodiversity spot.

The average trophic level of the demersal community is reported in Fig. 2.6.2 and shows a low trophism in correspondence with the central Adriatic Sea in front of the Istrian Peninsula. So, the average trophic level inside the OWF is less than 3.25 while the average in across the region is 3.4 (Fig. 2.6.2). A very high trophic level of the demersal community is estimated in the area between the islands in Kvarner (Fig. 2.6.2).



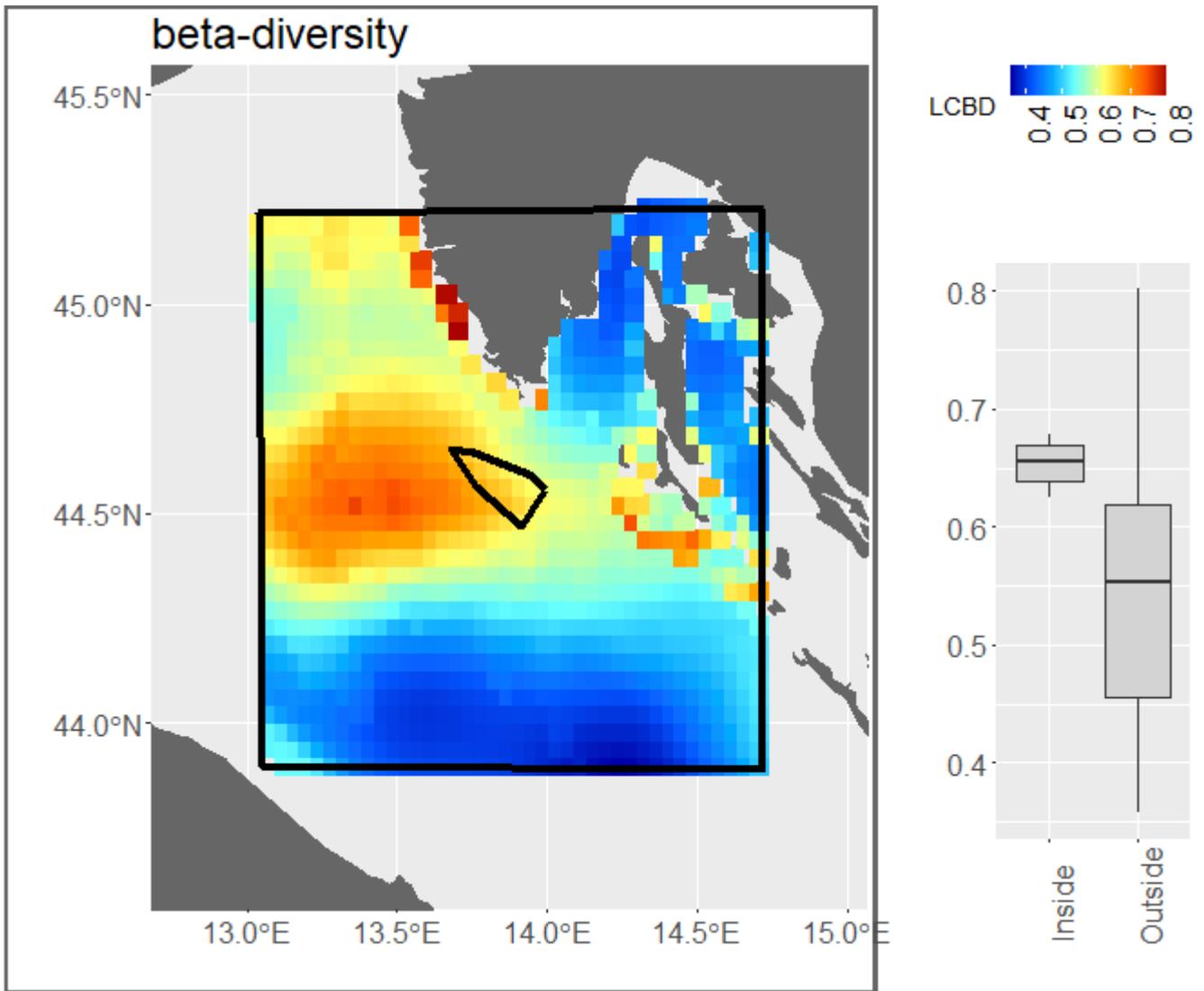


Figure 2.6.1 –Beta-diversity reconstructed for the Isthia Region using the Medits trawl survey data. Beta-diversity accounts both for the number of species and biomass, and is a measure of variability of the samples.



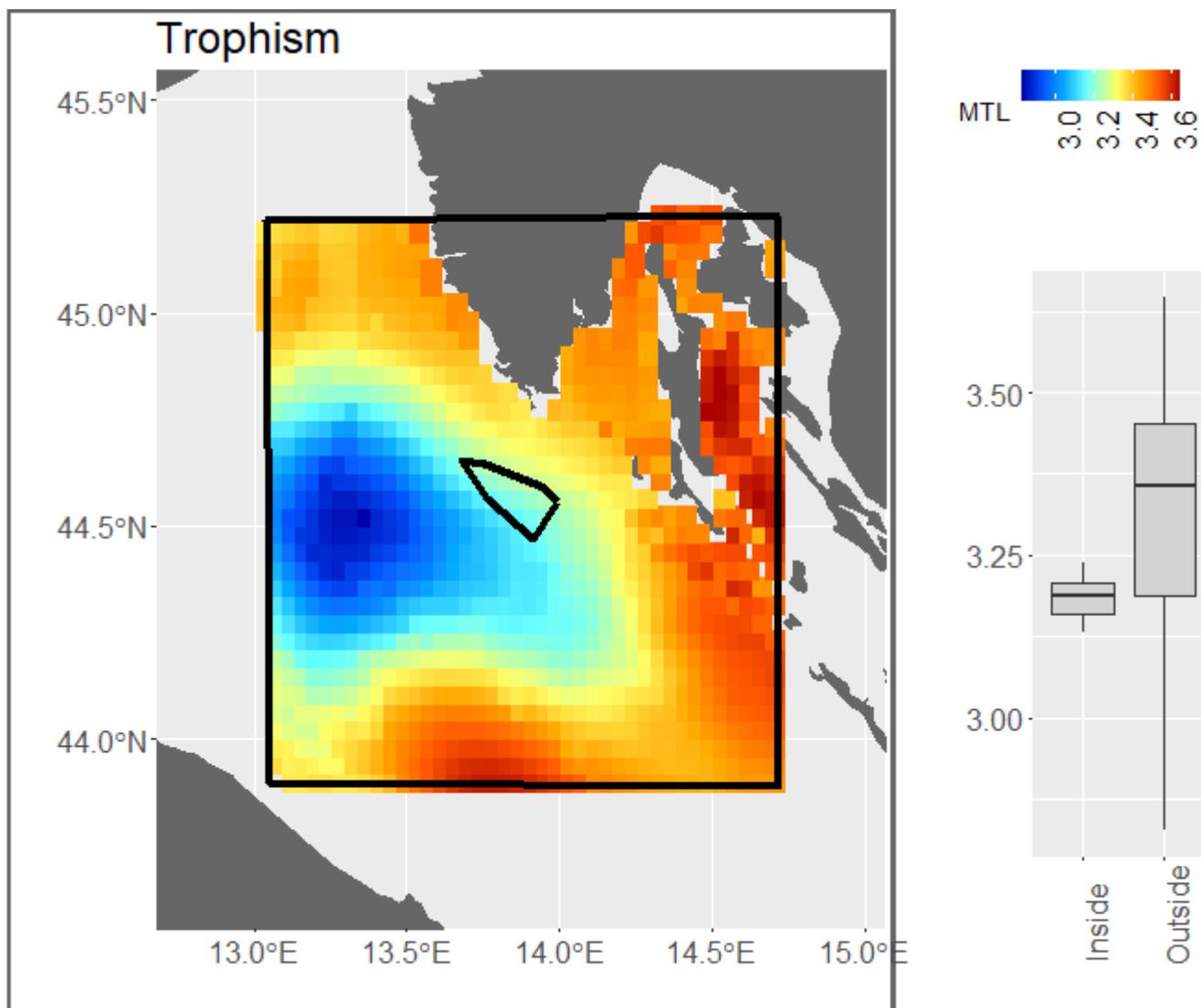


Figure 2.6.2 –Trophic level projections for the Istria Region obtained from the GAMM model using the Medits trawl survey data.

2.7 Marine mammal distribution

Sightings from 1986 to 2025 retrieved from GBIF show the sparse presence of dolphins (*T. truncatus*) in the Istria Region with a great number of sightings between Losinj-Cres and the other island of the archipelago (Fig. 2.7.1). With respect to the OWF area, no occurrence points are represented inside or in the surroundings. However, one limitation of these data is their reliance on occasional sightings, while systematic monitoring (see Fortuna et al., 2018) are outdated, but show high encounter rates in the whole area. More in depth analyses may need to be performed to clearly identify the role of this component in the Istria Region.



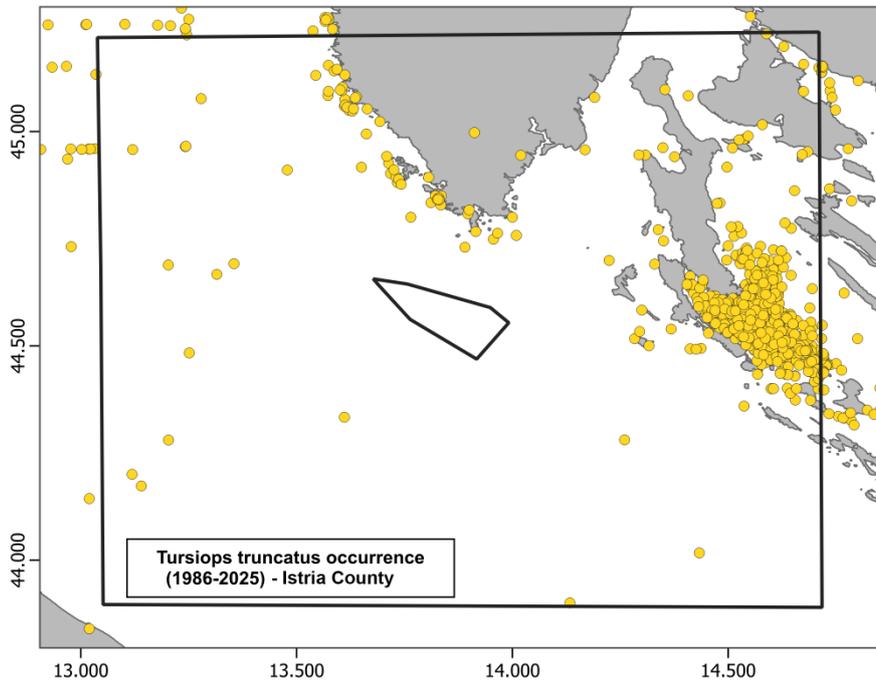


Figure 2.7.1 - *Tursiops truncatus* occurrence points from 1986 to 2025 in the Istria Region. The presence points were downloaded from GBIF (March 2025).

2.8 Seabird migration routes

Potential seabird site maps in the Istria Region (Fig. 2.8.1) extracted from the UNEP-MAP-RAC/SPA (2010) considers the pelagic distribution of seven pelagic Mediterranean endemic and near-endemic seabird species (listed in Table 1.8.1). The whole of Istria falls into the rank value of 2 (the lowest in the whole Adriatic Sea). Therefore, also the OWF area falls into this low rank of importance of the area for seabirds (Fig. 2.8.1).



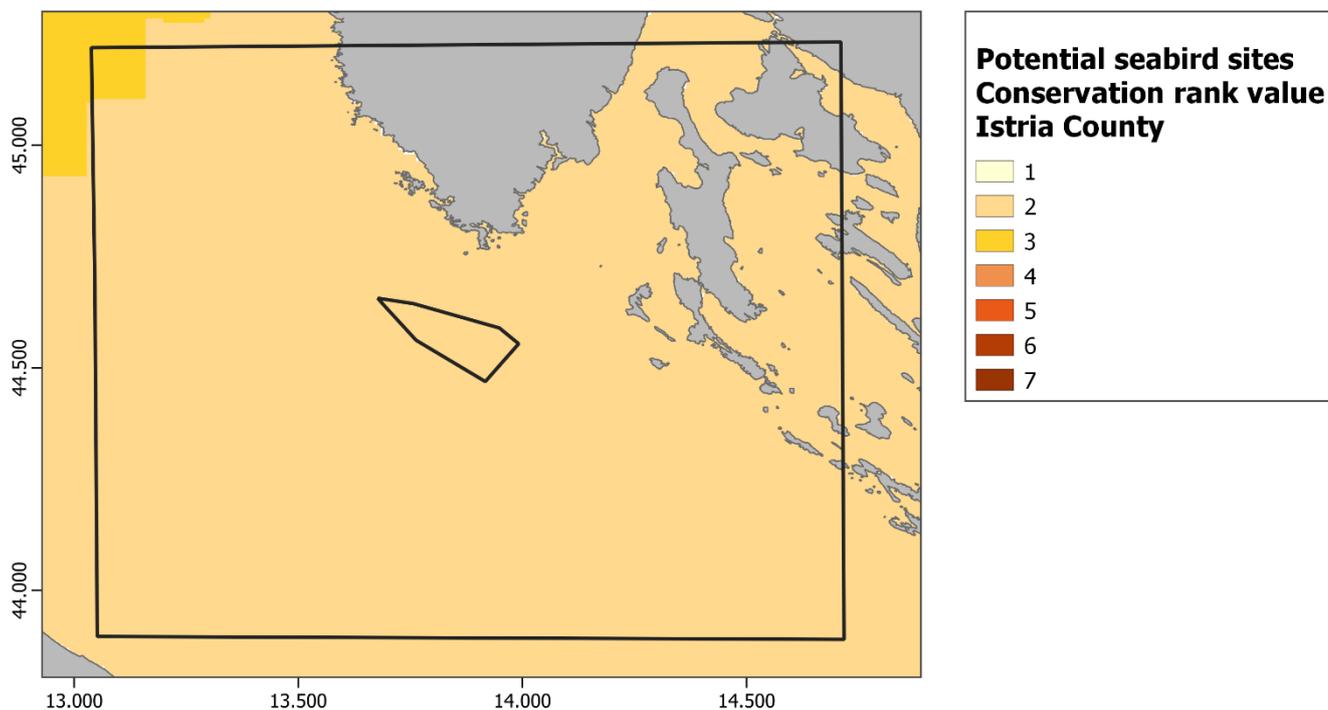


Figure 2.8.1 - Potential seabird sites in the Istria Region. The map was downloaded from <https://www.portodimare.eu/> and rescaled according to the map reported by UNEP-MAP (2010).

2.9 Sensitive & protected areas

Regarding sensitive and protected sites, the Istria Region is characterized by a high number of sites defined as Natura 2000 sites (Fig. 2.9.1), which basically involves all the islands of the Kvarner archipelago and large coastal strips around the tip of Istria and Losinj-Cres. Around Losinj and the southern part of Cres, moreover, a wide strip of sea is defined as “critical cetacean habitat” under ACCOBAMS (<https://accobams.org/conservations-action/protected-areas>), which confirms the importance of the area for this component (see section. 2.7). It is worth noting that several medium-small size marine sites are defined as Marine Protected Areas (MPA) within the national statute, including Brijuni MPA. Nevertheless, most of the Istria Region is of interest through the status of “Ecologically or Biologically Sensitive Area” (EBSA) (Fig. 2.9.1). The OWF site in Istria therefore, falls completely in the EBSA, although it is not touched by the most restrictive protection rules (MPAs). The OWF area is a few nautical miles from the Natura 2000 of the Istrian Peninsula.



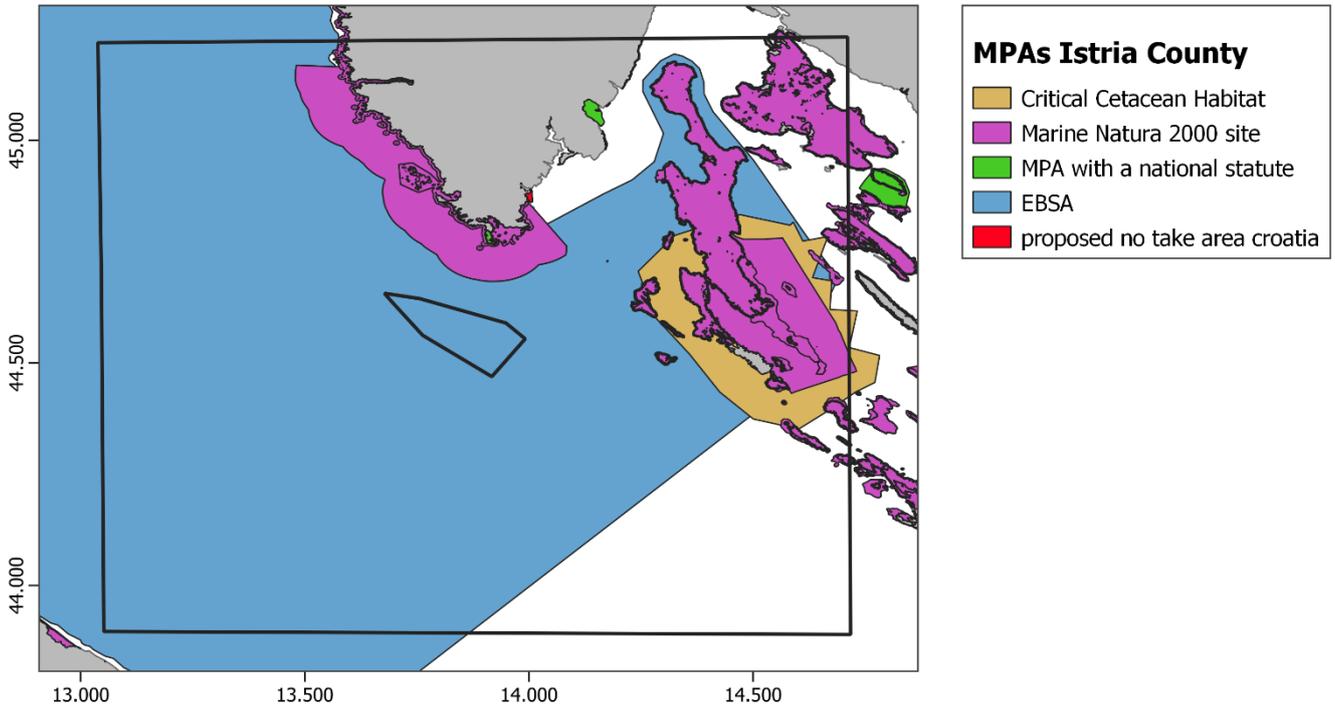


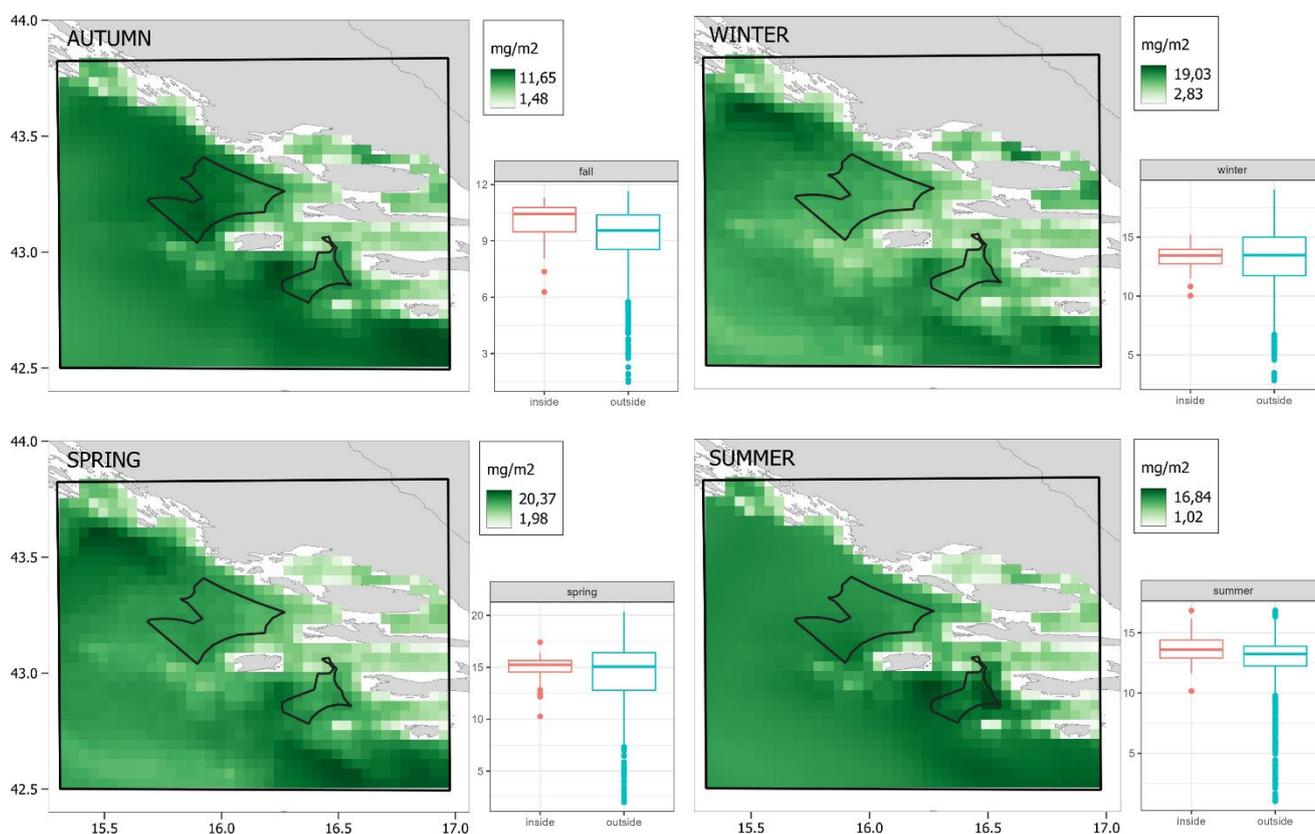
Fig. 2.9.1 -. Sensitive and marine protected areas in the Istria Region. Data source: mapamed.org, 2019 edition. The layer of the new proposed no take area in Istria (Ližnjan-Lisignano Sv. Stipan-Cuf) was provided by Doris Pajkovic of IRENA - Istrian Regional Energy Agency.



3. Split-Dalmatia Region

3.1 Water ecological characteristics

Chlorophyll-a concentration in Split-Dalmatia has a moderate seasonal signal (Fig. 3.1.1) with values around 15 mg Chl-a/m² throughout the year. The area identified for the OWF is divided into two parts by the Vis island and is characterized concentrations of chlorophyll in line with the surrounding regions (see box plots) in all seasons. In autumn and summer, the OWF selected zones have average concentrations that are slightly higher than those of the surroundings.



3.1.1. Map of chlorophyll in the Split region for each season in mg/m², inside and outside the region of interest. On the right side of each map a whisker boxplot of the value inside and outside the area.



3.2 Bottom habitats

Sediment grain size in Split-Dalmatia region has an average of approximately $\phi=4.5$. Notably the grain size in the area defined for OWF is slightly lower than of the regional range, i.e., it has an average of $\phi=4$, indicating grain sizes quite small, but relatively coarser in the area (Fig. 3.2.1). Also of interest is the fact that part of the OWF area south of Vis has a grain size finer than that of the northern part (coarser).

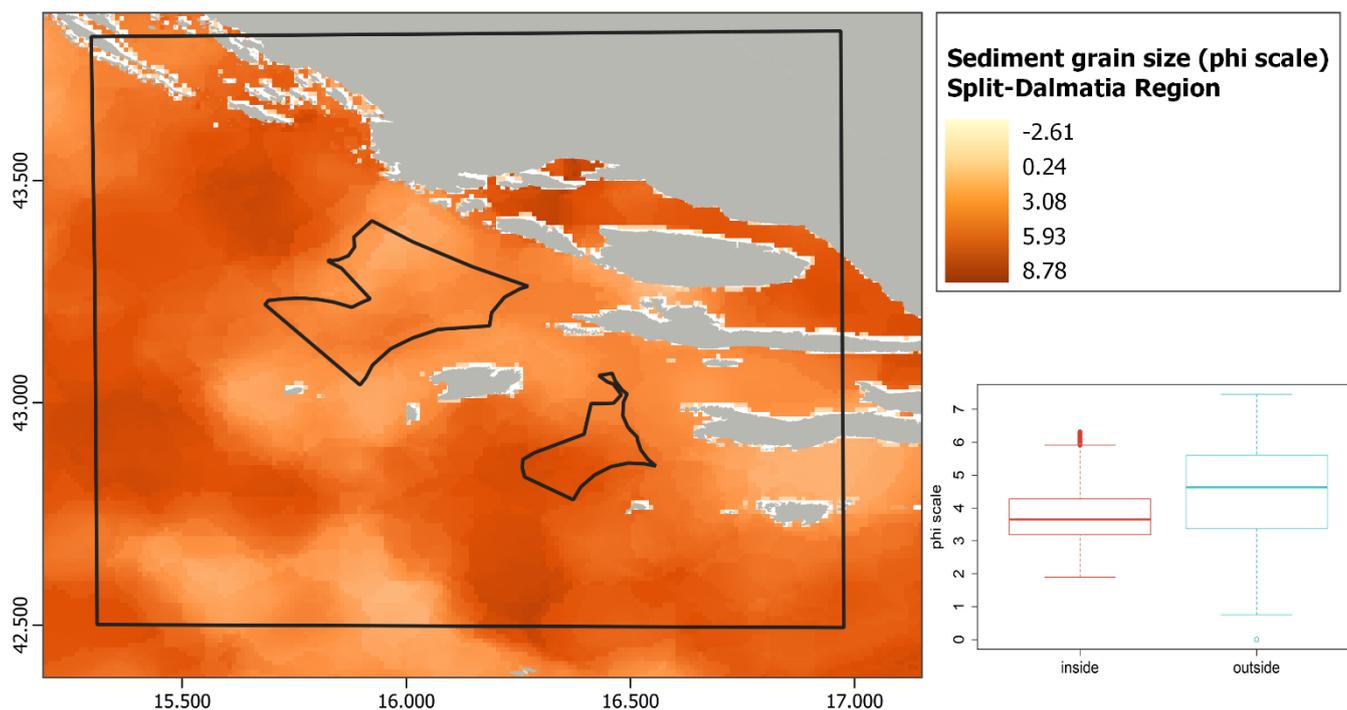


Figure 3.2.1 - Map of sediment grain size in Split-Dalmatia Region. Kindly provided by Dr Jenkins, University of Colorado (USA).

The EUNIS habitats mapped in the Split region (Fig. 3.2.2) are the following, in which the habitats within the proposed OWF area are marked with three asterisks (***):

- MB55: Mediterranean infralittoral sand***
- MC35: Mediterranean circalittoral coarse sediment***
- MD451: Biocenosis of Mediterranean open-sea detritic bottoms on shelf-edge***
- MB35: Mediterranean infralittoral coarse sediment***
- MC45: Mediterranean circalittoral mixed sediment***
- MB15: Mediterranean infralittoral rock***
- MC151: Coralligenous biocenosis***
- MB65: Mediterranean infralittoral mud***
- MC651: Biocenosis of Mediterranean circalittoral coastal terrigenous muds***
- MC451: Biocenosis of Mediterranean muddy detritic bottoms***
- MC55: Mediterranean Circalittoral sand



- MB252: Biocenosis of [*Posidonia oceanica*]***
- MD651: Biocenosis of Mediterranean offshore circalittoral coastal terrigenous muds***
- MD151: Biocenosis of Mediterranean shelf-edge rock***
- MF65: Mediterranean lower bathyal mud
- ME65: Mediterranean upper bathyal mud
- MB2531: Facies with [*Ficopomatus enigmaticus*]

EUNIS habitats are quite complex in the OWF defined area, but mostly related to muddy detritic bottoms, coarse sediment and to a minimal extent, circalittoral coastal terrigenous muds.

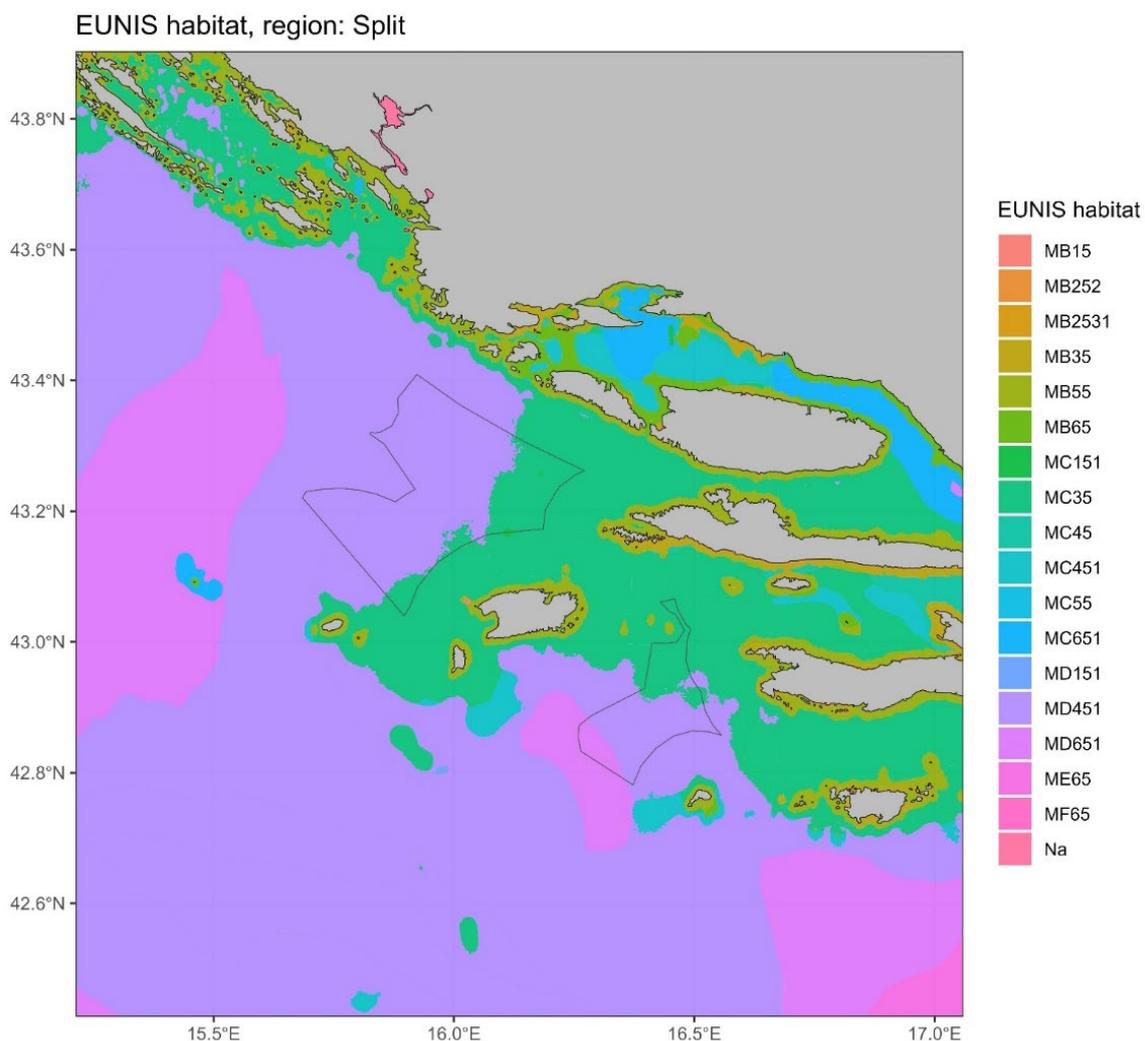


Figure 3.2.2 - EuSeaMap classification of bottom habitats in Split-Dalmatia region.



3.3 Seagrass habitats

Seagrass habitats for *Posidonia oceanica* and *Cymodocea nodosa* for Split – Dalmatia region (Fig. 3.3.1) show several coastal areas around the islands of Korcula, Vis and Brac where both *P. oceanica* and *C. nodosa* are present. Notably the two species do not overlap much with this area. It is worth noting that the areas chosen for the OWF installation do not include any point in which these benthic species are or are possibly established in the region.

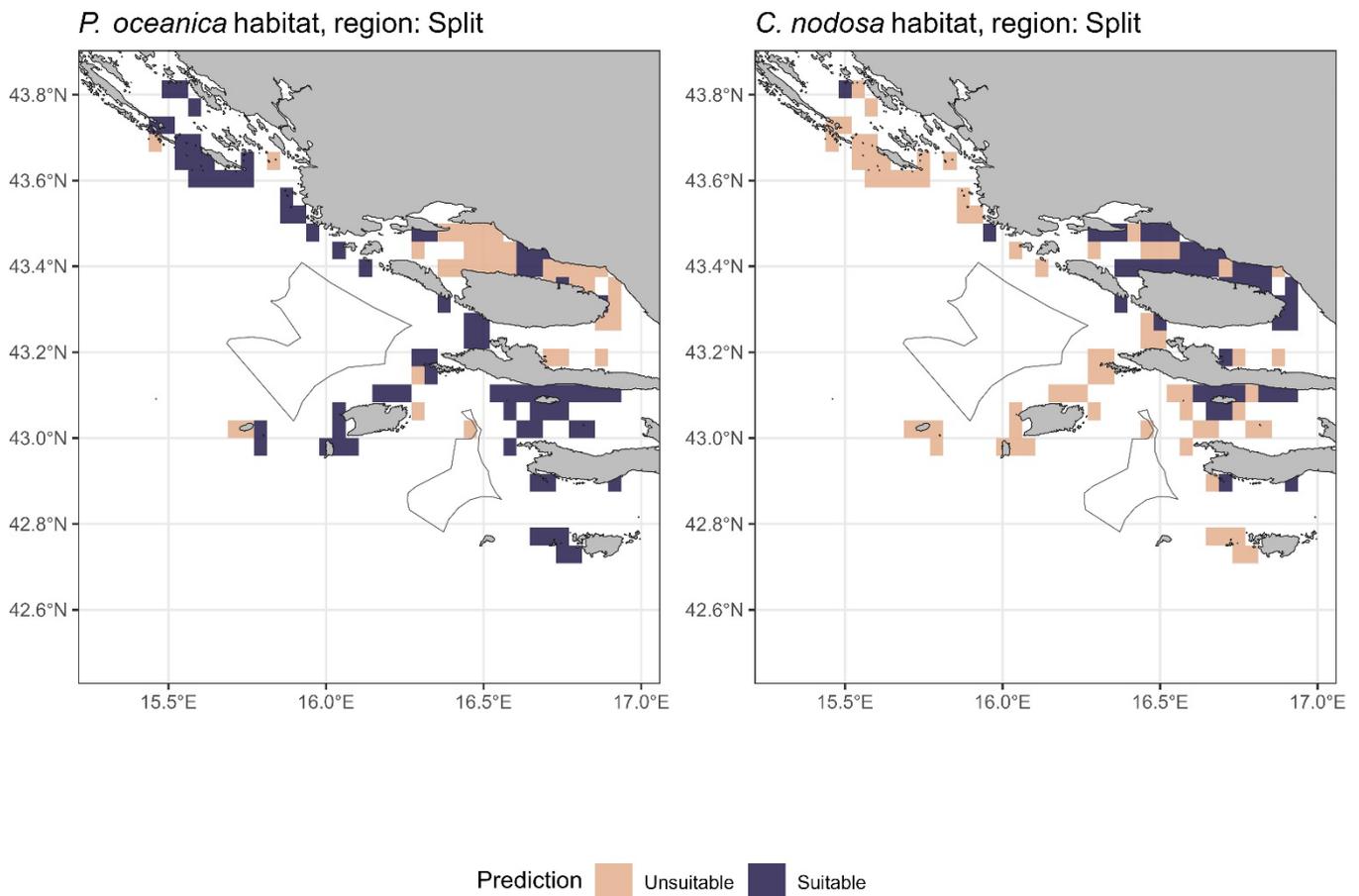


Figure 3.3.1 – Modelled distribution of *P. oceanica* and *C. nodosa* regarding unsuitable and suitable areas in Split – Dalmatia region.

3.4 Benthic biodiversity

Only scattered points are available for characterizing the benthic biodiversity from OBIS and GBIF. In the region species richness appears abundant, especially between the island and the mainland. The few data points in the area defined for future OWF indicate a very low number of species ($\log N < 1$), but it is worth noting that serious sampling should be done to assess the foreseen OWF, because too few data points were available for the whole area indicated for OWF.

OBIS and GBIF macrozoobenthos data, region: Split

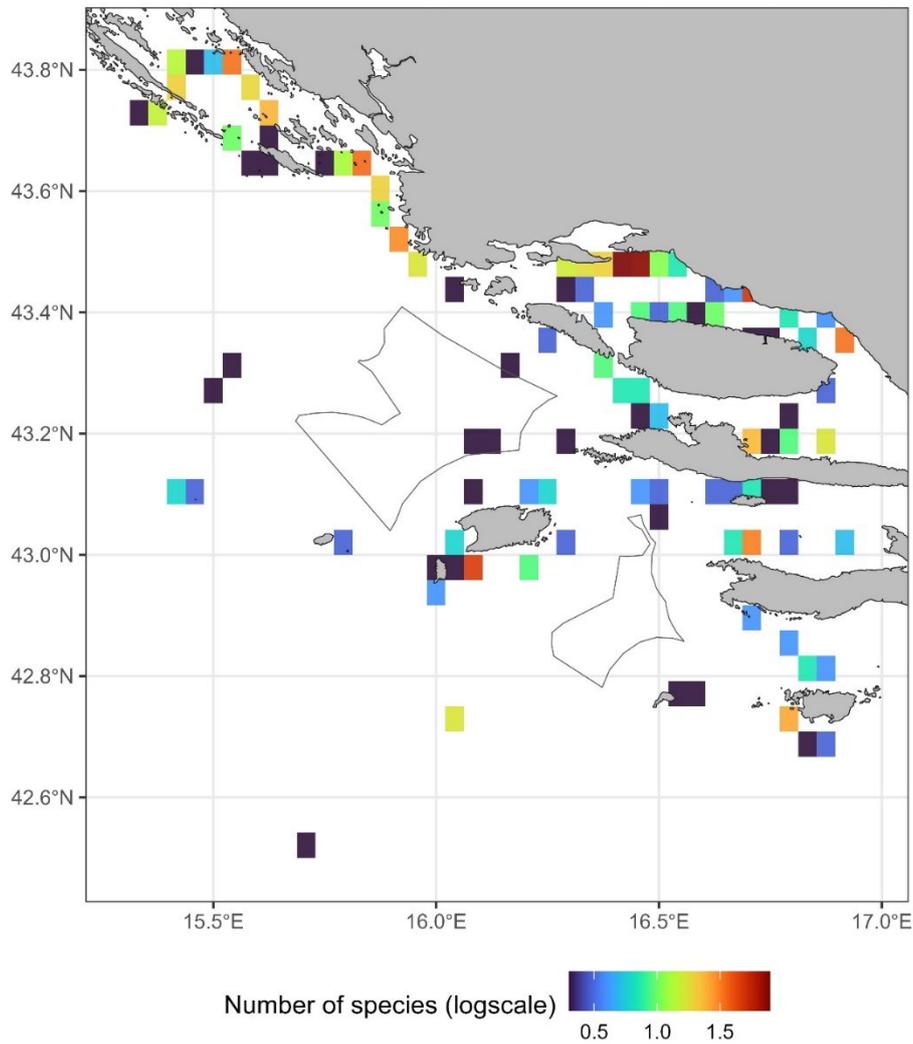


Figure 3.4.1 – Macrozoobenthos data from OBIS and GBIF for Split-Dalmatia region. Data coverage is very scattered, and sampling are reported in terms of richness (number of species).



3.5 Demersal species biomass and richness

Demersal species biomass in Split-Dalmatia region shows a low biomass in the order of 2.6 log kg/km² (Fig. 3.5.1). Peak biomass is in the order of 10³ kg/km² (note the figure is in log scale) and can be found along the coast, but not included in the OWF site (Fig. 3.5.1). Richness of the demersal community in Split-Dalmatia region displays a pattern with high values toward the southern part of the domain (up to 32 species) and generally a low intermediate number of species in the deep offshore areas (N=20; Fig. 3.5.2). This pattern can have a relationship with winter and spring production patterns seen using chlorophyll-a as an indicator. The average number of species in the region is approximately 25 while the OWF areas have an intermediate-high richness, placing them further up in the range of the region although with a similar average (26 species). Overall, the OWF is placed in an area of an intermediate-high richness value compared to the surroundings (Fig. 3.5.2).

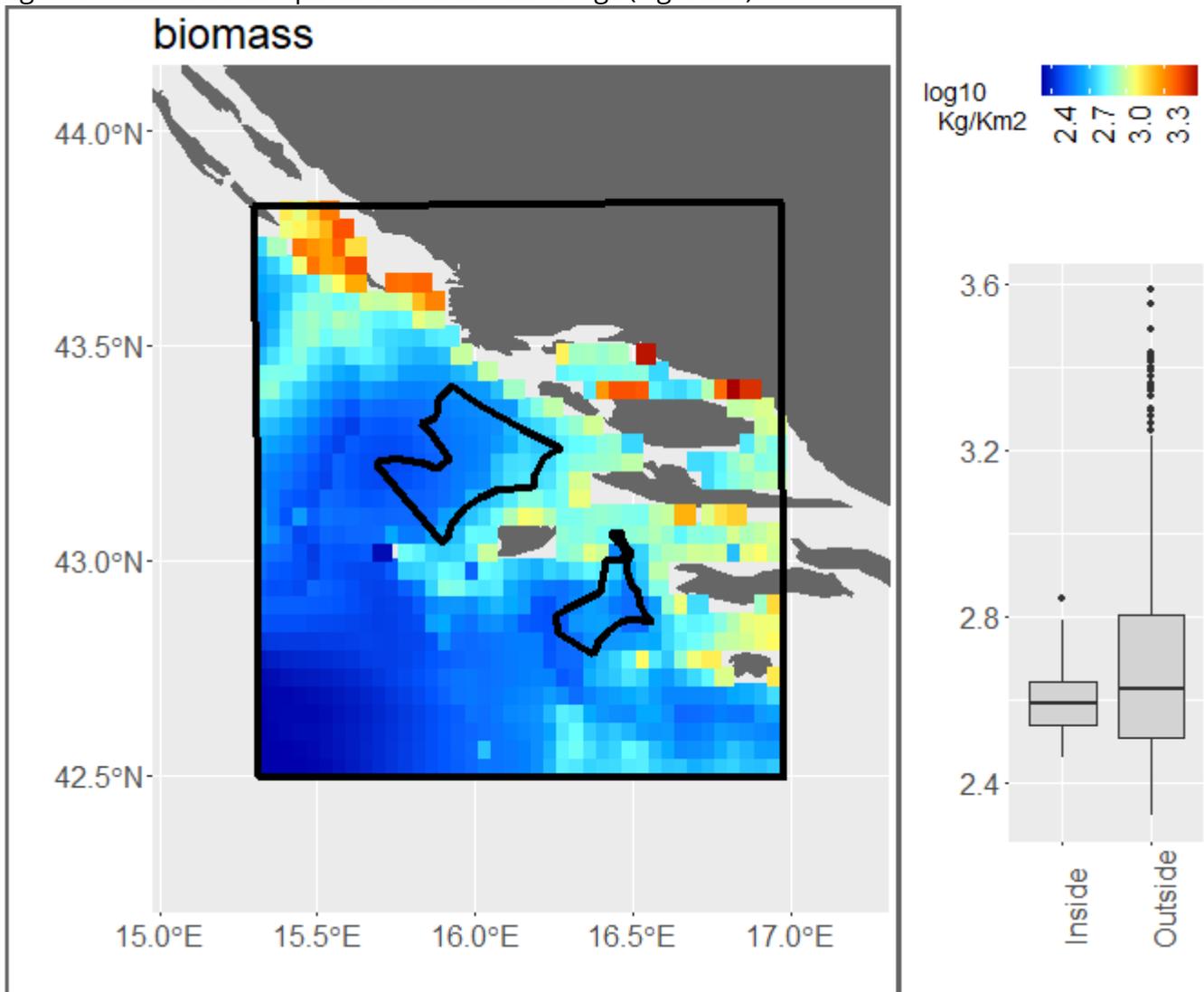


Figure 3.5.1. - Demersal species biomass for Split-Dalmatia region obtained from the GAMM model using the Medits trawl survey data. The scale is logarithmic.



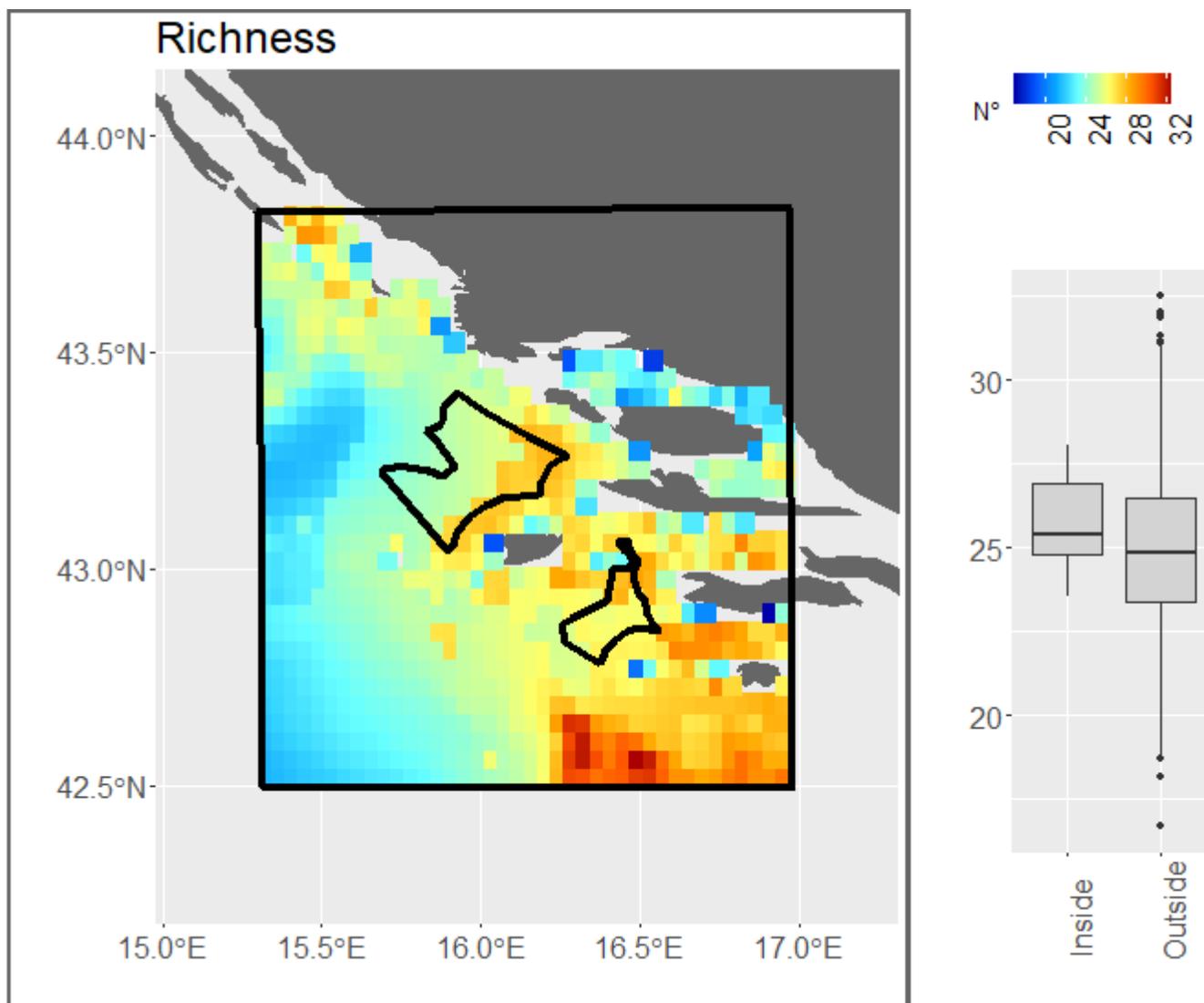


Figure 3.5.2 – Fish species richness (number of species) reconstructed for Split-Dalmatia region using the Medits trawl survey data.

3.6 Demersal species biodiversity and trophic level

Fish beta-diversity considers both number of species and their biomass, taking into account their degree of variability at the regional scale: the beta-diversity in Split-Dalmatia region is calculated using the whole Adriatic Sea as a reference (Fig. 3.6.1). Results for region indicate a high beta-diversity in a few spots close to the islands (Brač, Vis, Korčula) while more stable-low biodiversity in the areas north and south of Vis, coinciding almost with the OWF sites (Fig. 3.6.1). The average value of beta-diversity in the region is thus quite low 0.43 while the OWF area falls close to the area of low beta-diversity and accounts for 0.38 of beta-diversity.



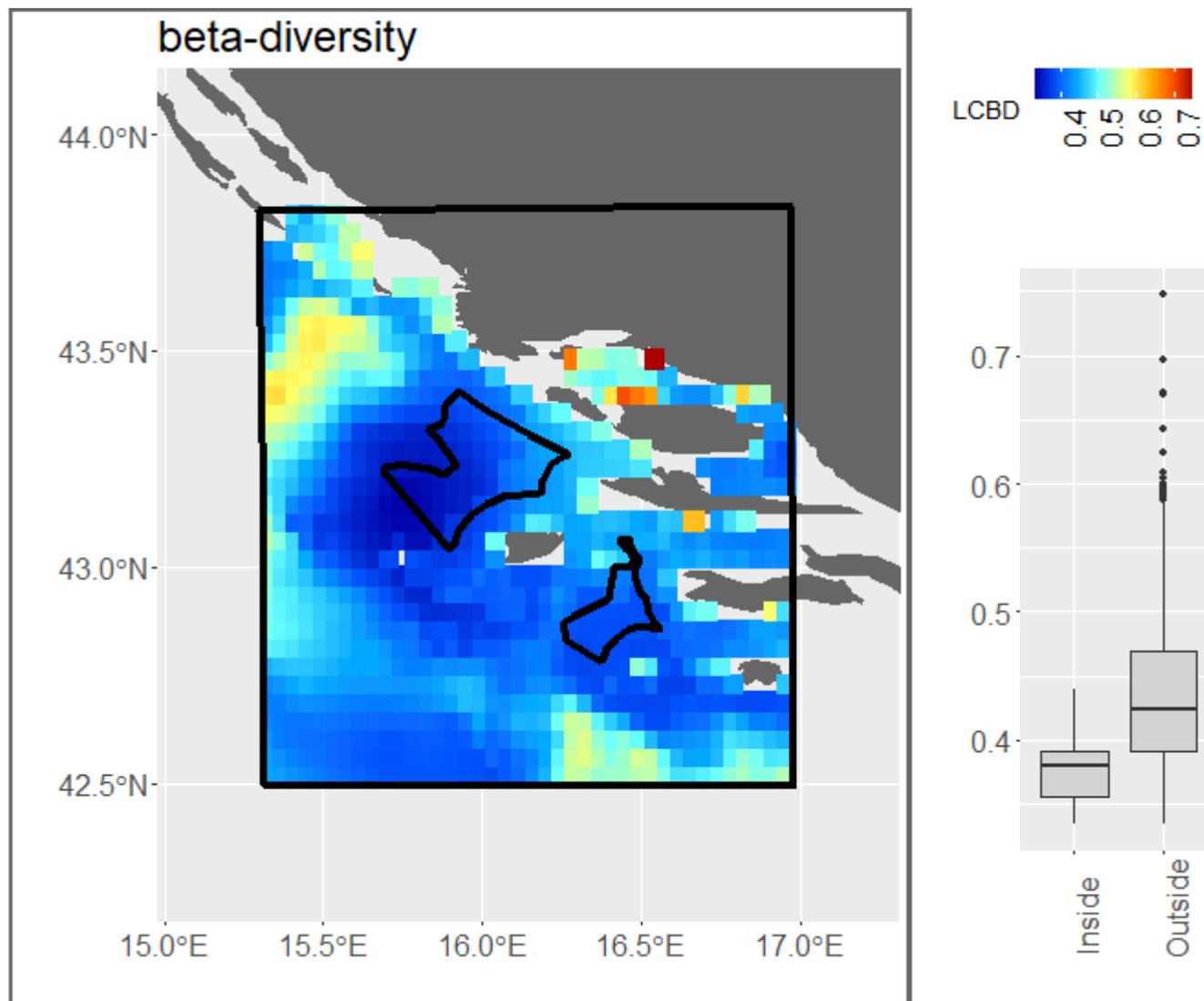


Figure 3.6.1 –Beta-diversity reconstructed for Split-Dalmatia region using the Medits trawl survey data. Beta-diversity accounts both for the number of species and biomass, and is a measure of variability of the samples.

The average trophic level of the demersal community is reported in Fig. 3.6.2 and shows a low trophism in correspondence with the coast and higher trophic level toward the centre of the Adriatic Sea. So, the average trophic level inside the OWF is less than 3.7 while the average in Split-Dalmatia region is 3.8 (Fig. 3.6.2). ery high trophic level of the demersal community is estimated in the area close to Pomo pit (Fig. 3.6.2).



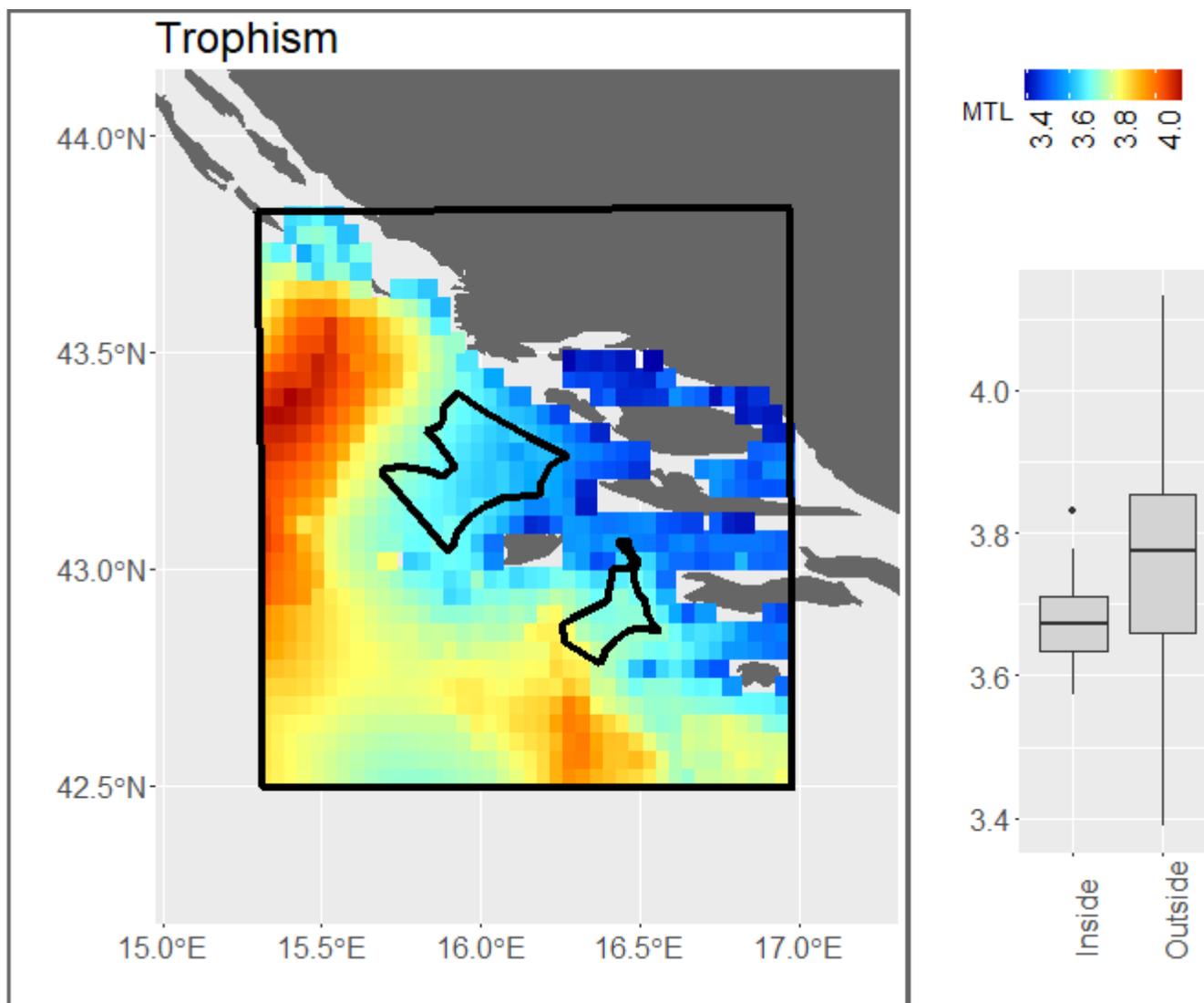


Figure 3.6.2 –Trophic level projections for Split-Dalmatia region obtained from the GAMM model using the Medits trawl survey data.

3.7 Marine mammal distribution

Marine mammal sightings from 1986 to 2025 retrieved from GBIF show the sparse presence of dolphins (*T. truncatus*) in Split – Dalmatia region with occurrences especially in the outer part of the islands (Fig. 3.7.1). With respect to the OWF area, only one occurrence point was reported in the southern part. However, considering the limitations of these observations (not necessarily resulting from systematic monitoring), these results should be accepted with caution with the recommendation to perform additional analyses.



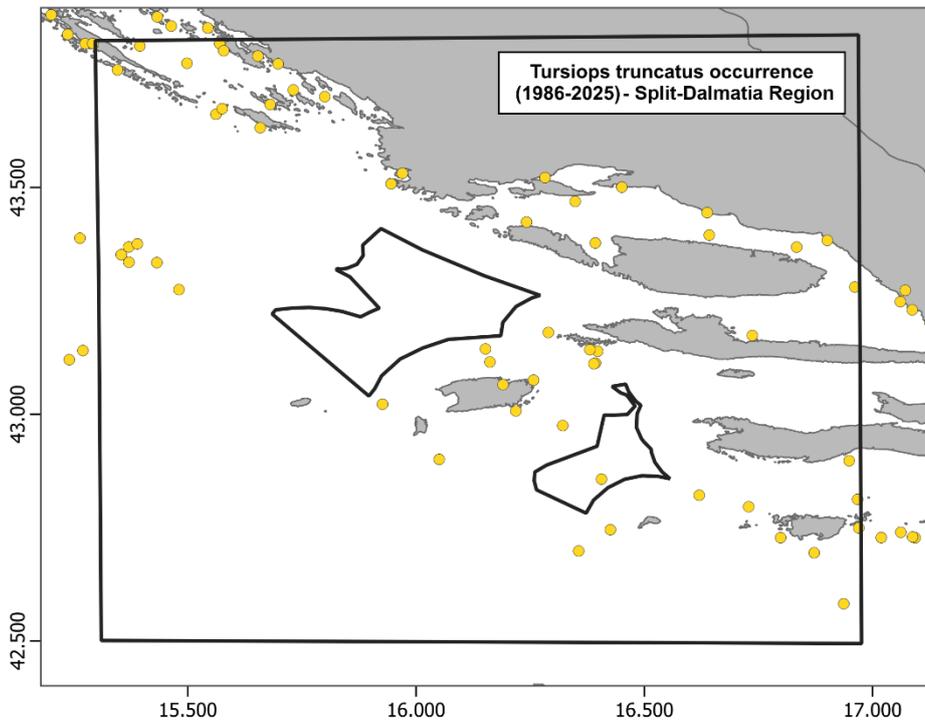


Figure 3.7.1 - *Tursiops truncatus* occurrence points from 1986 to 2025 in Split-Dalmatia Region. The presence points were downloaded from GBIF (March 2025).

3.8 Seabird migration routes

The map of potential seabird site maps in Split-Dalmatia region (Fig.3.8.1) extracted from the UNEP-MAP-RAC/SPA (2010) considers the pelagic distribution of seven pelagic Mediterranean endemic and near-endemic seabird species (listed in Table 1.8.1). Split-Dalmatia falls into an area with high-ranking values in large portions: the highest ranking for the whole Adriatic Sea falls in this region. The OWF area also falls into quite a high-ranking area for seabirds: the northern part of the OWF is classified as rank order 4 and the part of OWF south of Vis,5 (Fig. 3.8.1).



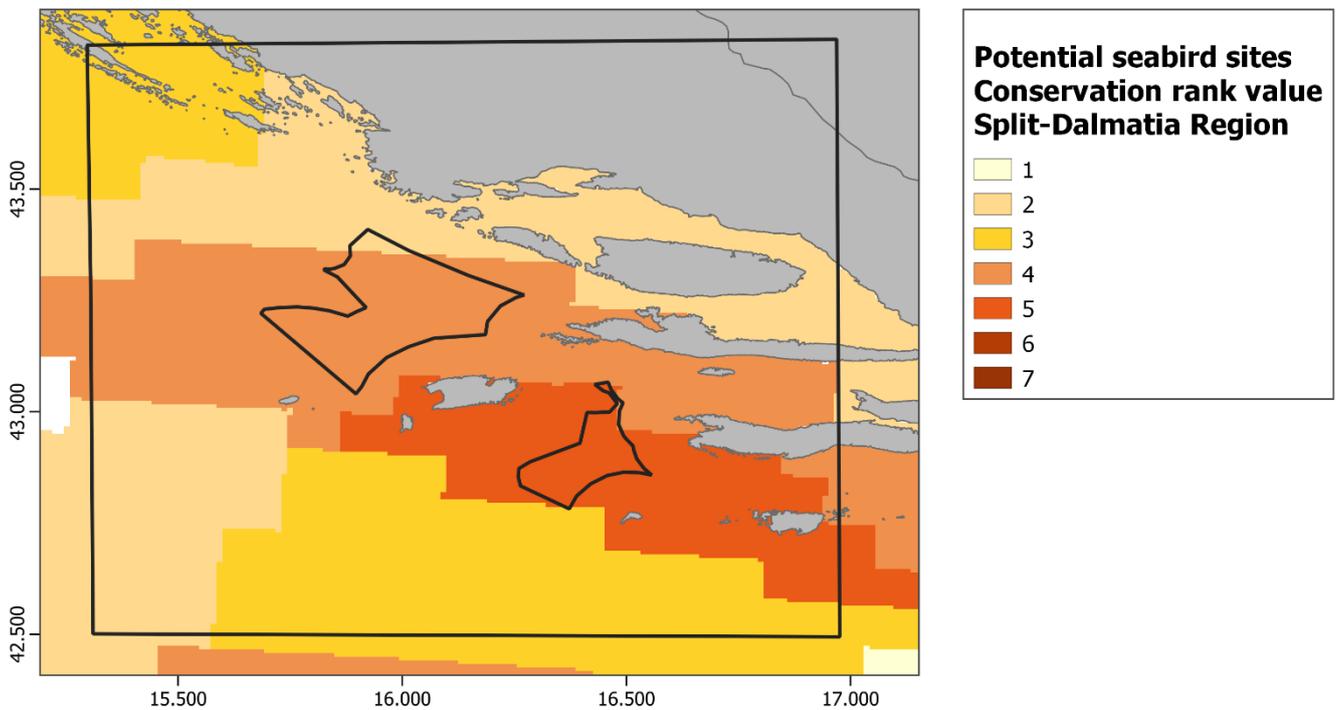


Figure 3.8.1 - Potential seabird sites in Split-Dalmatia Region. The map was downloaded from <https://www.portodimare.eu/> and rescaled according to the map reported by UNEP-MAP (2010).

3.9 Sensitive & protected areas

Split-Dalmatia region has several sensitive and protected sites that include Natura 2000 marine areas around Vis and the southern islands (Fig. 3.9.1). Moreover, in this region there is a large part of the Pomo Pit that falls under a Fisheries Restricted Area (FRA), and other Ecologically or Biologically Sensitive Areas (EBSA), especially close to the Pomo Pit zone. A MPA is also placed in the Kornati islands in the northern part of the region (see Fig. 3.9.1). Despite these distributed sensitive and protected areas, none (MPAs, Natura 2000 etc) overlap with the chosen OWF area for Split-Dalmatia and only the Pomo Pit FRA borders the OWF in the part north of Vis Island (Fig. 3.9.1).



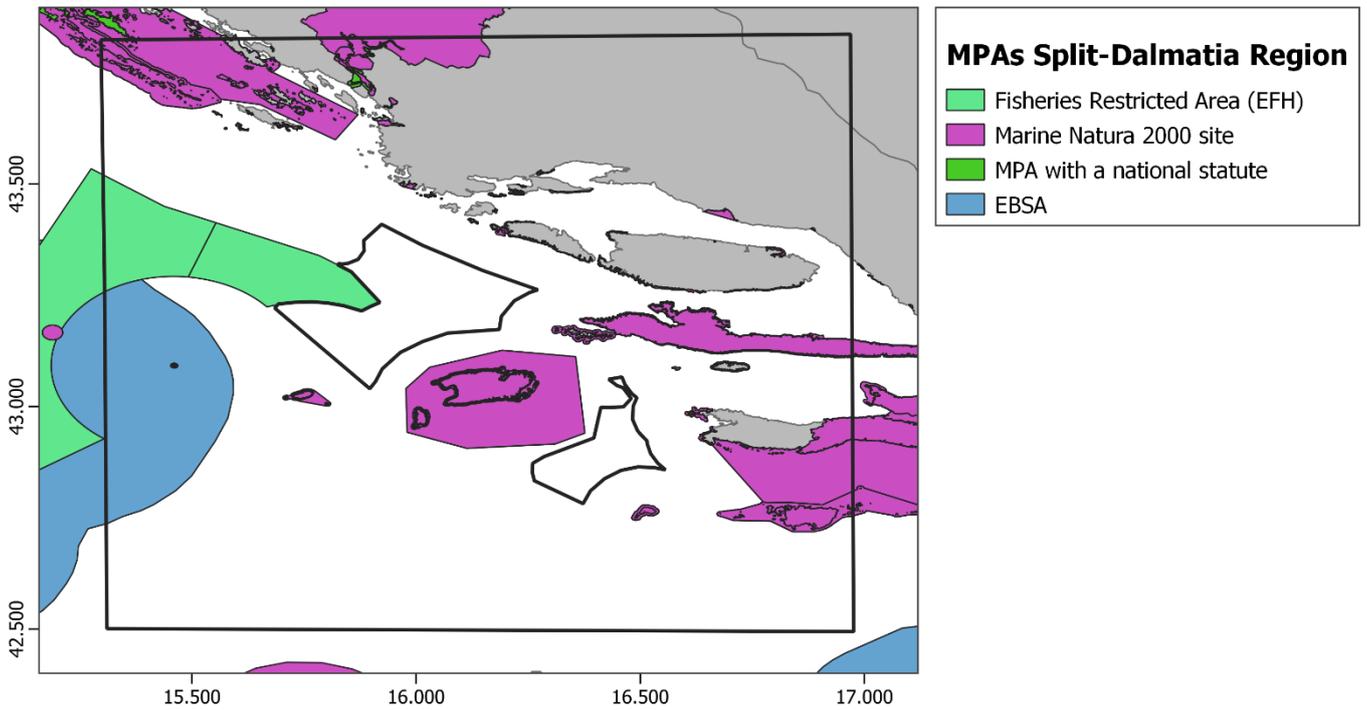


Figure 3.9.1 - Sensitive and Marine Protected Areas in Split-Dalmatia Region. Data source: mapamed.org, 2019 edition. Some marine Natura 2000 sites were integrated with data from protectedplanet.net (2024).



4. Veneto Region

4.1 Water ecological characteristics

Chlorophyll-a concentration in the region has a seasonal signal (see colour scale and box plots in Fig. 4.1.1) with a lower level occurring typically in summer (average 7 mg Chl-a/m²): the high productivity in the area (average across all other seasons is close to 10 mg Chl-a/m²) is also due to the high influence of this region by the Po River outflow. The area identified for the OWF is characterized by concentrations of chlorophyll similar within the range of the surroundings and with similar averages for autumn, winter and spring. The summer average (approximately 6 mg Chl-a/m²) falls in the lower range of that observed in the surroundings, which is approximately 7 mg Chl-a/m².

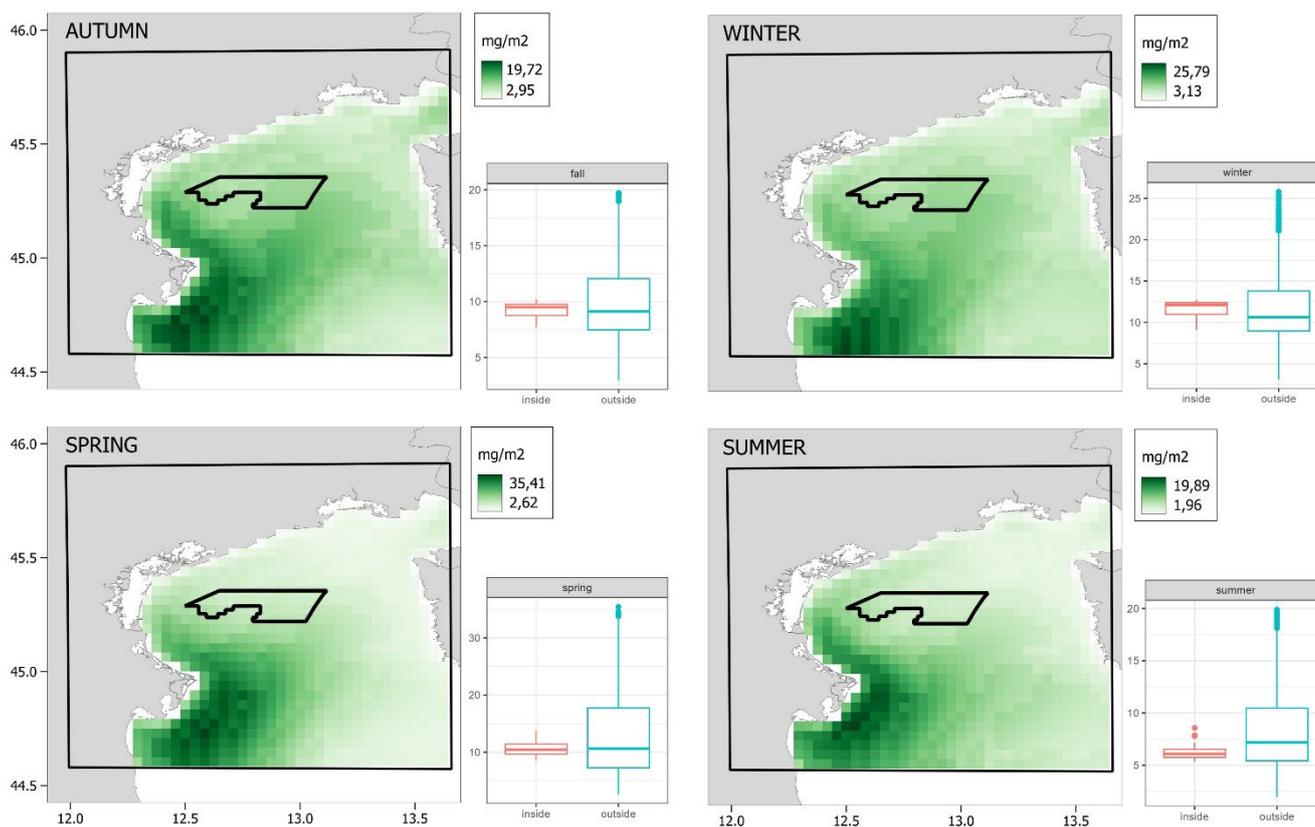


Figure 4.1.1. Map of chlorophyll in the Veneto Region for each season in mg/m², inside and outside the region of interest. On the right side of each map is a whisker boxplot of the value inside and outside the area.



4.2 Bottom habitats

Sediment grain size in the Veneto Region has an average of approximately $\phi=3.5$ while the area defined for OWF has a very slightly lower average of $\phi=3$ (Fig. 4.2.1), indicating coarse grain sizes in the area (on average). Notably, the part of the OWF area that is located more offshore has a grain size smaller (ϕ bigger) than that of the part of the OWF area close to the coast. Very close to the coast the ϕ reaches very high values (especially close to Po River delta), indicating mud or very fine particles.

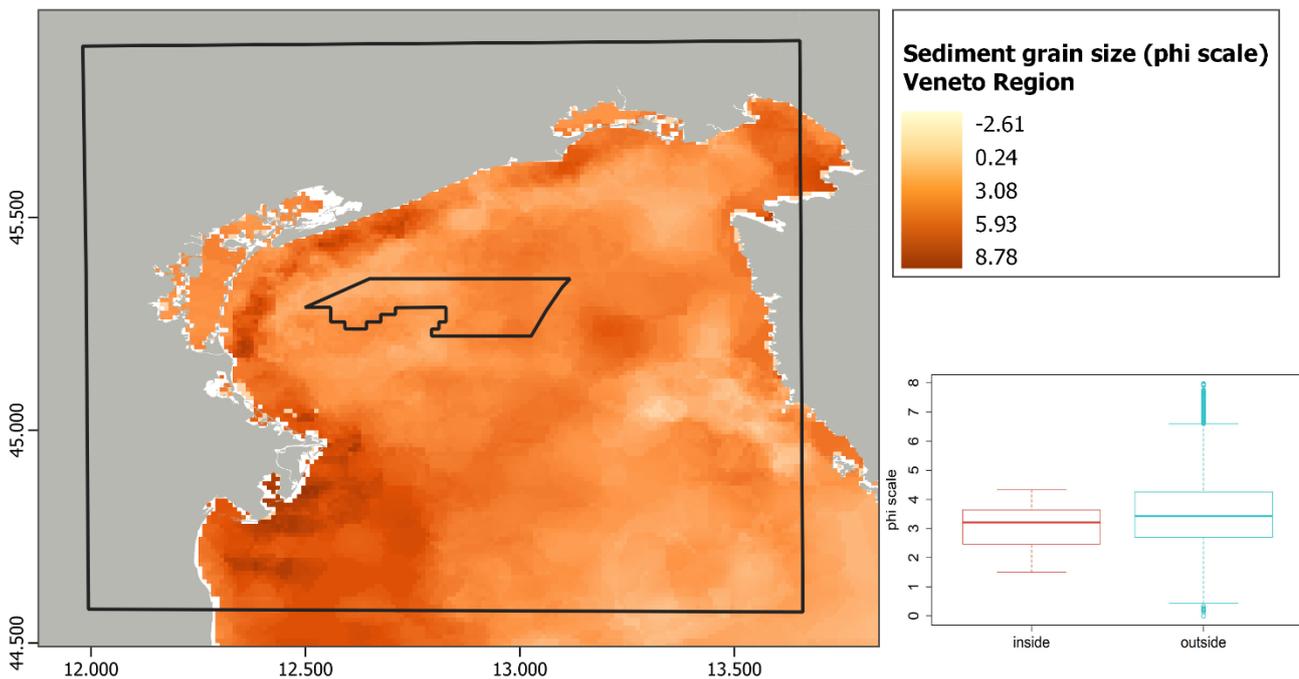


Fig. 4.2.1 - Map of sediment grain size in the Veneto Region. Kindly provided by Dr Jenkins, University of Colorado (USA).

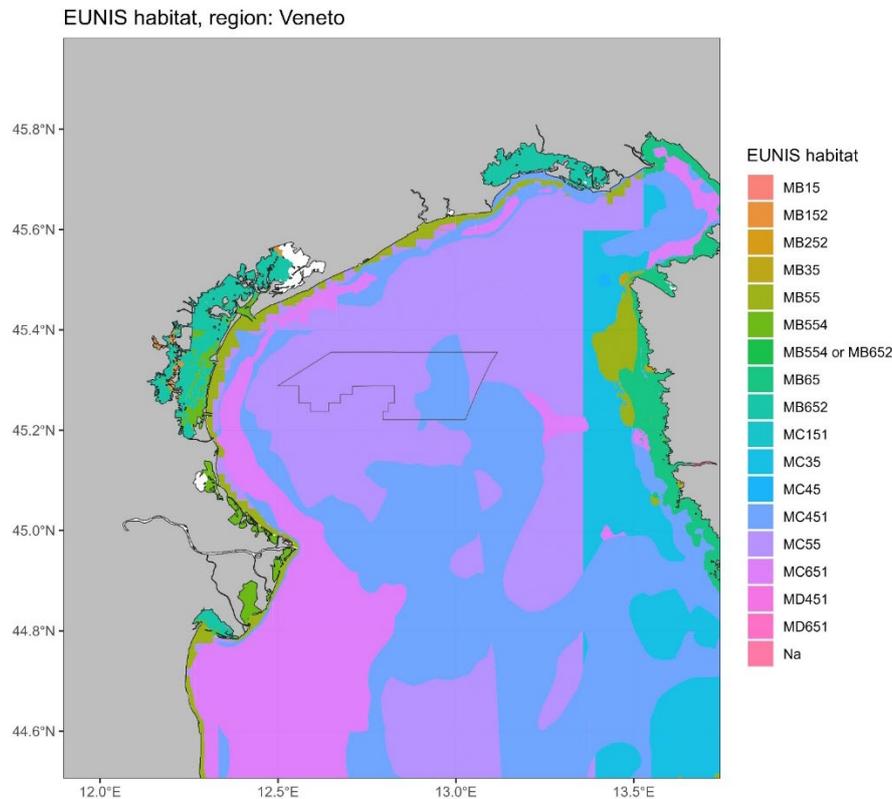


Figure 4.2.2 - EuSeaMap classification of bottom habitats in the Veneto Region.

The EUNIS habitats mapped in the Veneto Region are the following, in which the habitats within the proposed OWF area are marked with three asterisks (***):

- MB55: Mediterranean infralittoral sand
- MB554: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand
- MB652: Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud
- MC55: Mediterranean Circalittoral sand***
- MC35: Mediterranean circalittoral coarse sediment
- MB35: Mediterranean infralittoral coarse sediment
- MB15: Mediterranean infralittoral rock
- MC151: Coralligenous biocenosis
- MC651: Biocenosis of Mediterranean circalittoral coastal terrigenous muds
- MB65: Mediterranean infralittoral mud
- MC451: Biocenosis of Mediterranean muddy detritic bottoms***
- MD451: Biocenosis of Mediterranean open-sea detritic bottoms on shelf-edge
- MC45: Mediterranean circalittoral mixed sediment
- MB252: Biocenosis of [Posidonia oceanica]
- MD651: Biocenosis of Mediterranean offshore circalittoral coastal terrigenous muds



- MB554 or MB652: Assemblages of Mediterranean euryhaline and/or eurythermal lagoon biocenosis on sand or Assemblages of the euryhaline and/or eurythermal lagoon biocenosis on mud
- MB152: Biocenosis of the Mediterranean euryhaline and/or eurythermal lagoon on rock

Clearly the area proposed for OWF is dominated by circalittoral sandy bottoms.

4.3 Seagrass habitats

Seagrass habitats for *Posidonia oceanica* and *Cymodocea nodosa* for the Veneto Region (Fig. 4.3.1) show all coastal areas from the Po River delta to Istria where only *C. nodosa* is present. Notably the two species do not overlap much with this area. It is also worth considering that the areas chosen for the OWF installation do not include any point in which these benthic species are or are possibly established in the region.

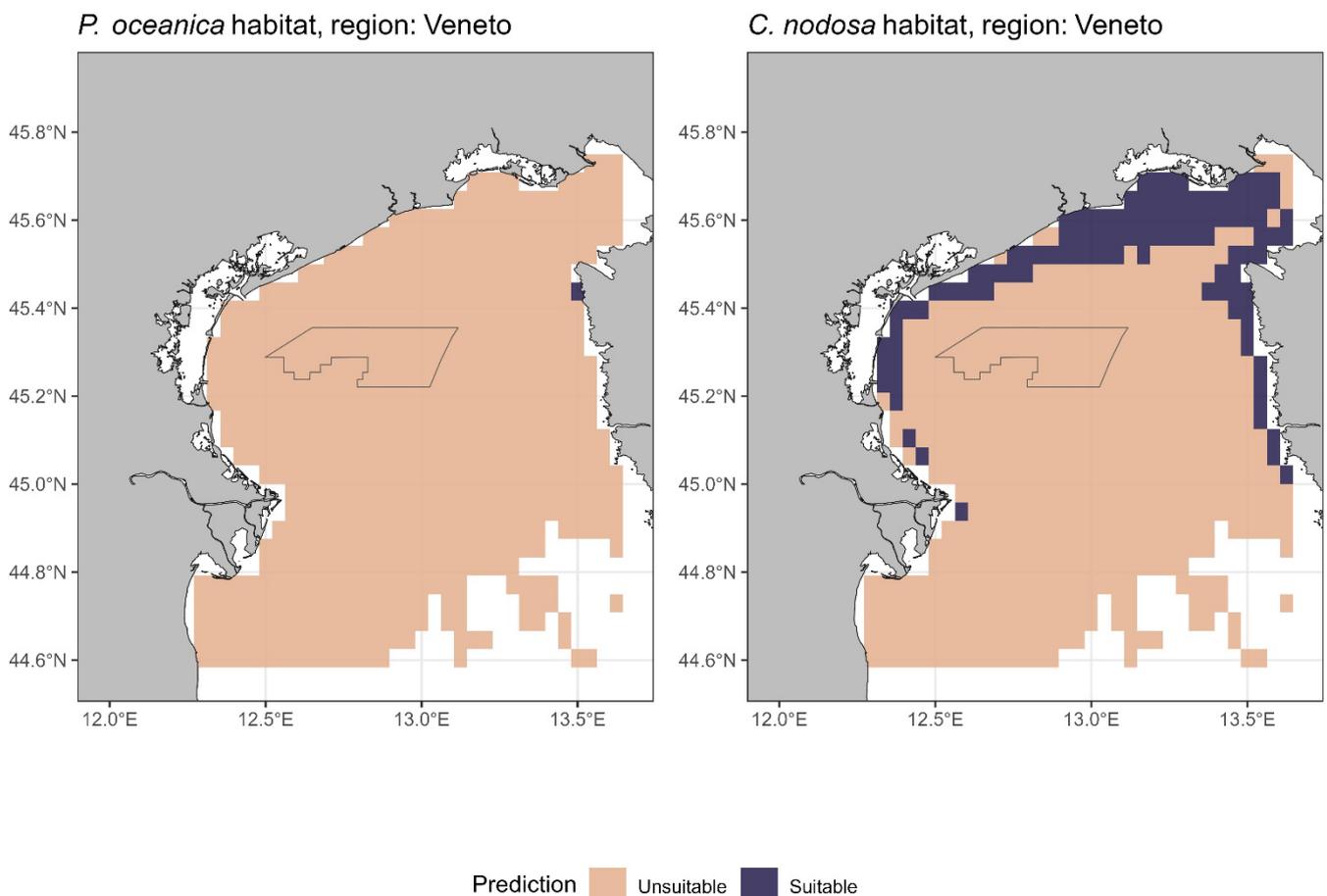


Figure 4.3.1 – Modelled distribution of *P. oceanica* and *C. nodosa* regarding unsuitable and suitable areas in the Veneto Region.



4.4 Benthic biodiversity

The Veneto Region has quite a substantial number of benthic species observations obtained from OBIS and GBIF datasets. It is worth noting that the data points with the highest number of species are all close to the coastline, both on the eastern and western side of the Adriatic (Fig. 4.4.1). Offshore, the number of benthic species declines ($\log N < 1$) as well as datapoints. Therefore, the area defined for future OWF in the Veneto Region is likely an area with a very low number of species ($\log N < 1$), which is also confirmed for the few datapoints available that overlap with the OWF area (Fig. 4.4.1).

OBIS and GBIF macrozoobenthos data, region: Veneto

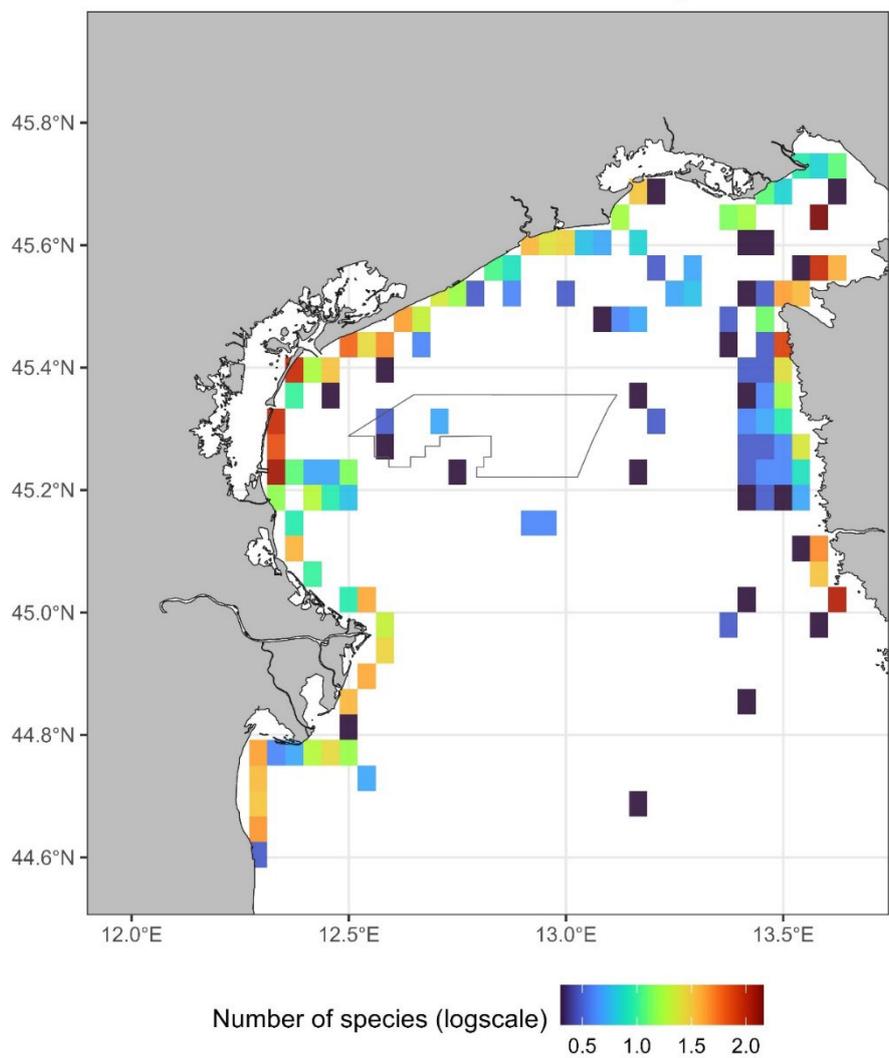


Figure 4.4.1 – Macrozoobenthos data from OBIS and GBIF for the Veneto Region. Data coverage is very scattered, and sampling are reported in terms of richness (number of species).



4.5 Demersal species biomass and richness

Demersal species biomass in Veneto shows a very high biomass in the central part of the Adriatic Sea in front of the Venice Lagoon (Fig. 4.5.1). Peak biomass is in the order of 10^3 kg/km² (note the figure is in log scale). Biomass inside the OWF in the Veneto Region has similar values to the average of the region, i.e., 3.4 log kg/km² (Fig. 4.5.1).

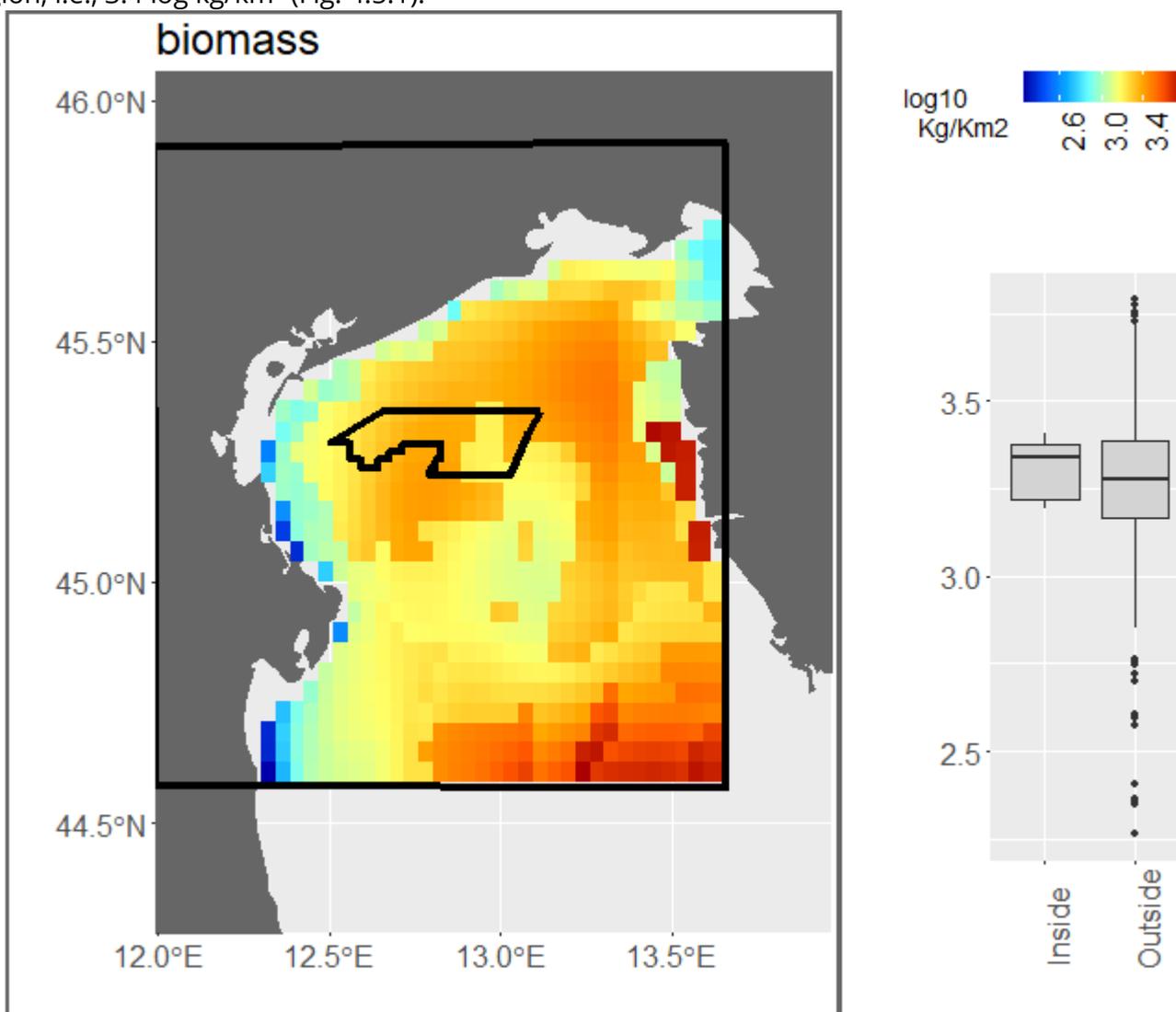


Figure 4.5.1 –Demersal species biomass for the Veneto Region obtained from the GAMM model using the Medits trawl survey data. The scale is logarithmic.

Demersal species richness in the Veneto Region displays a pattern with high values toward the deepest areas in the central-eastern parts of the domain with the number of species in the Medits samples as high as 28 (Fig. 4.5.2). The average number within the demersal community in Veneto is



quantified as $N = 21$ (box plot of Fig. 4.5.2) with a clear tendency for demersal species to be lower in numbers close to the shallow eastern coastlines. The potential OWF area identified is therefore, in an area with a large gradient of richness: its shallower western part is clearly characterized by low richness while the eastern part of the OWF falls into medium-high fish richness (approximately $N = 20$). Overall, the OWF has an average richness of 20, which is close to the average of the region (box plots in Fig. 4.5.2).

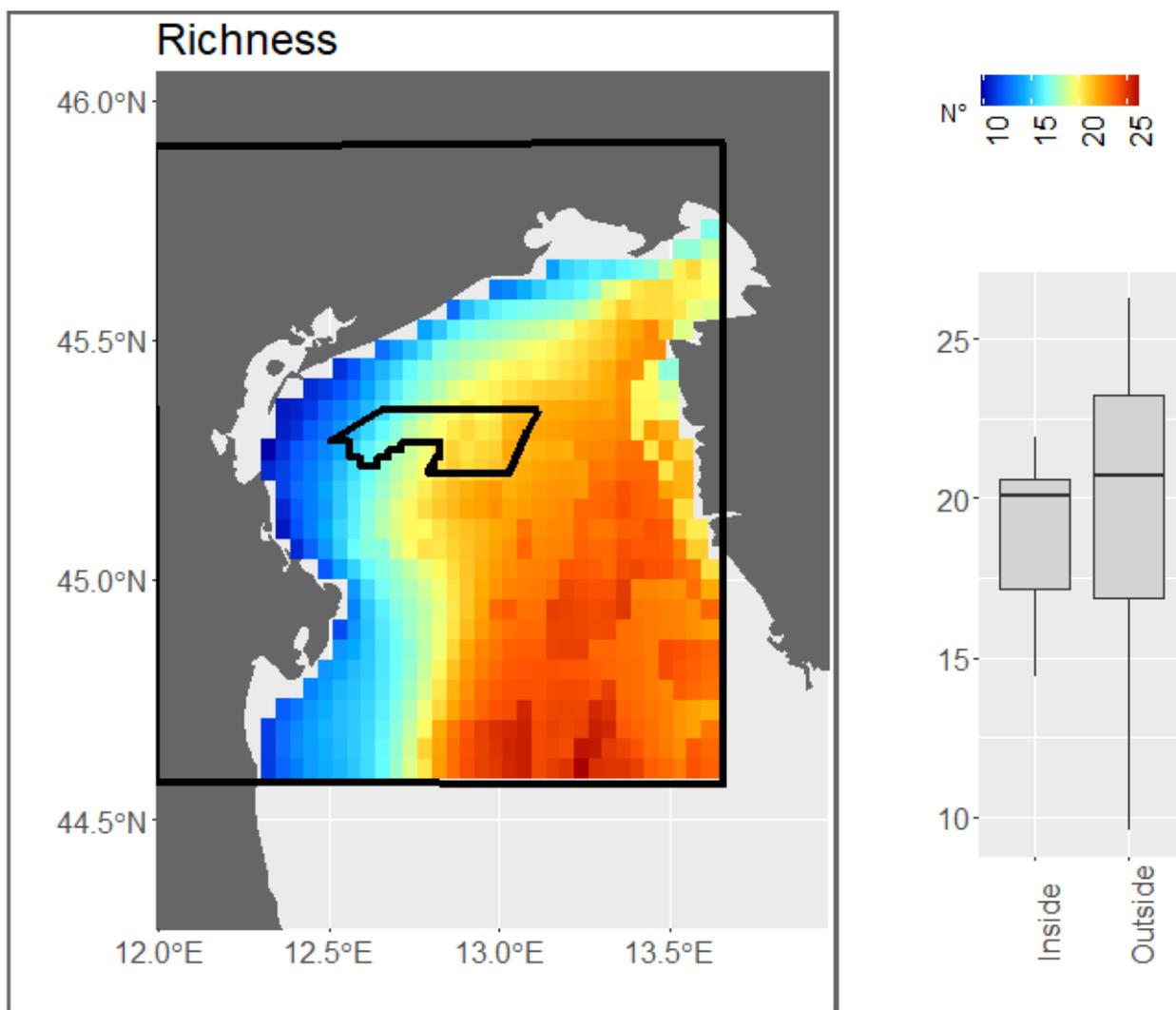


Figure 4.5.2 – Fish species richness (number of species) reconstructed for the Veneto Region using the Medits trawl survey data.

4.6 Demersal species biodiversity and trophic level

The beta-diversity for the demersal fish community for the Veneto Region, which is calculated using the whole Adriatic Sea as a reference (Fig. 4.6.1), shows values comprised of a range from 0.55 and 0.80. The lowest values are in the central part of the region, offshore in front of the Po River delta and the highest values are close to the coasts of the Istrian Peninsula, especially in the northern part of the region, in front of the Tagliamento River-Grado Lagoon system (Fig. 4.6.1). Overall, the average beta-diversity in the region is 0.65. The OWF area identified for the Veneto Region falls just south of the hot spot of beta-diversity and thus, has an intermediate-high value of 0.71 (box plot in Fig. 4.6.1) although the variability of beta-diversity is quite high also within the defined OWF area.

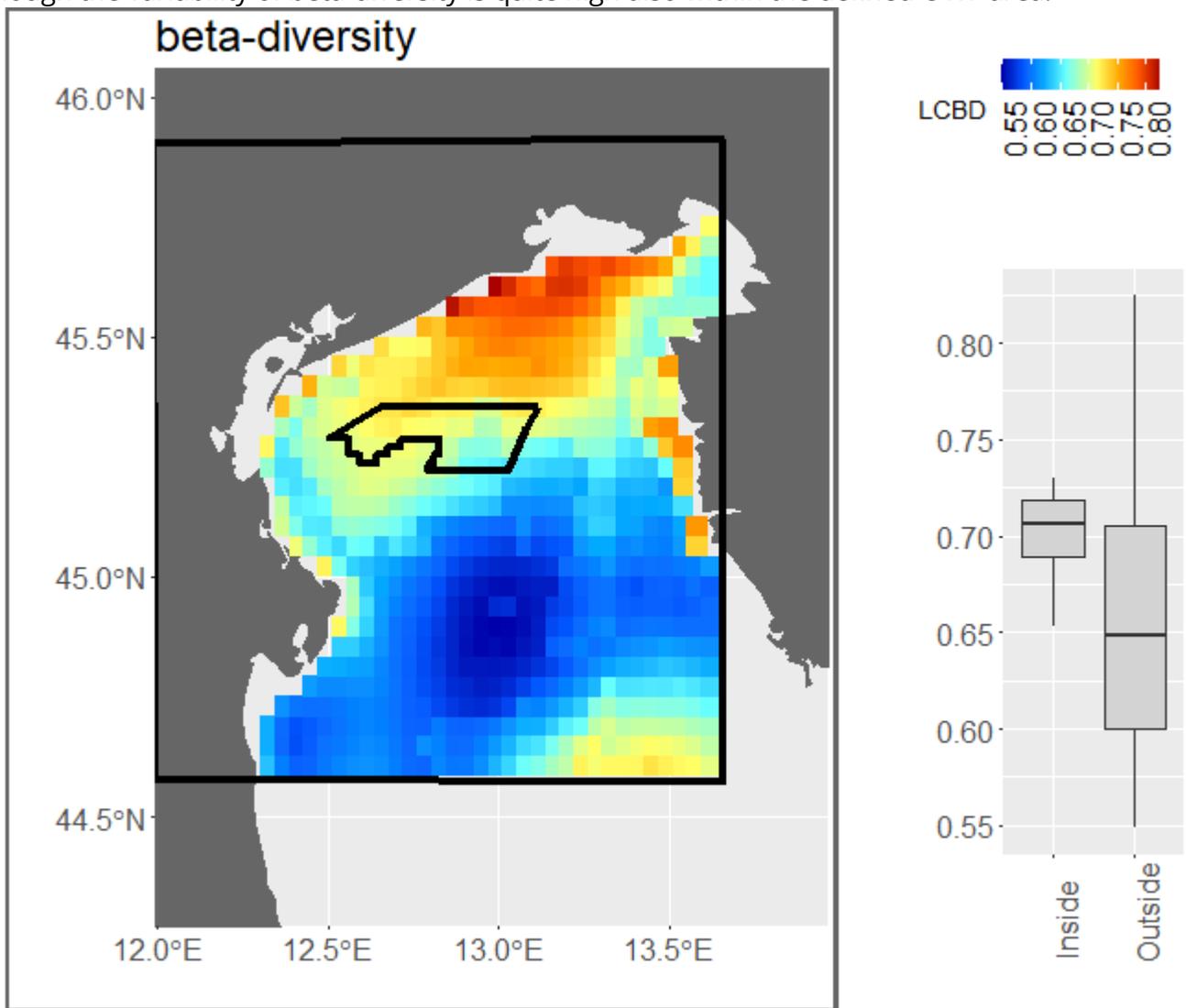


Figure 4.6.1 –Beta-diversity reconstructed for the Veneto Region using the Medits trawl survey data. Beta-diversity accounts both for the number of species and biomass, and it is a measure of variability of the samples.



The average trophic level of the demersal community is reported in Fig. 4.6.2 and shows a low trophism in correspondence with the coast of the very north of the Adriatic and higher trophic levels toward the Gulf of Trieste and Istria Peninsula. The average trophic level inside the OWF is less than 3.2 while the average in the Veneto Region is 3.3 (Fig. 4.6.2).

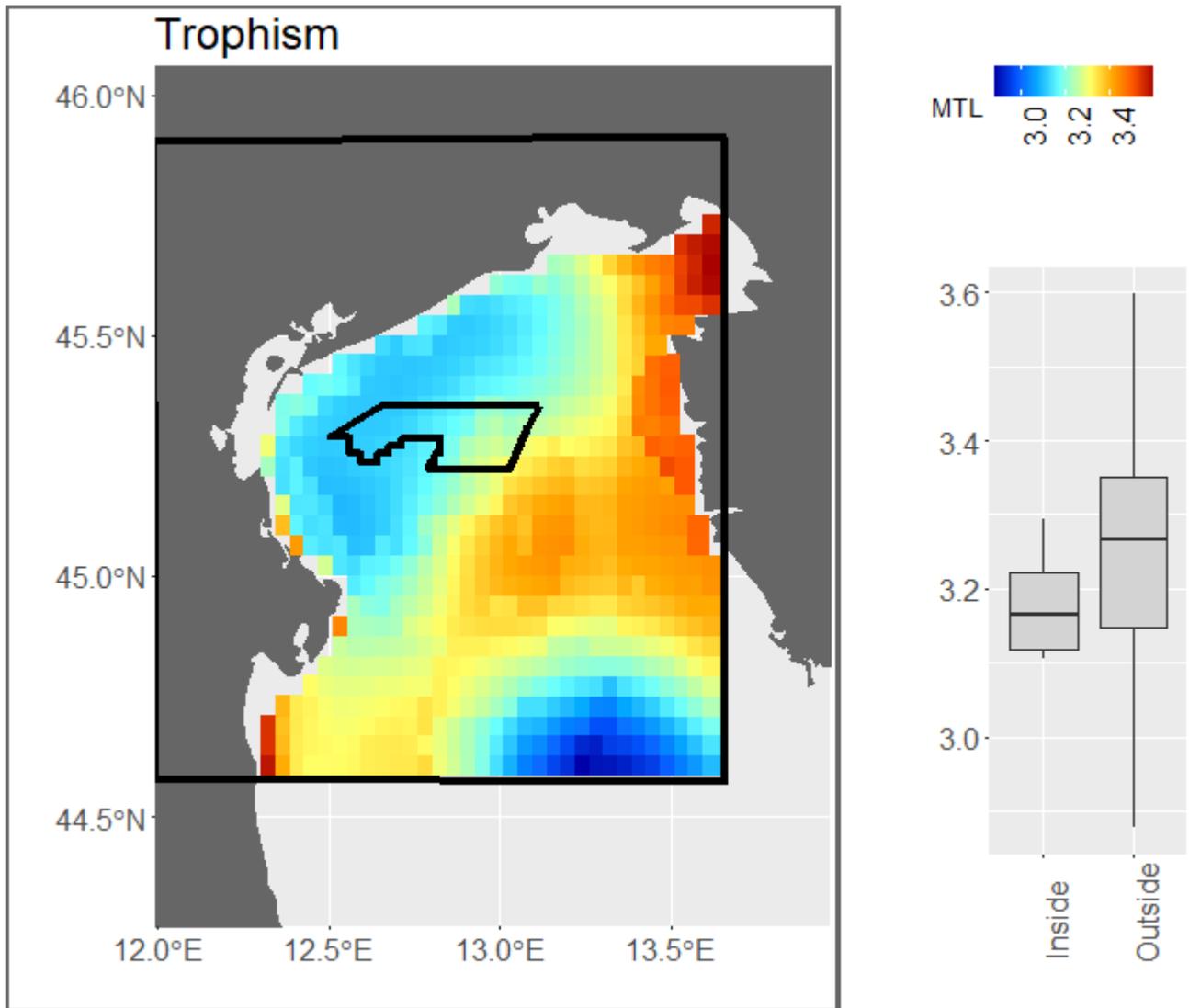


Figure 4.6.2 –Trophic level projections for the Veneto Region obtained from the GAMM model using the Medits trawl survey data.

4.7 Marine mammal distribution

Marine mammal sightings from 1986 to 2025 retrieved from GBIF show a diffused presence of dolphins (*T. truncatus*) in the Veneto Region (Fig. 4.7.1) with clear areas of over aggregations of data points in the Gulf of Trieste and along the coasts of Istria. Although sightings have clear limitations,



because they are not derived from from systematic monitoring, these observations do highlight a large and distributed presence of mammals in the area, which is of potential interest to all the region. With respect to the OWF area, the few occurrence points that were reported (Fig. 4.7.1) highlight a potential overlap between the OWF and the presence of bottlenose dolphins that might require further investigation.

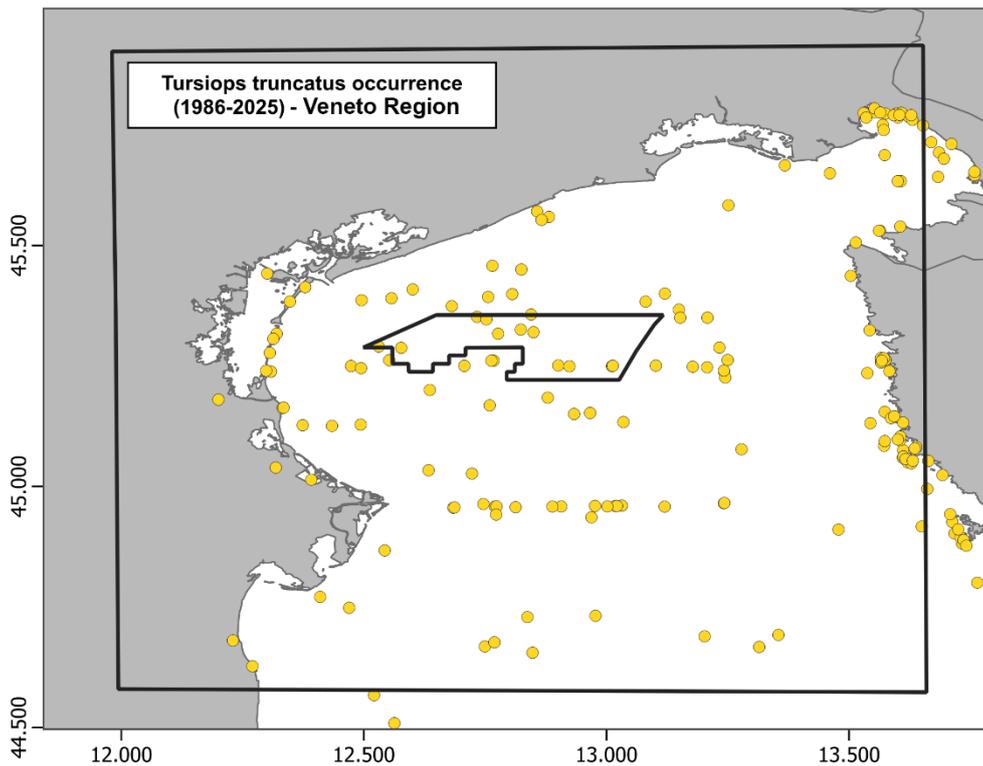


Figure 4.7.1 - *Tursiops truncatus* occurrence points from 1986 to 2025 in the Veneto Region. The presence points were downloaded from GBIF (March 2025).

4.8 Seabird migration routes

Potential seabird site maps in the Veneto Region (Fig.4.8.1) extracted from the UNEP-MAP-RAC/SPA (2010) considers the pelagic distribution of seven pelagic Mediterranean endemic and near-endemic seabird species (listed in Table 1.8.1). Most of the north-western part of the region falls into rank value 3 (the intermediate rank level in Adriatic Sea). Therefore, the OWF area also falls into this intermediate rank of importance as an area for seabirds (Fig. 4.8.1).

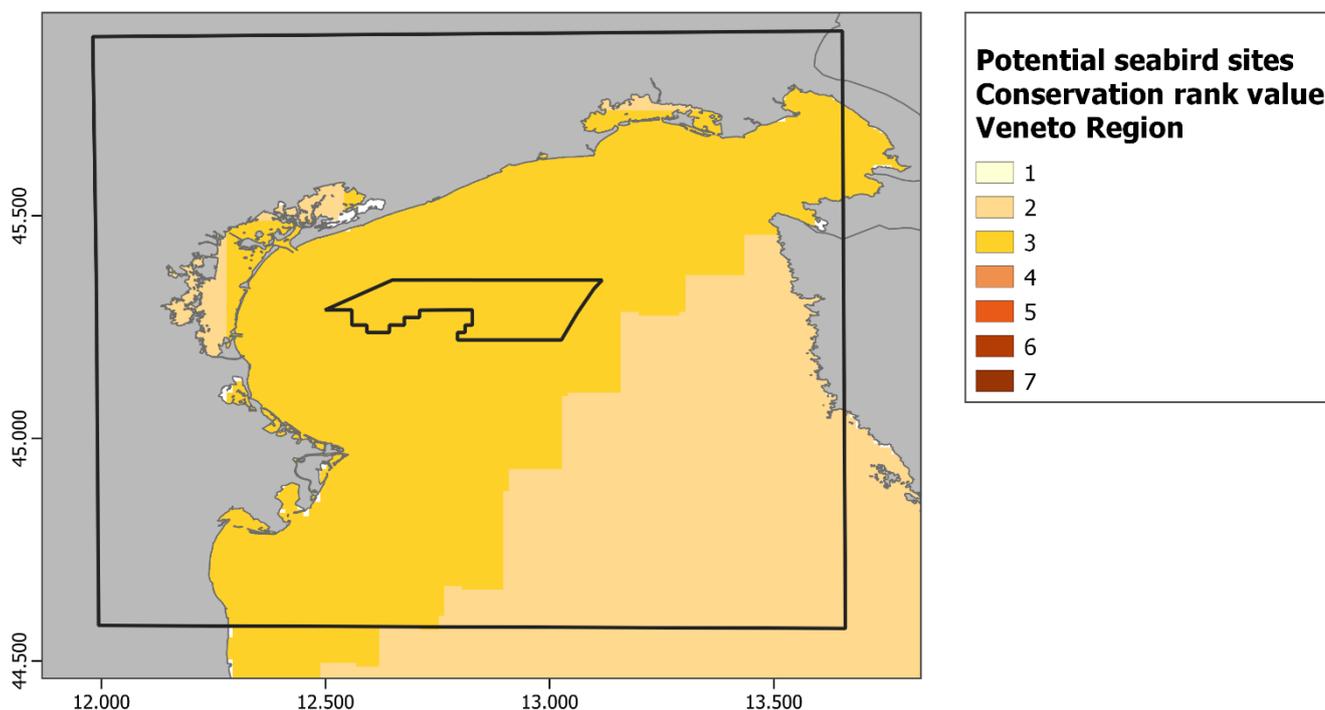


Figure 4.8.1 Potential seabird sites in the Veneto Region. The map was downloaded from <https://www.portodimare.eu/> and rescaled according to the map reported by UNEP-MAP (2010).

4.9 Sensitive & protected areas

Regarding sensitive and protected sites, the Veneto Region is characterized by a high number of sites defined as Natura 2000 sites (Fig.4.9.1), but most of them are in the coastal lagoons and deltas (coastal waters), from Comacchio to the Po River delta, the Venice Lagoon, Grado and Marano Lagoon etc. Moreover, some large Natura 2000 sites are defined offshore just south of the Po delta and along the coastline of Istria. Small additional Natura 2000 sites are located in front of the Venice Lagoon and Grado-Marano lagoon protecting the rocky outcrops, named as “trezze” or “grebeni” or “tegnue” (“Tegnue di Chioggia” and “San Pietro e Bardelli” Natura 2000 sites). A Ramsar Site has been defined in the Po River delta while small MPAs are defined in the Gulf of Trieste (Miramare (IT), Piran and



Koper (SLO)). The whole northern Adriatic Sea is of concern through the given status of “Ecologically or Biologically Sensitive Area” (EBSA) (Fig. 4.9.1). The OWF defined for the Veneto Region therefore, is not touched by the most restrictive protection rules (MPAs, Natura 2000 etc), but the whole OWF is nevertheless, under the EBSA.

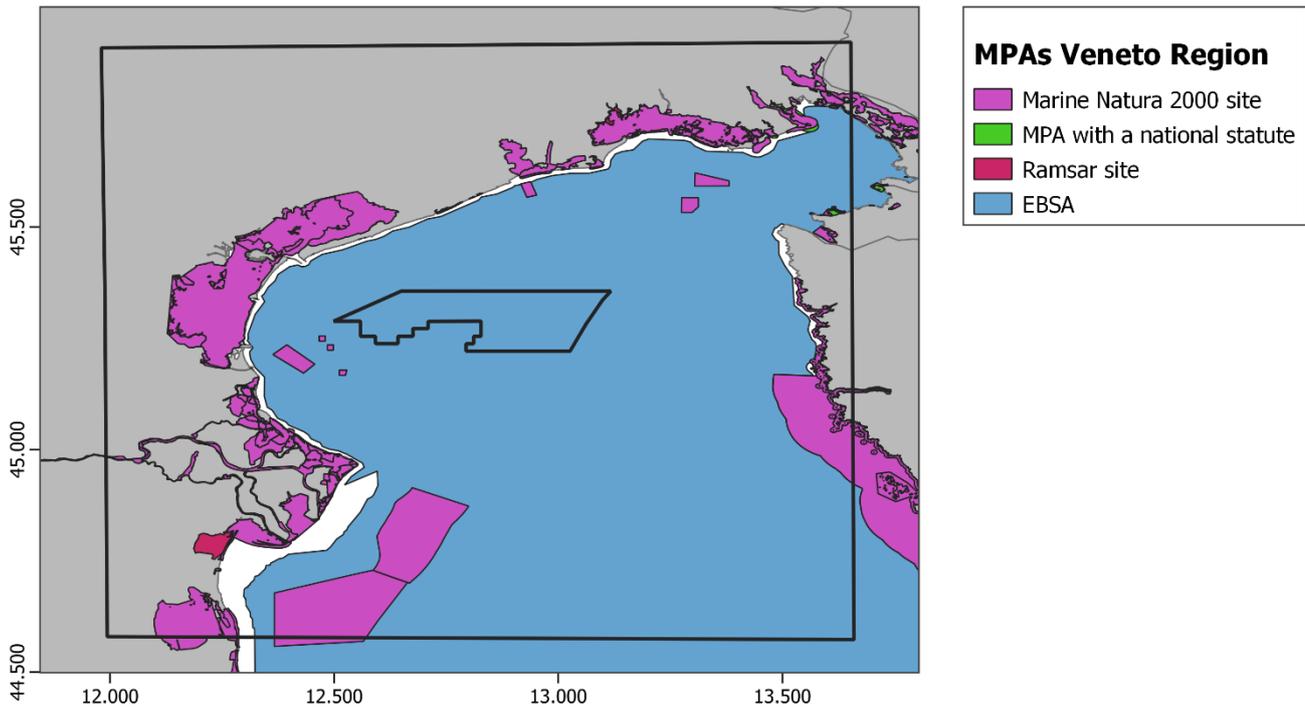


Figure 4.9.1 - Sensitive and marine protected areas in the Veneto Region. Data source: mapamed.org, 2019 edition. Some marine Natura 2000 sites were integrated with data from protectedplanet.net (2024).



5. Apulia Region

5.1 Water ecological characteristics

Chlorophyll-a concentration in the Apulia Region has some seasonal signal (see box plots in Fig. 5.1.1) with the highest values occurring in winter (average 17 mg Chl-a/m², peaks at 26,27 mg Chl-a/m² along the coast). It is worth nothing, however, a very clear spatial pattern with high coastal concentrations along the coast in summer and, although with lower averages (10 mg Chl-a/m²), more evenly distributed Chl-a, above all in autumn. Notably, the high transparent water column makes productivity of the outer shelf in spring very high compared to coastal Chl-a values. The results are that the area for OWF identified for the Apulia Region has generally a very high productivity (close to 15 mg Chl-a/m²) in all seasons except for autumn when the area identified for the OWF is characterized by concentrations of low chlorophyll compared to the rest of the region (approximately 10 mg Chl-a/m²).

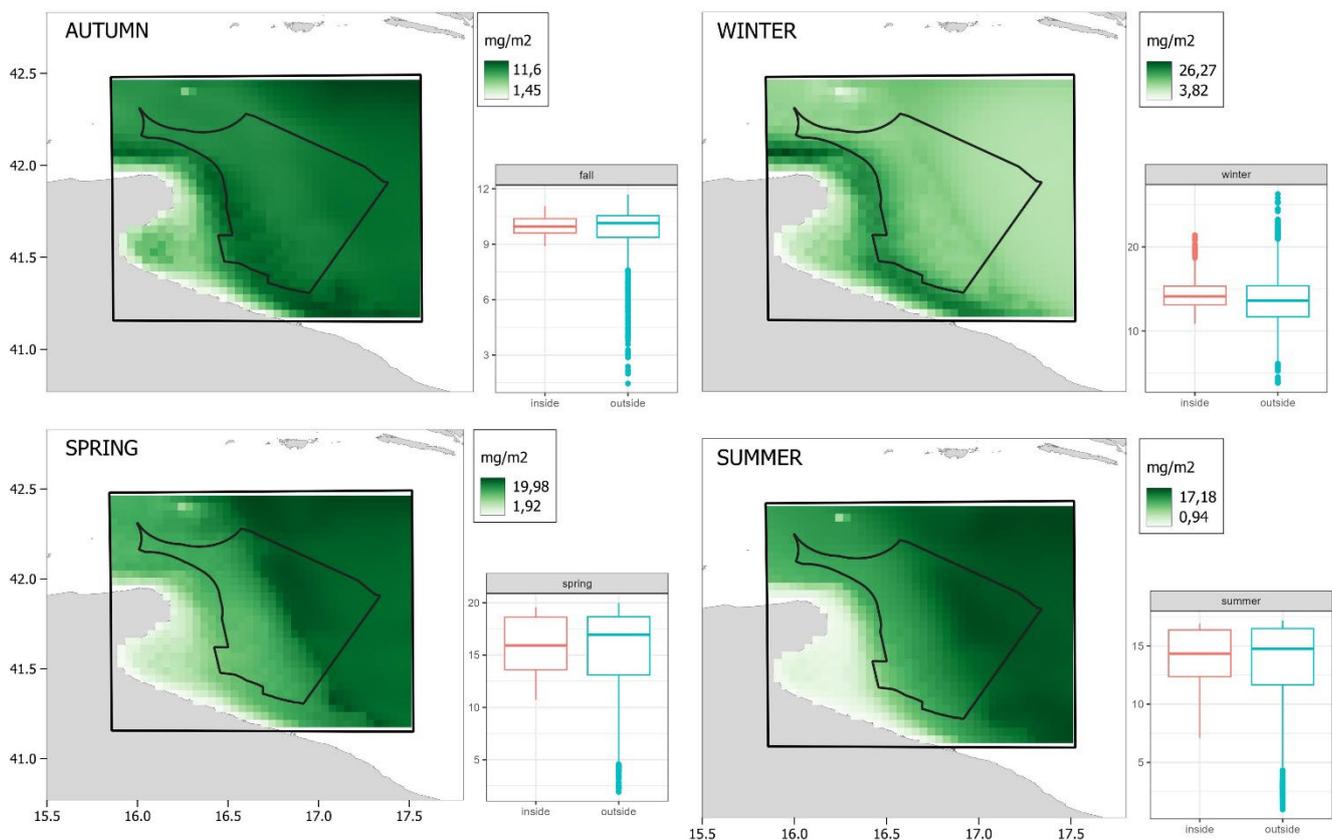


Figure 5.1.1. Map of chlorophyll in the Apulia Region for each season in mg/m², inside and outside the region of interest. On the right side of each map a whisker boxplot of the value inside and outside the area.

5.2 Bottom habitats

Sediment grain size in Apulia has an average of approximately $\phi=5$, which is very similar to the grain size of the area defined for OWF (Fig. 5.2.1), indicating very fine grain sizes in the area (on average). Notably within the OWF area, there are spots of coarser grain size, especially offshore and close to the Gargano pit.

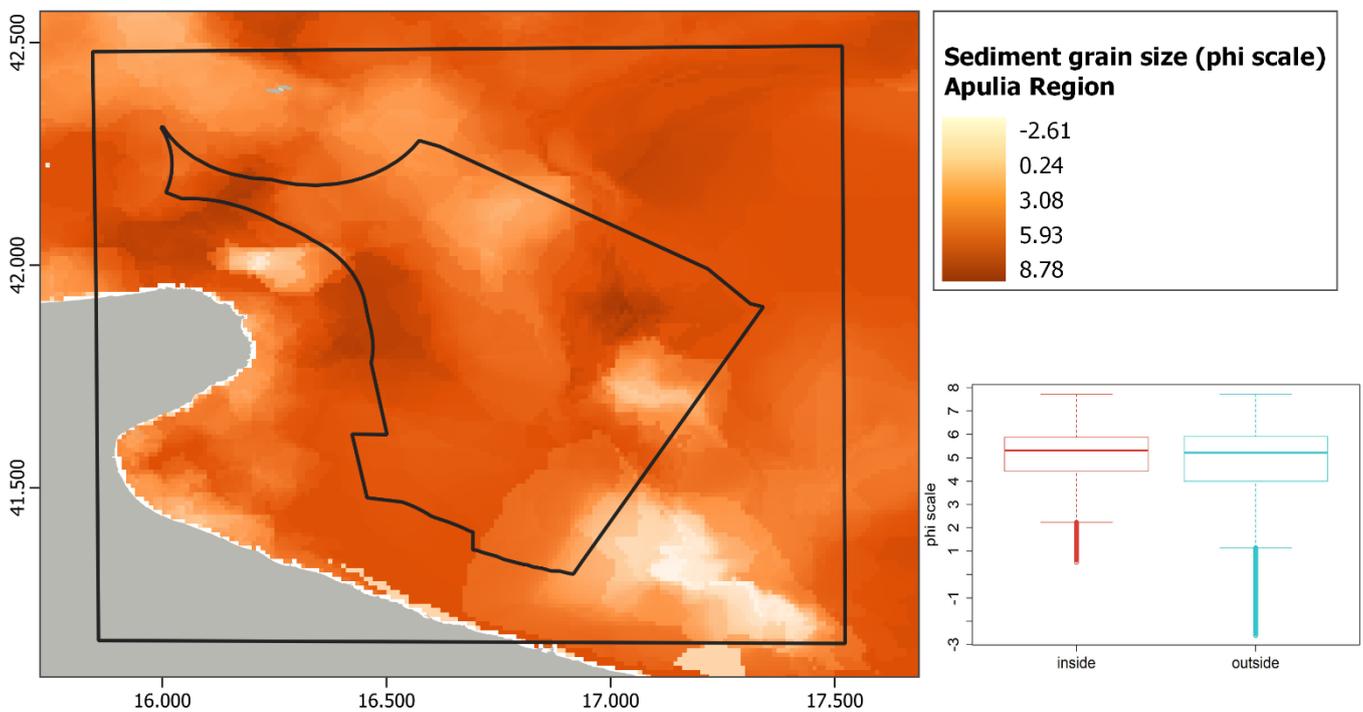


Fig. 5.2.1 - Map of sediment grain size in the Apulia Region. Kindly provided by Dr Jenkins, University of Colorado (USA).

The EUNIS habitats mapped in the Apulia region are the following (habitats within the proposed area are marked with three asterisks ***):

- MB55: Mediterranean infralittoral sand***
- MC35: Mediterranean circalittoral coarse sediment***
- MB35: Mediterranean infralittoral coarse sediment***
- MD451: Biocenosis of Mediterranean open-sea detritic bottoms on shelf-edge***
- MB15: Mediterranean infralittoral rock***
- MC151: Coralligenous biocenosis***
- MD151: Biocenosis of Mediterranean shelf-edge rock



- MC451: Biocenosis of Mediterranean muddy detritic bottoms***
- MB65: Mediterranean infralittoral mud
- ME65: Mediterranean upper bathyal mud***
- MB252: Biocenosis of [Posidonia oceanica]***
- MB2523: Facies of dead "mattes" of [Posidonia oceanica] without much epiflora***
- MD651: Biocenosis of Mediterranean offshore circalittoral coastal terrigenous muds***
- MC651: Biocenosis of Mediterranean circalittoral coastal terrigenous muds***
- MC45: Mediterranean circalittoral mixed sediment
- ME55: Mediterranean upper bathyal sand
- MF55: Mediterranean lower bathyal sand
- MF65: Mediterranean lower bathyal mud***
- MB2531: Facies with [Ficopomatus enigmaticus]
- MC55: Mediterranean Circalittoral sand***

There is a clear gradient of sediments from coastal terrigenous muds, to muddy detritic bottoms and to bathyal mud.

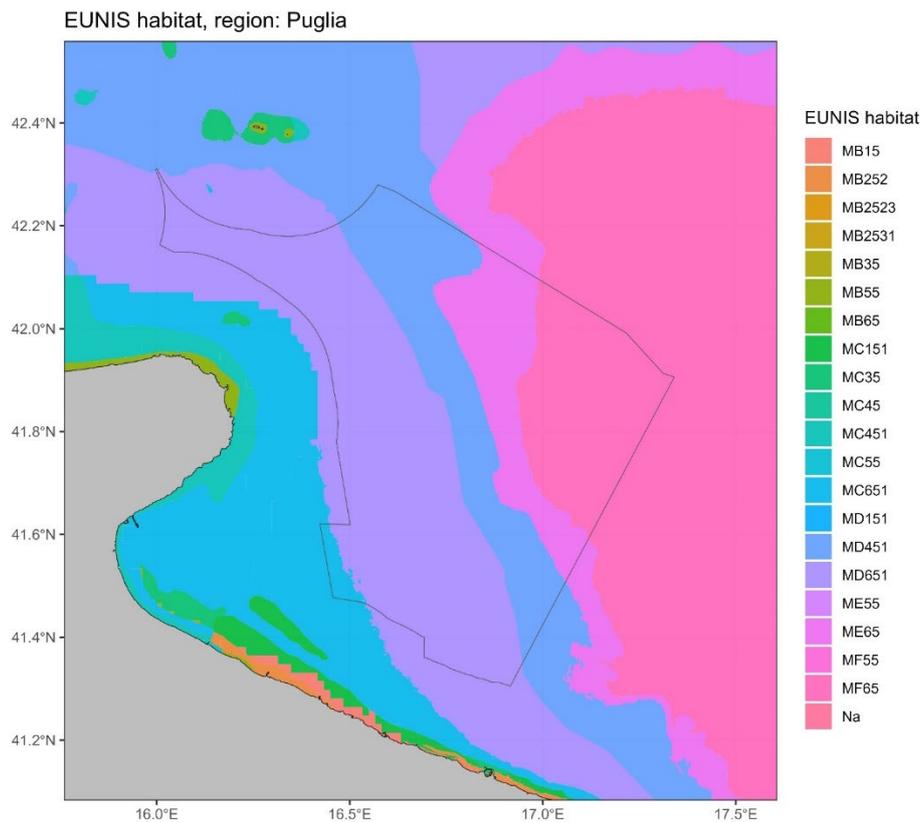


Figure 5.2.2 - EuSeaMap classification of bottom habitats in the Apulia Region.



5.3 Seagrass habitats

Seagrass habitats for *Posidonia oceanica* for the Apulia Region (Fig. 5.3.1) show minimal presence around the island of Pelagosa and along the coast. Larger areas along the coast highlights the presence of *Cymodocea nodosa*, in the area of Manfredonia gulf. Notably, none of the two species are present in the area chosen for the OWF installation in the region, also because of a depth limiting the possibility for this marine vegetation to grow.

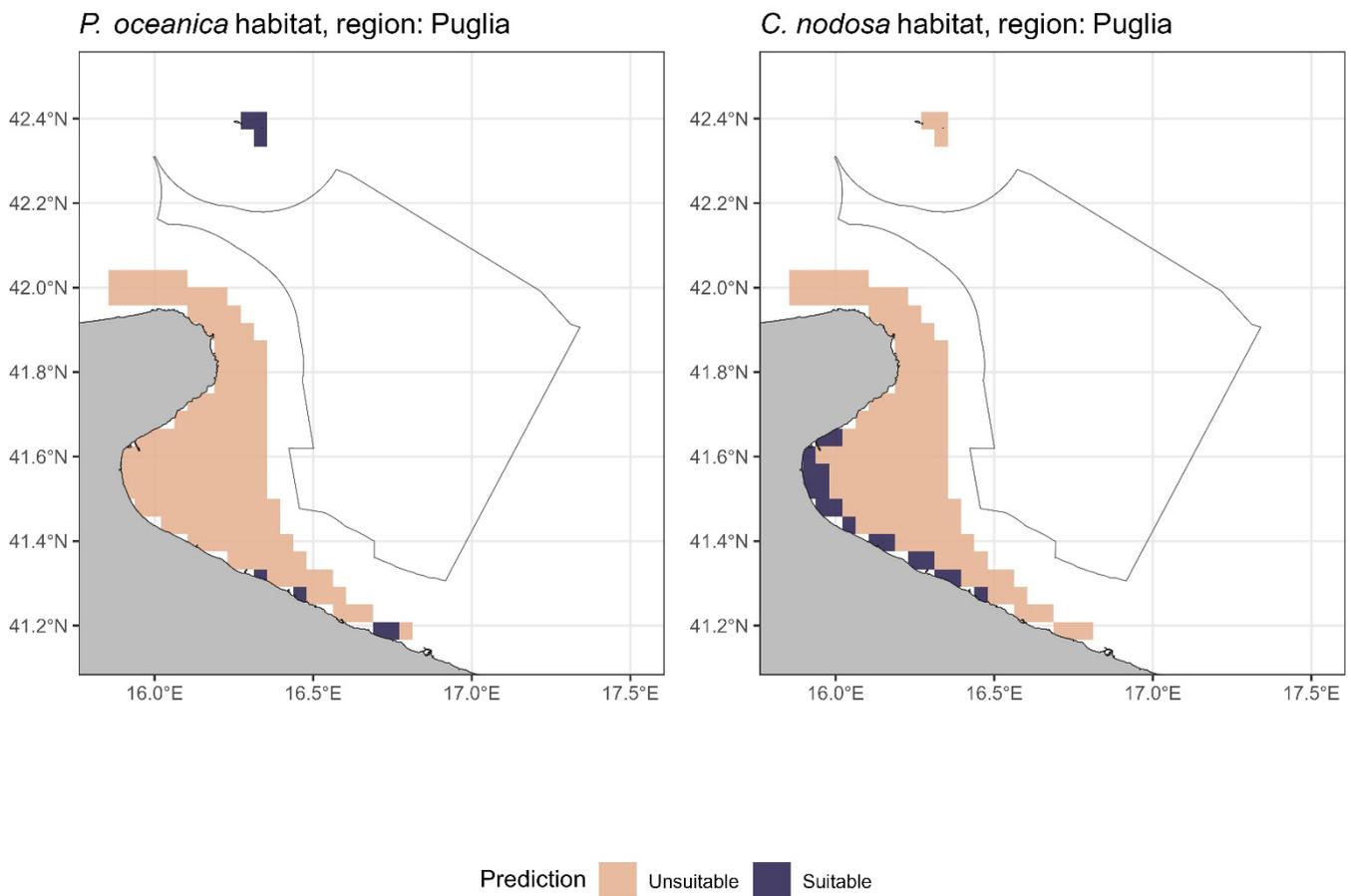


Figure 5.3.1 – Modelled distribution of *P. oceanica* and *C. nodosa* regarding unsuitable and suitable areas in the Apulia Region.



5.4 Benthic biodiversity

Unfortunately, benthic data for carrying out a comprehensive analysis of benthic biodiversity are missing. Therefore, OBIS and GBIF data regarding presence/absence are used. This information shows scattered data points in the Apulia Region with generally a very low number of species, especially offshore ($\log N < 1$), and more data points exhibiting a higher number of species close to the coast ($\log N > 2$). The area defined for future OWF in Apulia contains only few data points that are offshore and with a very low number of species ($\log N < 1$).

OBIS and GBIF macrozoobenthos data, region: Puglia

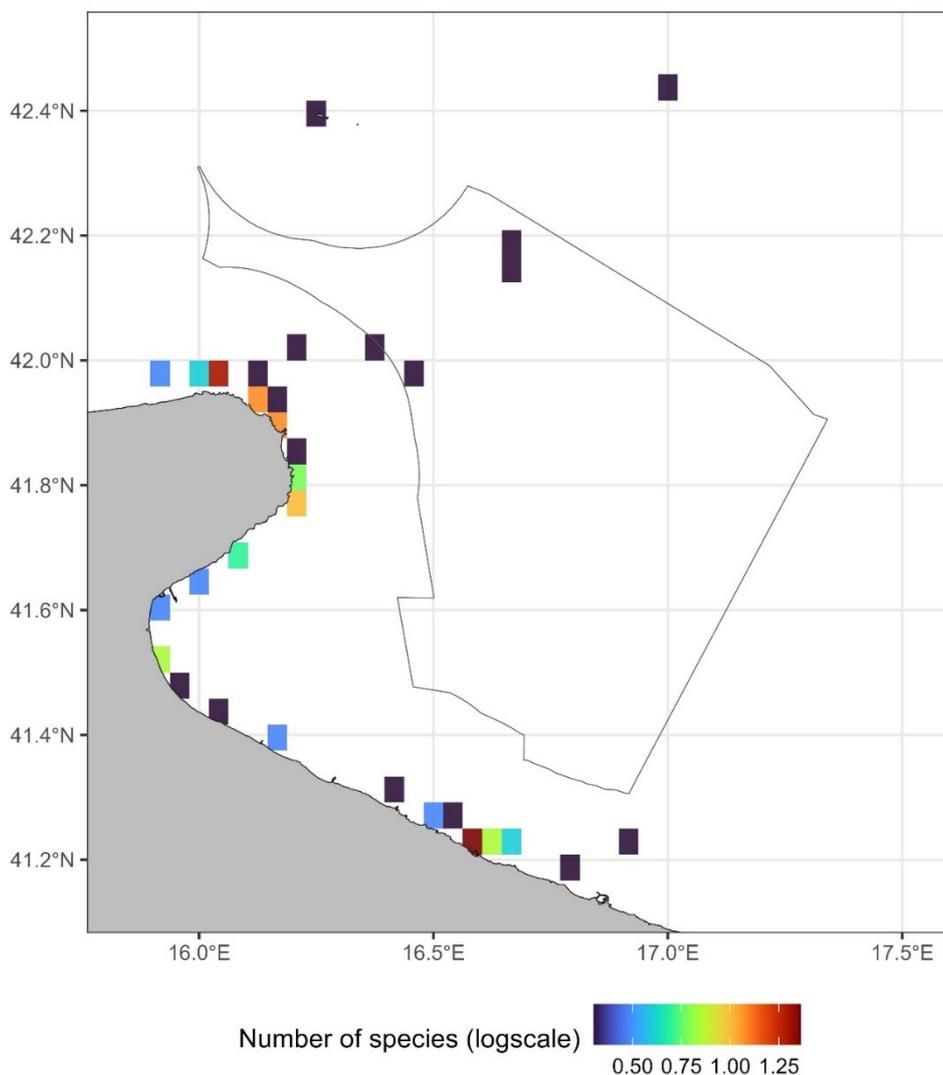


Figure 5.4.1 – Macrozoobenthos data from OBIS and GBIF for the Apulia region. Data coverage is very scattered, and sampling are reported in terms of richness (number of species).



5.5 Demersal species biomass and richness

Demersal species biomass in Apulia shows a pattern of relatively low biomass in the central part of the region (Fig. 5.5.1). Peak biomass is in the order of 10^3 kg/km² (note the figure is in log scale) toward the north at high depth. Biomass inside the OWF has similar values to the average of the region, i.e., 2.5 log kg/km² (Fig. 5.5.1), so it is quite low compared to the macroregion.

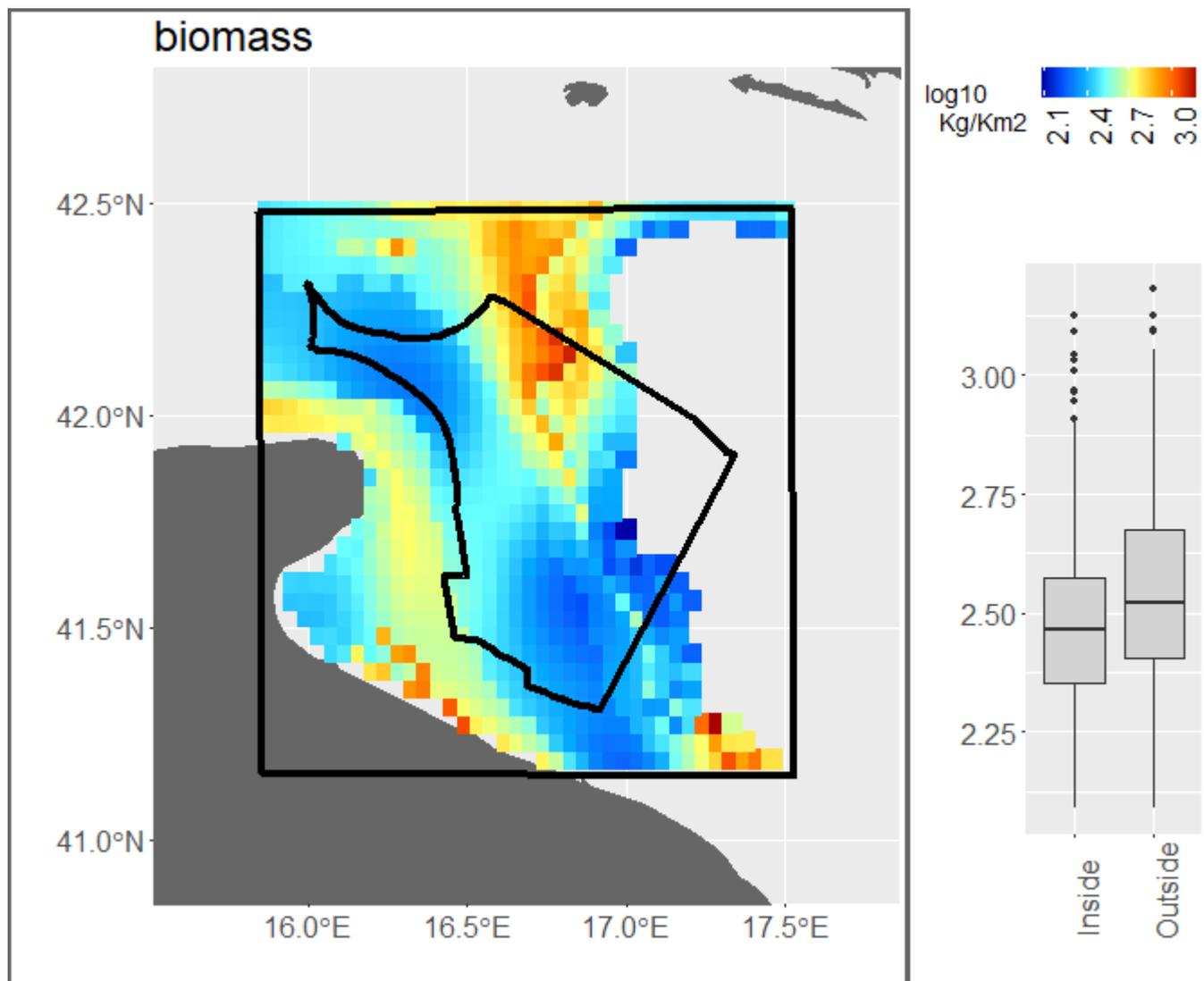


Figure 5.5.1 –Demersal Species biomass for the Apulia region obtained from the GAMM model using the Medits trawl survey data. The scale is logarithmic.

Demersal species richness in Apulia is very high, with a marked pattern dominated by the bathymetry (Fig. 5.5.2): close to coastal low depth areas the number of species is low (around 20) but richness



increases at a depth of 400-500m, constituting a strip with richness values as high as 50. This pattern may have a relationship with the chlorophyll-a indicator other than bathymetry. The average number of species in the region is approximately 27 while the OWF areas have intermediate-high richness, placing them higher in the range of the region although with a similar average (28 species). Overall, the OWF is situated in an area of great variability for richness (Fig.5.5.2).

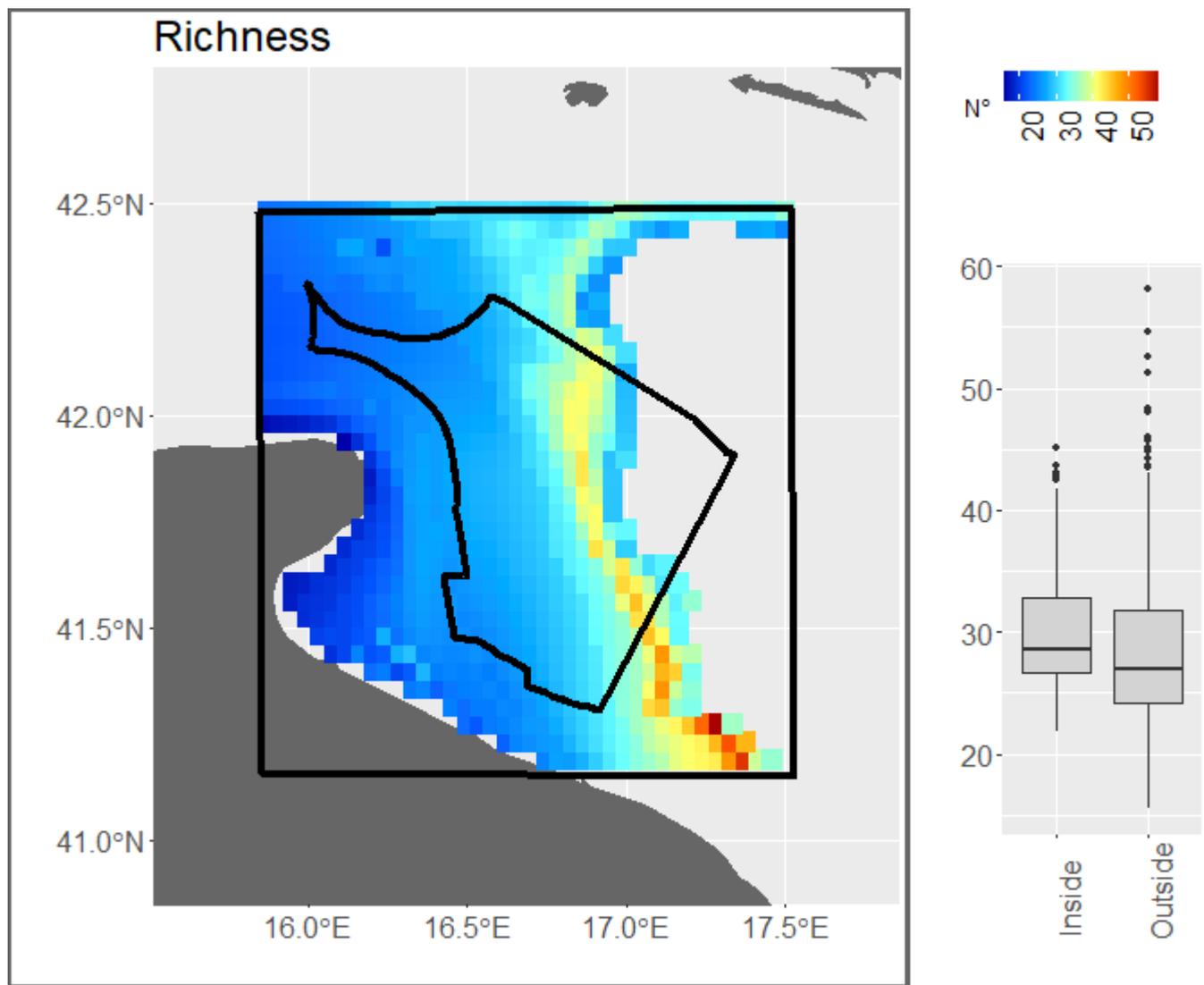


Figure 5.5.2 – Fish Species richness (number of species) reconstructed for the Apulia Region using the Medits trawl survey data.

5.6 Demersal species biodiversity and trophic level

The beta-diversity of the fish community in the Apulia Region considers both number of species and their biomass, but also their degree of variability at the regional scale: in any case, beta-diversity uses the whole Adriatic Sea as a reference (Fig. 5.6.1). Results for Apulia indicate a very similar pattern of beta-diversity with richness: very high beta-diversity hot spots at higher depths (close to the 600-800 bathymetric layer) and much lower beta diversity for shelf areas. The OWF areas are quite large so in order to cover this range of variability (Fig. 3.6.1), the average beta-diversity in the region was calculated and stands at approximately 0.48 while in the OWF zone, it is 0.44.

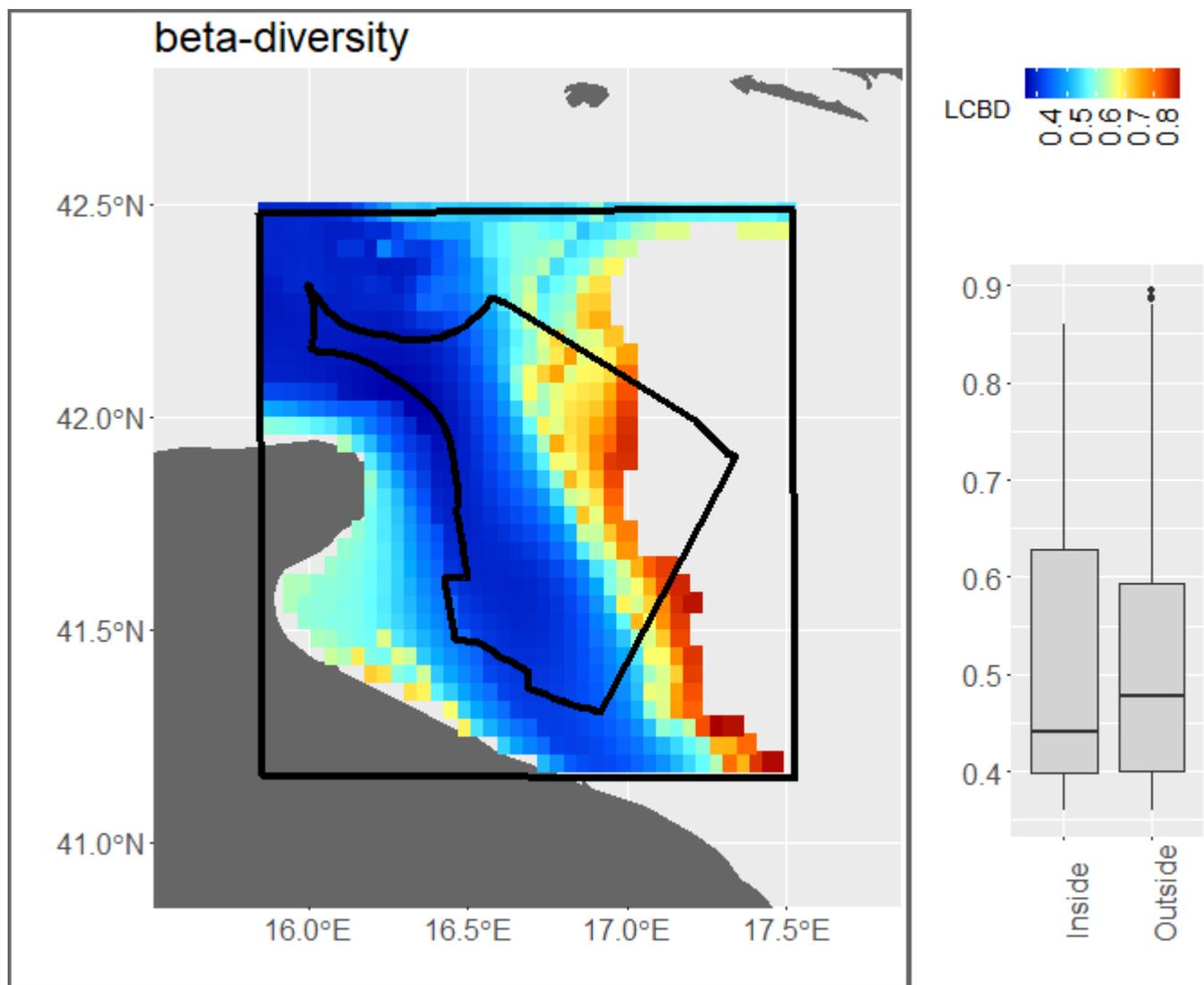


Figure 5.6.1 –Beta-diversity reconstructed for the Apulia region using the Medits trawl survey data. Beta-diversity accounts both of number of species and biomass and it is a measure of variability of the samples.



The average trophic level of the demersal community in Apulia region is low and reported in Fig. 5.6.2 and shows a very low trophism in correspondence of the coast and increasing MTL at deeper areas. The average trophic level inside the OWF is less than 3.5 which is similar to the average in the Veneto region (Fig. 5.6.2).

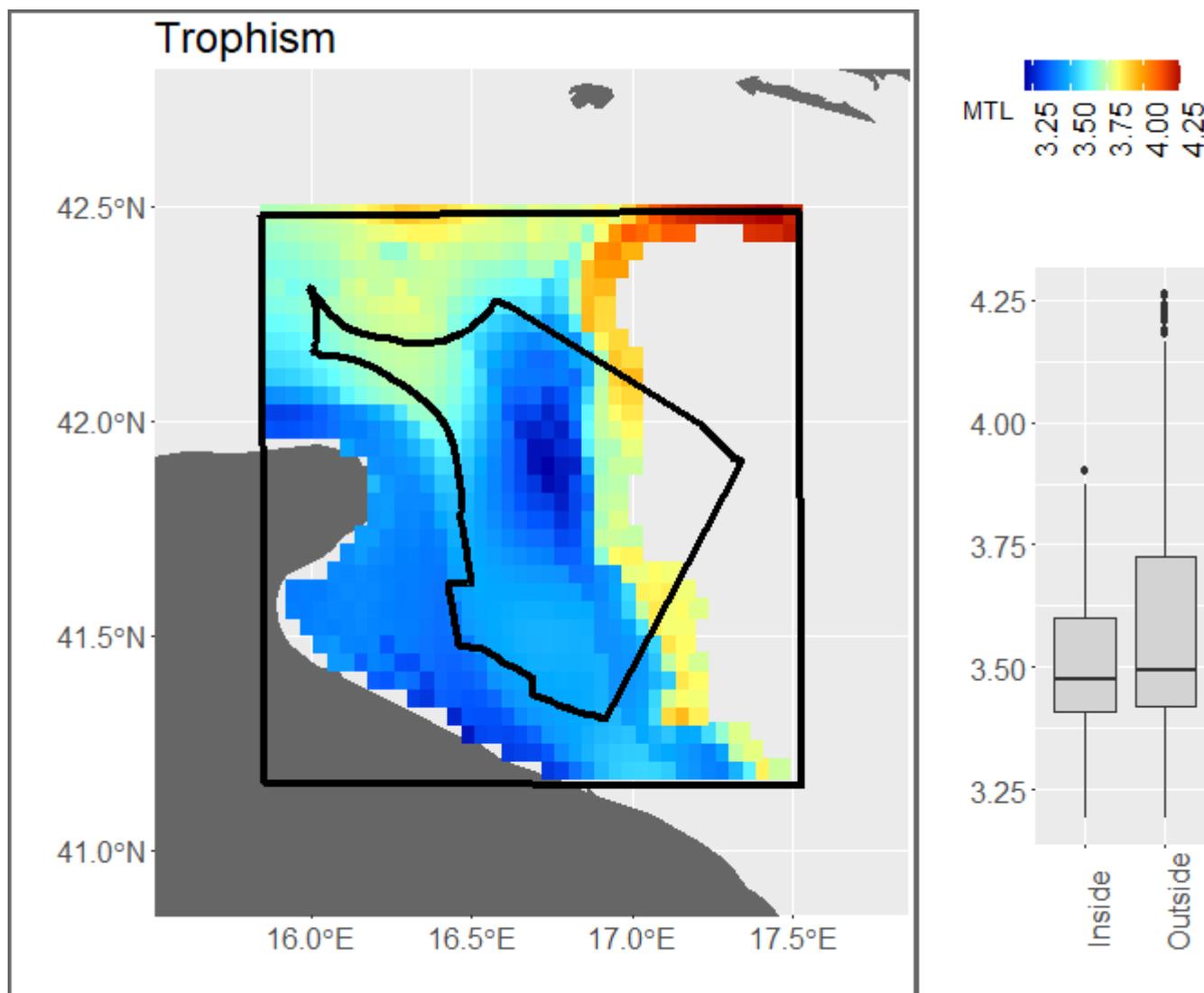


Figure 5.6.2 –Trophic level projections for the Apulia region obtained from the GAMM model using the Medits trawl survey data.

5.7 Marine mammal distribution

Sightings from 1986 to 2025 retrieved from GBIF show the sparse presence of dolphins (*T. truncatus*) in the Apulia Region with a great number of sightings very far offshore and few in shelf areas (Fig.5.7.1). In general, however, the number of sightings is very low. With respect to the OWF area, a



few occurrence points are represented inside or in the surroundings thus indicating the possible reduced presence of marine mammals in the area. One limitation of these data is their reliance on occasional sightings; however, for Apulia, systematic monitoring (see Fortuna et al., 2018) - although outdated - shows low encounter rates in the region (see Fig. 1.7.2). In any case, more in depth analyses are recommended to clearly identify the role of this component in the region.

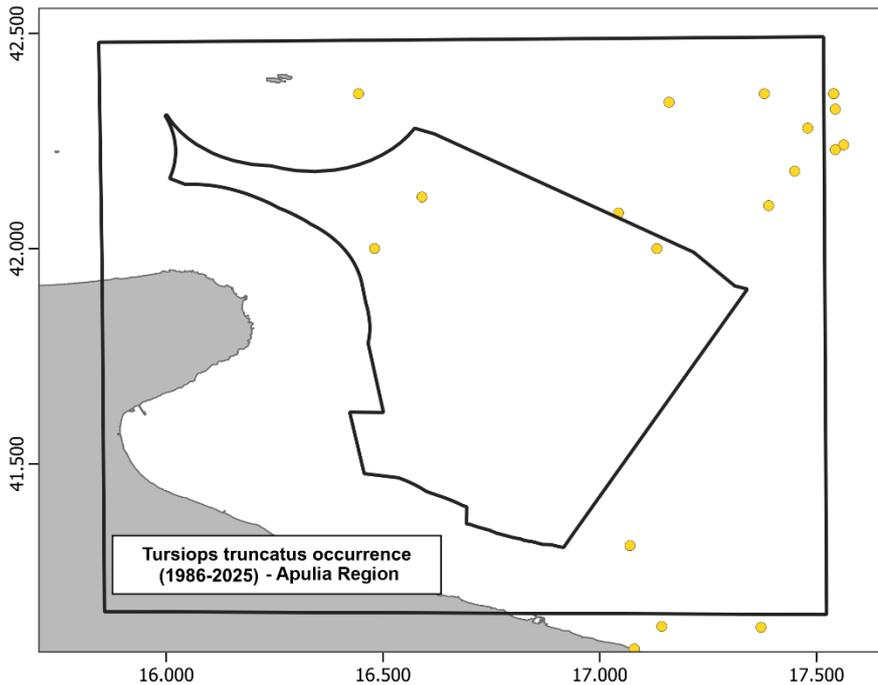


Figure 5.7.1 - *Tursiops truncatus* occurrence points from 1986 to 2025 in the Apulia Region. The presence points were downloaded from GBIF (March 2025).

5.8 Seabird migration routes

Potential seabird site map in the Apulia Region (Fig. 5.8.1) extracted from the UNEP-MAP-RAC/SPA (2010) considers the pelagic distribution of seven pelagic Mediterranean endemic and near-endemic seabird species (listed in Table 1.8.1). The region is characterized by a gradient of the rank of importance from as high as 4 in the north-western part of the region (close to Apulia coastline) to the very low values (1) in the southern part of Apulia. Notably the OWF area falls into several categories with great portions in the north under rank order 4, to a central part of value 2 and large areas of low ranking importance for seabirds in the south-eastern parts (Fig. 5.8.1).



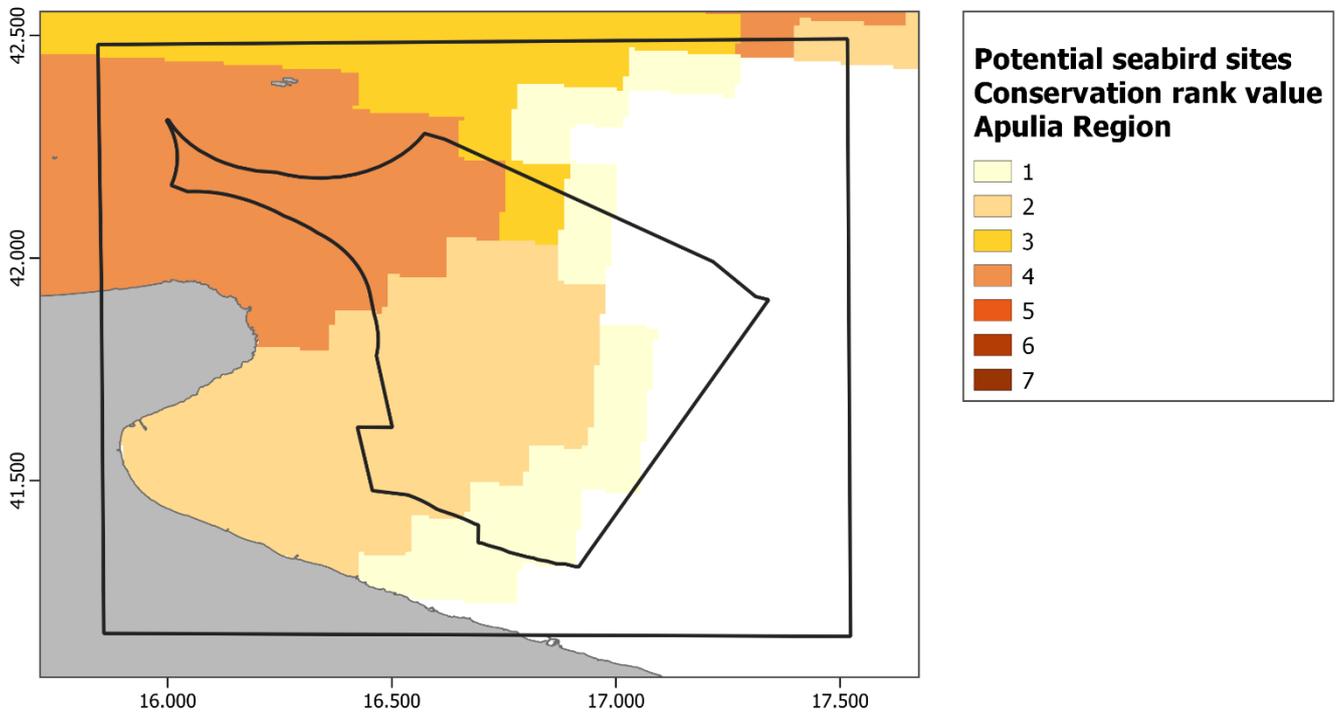


Figure 5.8.1 - Potential seabird sites in the Apulia Region. The map was downloaded from <https://www.portodimare.eu/> and rescaled according to the map reported by UNEP-MAP (2010).

5.9 Sensitive & protected areas

The Apulia Region includes two Natura 2000 marine areas, Tremiti Islands and Palagruža island in the northern part of the region, and a large Ecologically or Biologically Sensitive Area (EBSA) around the deep zones (depth > 400 m) (Fig. 5.9.1). Moreover, in this region, there is a large part of the deep area (depth > 1000m) that is a Fisheries Restricted Area (FRA). Despite these distributed sensitive and protected areas, none (MPAs, Natura 2000 etc) overlap with the chosen OWF site for the Apulia Region while the EBSA overlaps with the OWF in its the southern part of its domain (Fig. 5.9.1).



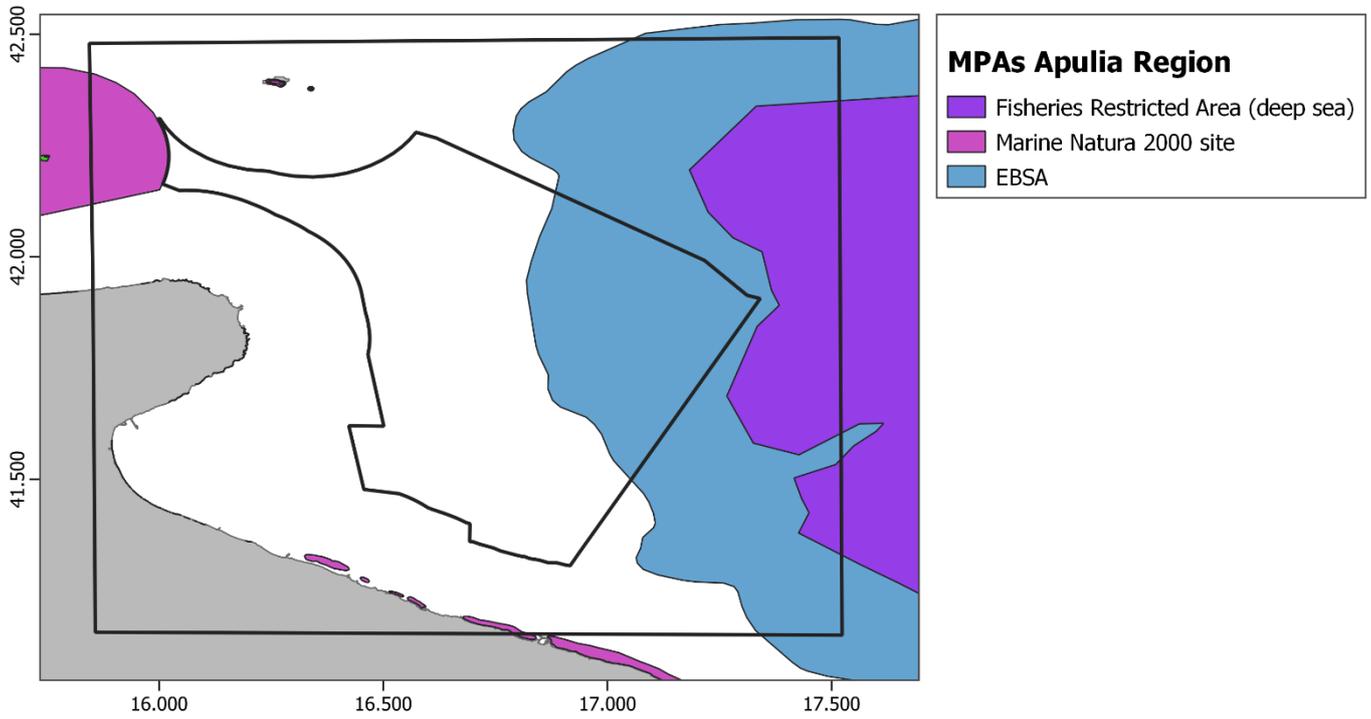


Figure 5.9.1 - Sensitive and marine protected areas in the Apulia Region. Data source: mapamed.org, 2019 edition. Some marine Natura 2000 sites were integrated with data from protectedplanet.net (2024).



6. Concluding remarks and discussion

In order to understand the ecosystem characteristics in the programme area and in particular in the four regions where the future OWF were identified, the deliverable investigated nine aspects considered relevant for an ecosystem analysis:

1. Water ecological characteristics
2. Bottom habitats
3. Seagrass habitats
4. Benthic biodiversity
5. Demersal species biomass and richness
6. Demersal species biodiversity and trophic level
7. Marine mammal distribution
8. Seabird migration routes
9. Sensitive & protected areas

Results highlighted that the identified locations for OWF in the four regions have peculiarities that make each sensitive for a different aspect. For instance, the OWF site in Istria Region seems to be positioned quite close to an area of high biomass of demersal species (Fig. 2.5.1) and beta diversity (Fig. 2.6.1). Conversely, OWF areas in Split-Dalmatia County and Apulia Regions are positioned in low sensitive areas for most of the ecological themes except for migratory birds, where OWF areas occur in a high-ranking order of importance (Fig. 3.8.1 and 5.8.1). In the case of OWF areas in the Veneto Region, the aspect most sensitive appears to be the high presence of mammals (Fig. 4.7.1). These critical aspects specific for each area should be further investigated with local, high-resolution data.

It is worth noting, however, that the analysis revealed gaps in several data (e.g., marine mammals) and the need to improve resolution for other ecological aspects (demersal community data; migratory bird sensitivity). In the future, these gaps might need to be closed in the case of further developments of OWF, as well as improving resolution, to facilitate the optimization of the placement of OWF within the areas identified.

7. Acknowledgements

Dr. Jenkins from the University of Colorado for providing data on the sediment type of the Adriatic seafloor.



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