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# BEYOND - Blue Economy sYnergies fOr sustainable Development

## D.1.4.2

## Pilot regions preliminary fishing and aquaculture potential analysis

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# 1. Introduction

This deliverable presents the analysis conducted in Activity A.1.4, "Current state blue economy potential analysis", to assess the potential goods and services provided by fisheries and aquaculture within the four identified regions.

This constitutes a preliminary analysis of the fishing and aquaculture potential in the four pilot regions, which will inform discussions with stakeholders on the value of the areas under investigation. The analysis considers the maximum available current and future production potential in the regions to calculate the potential sector value. The report is based on existing data at the highest possible resolution and is prepared for integration into the BEYOND GIS platform.

This information will be essential in the next stages of the project to determine the potential impacts of offshore wind farms (OWFs) in relation to environmental issues, marine ecosystem-specific requirements, and benefits to other blue economy sectors, particularly fishing and aquaculture. The results may be used to identify optimal OWF locations. They will also influence the design and construction characteristics of OWFs, such as the distance between pylons and proposals for possible seabed interventions, including specific cable layouts or artificial reefing, if these are considered beneficial for marine species in the area or required for specific protection regimes.

To assess the potential effects of OWF on the fisheries and aquaculture sectors, this preliminary analysis examines the overlap between identified OWF in the four regions and currently available information. Notably, the impacts of OWF on fishing are varied and can be both direct and indirect. Direct impacts involve the inability of fisheries to operate within OWF areas (assuming a complete ban on fishing within OWF).

These direct impacts could be estimated from actual catches in the OWF domain, assuming these cannot be collected in the future, and require detailed information on the spatial distribution of catches, which is not available. Indirect effects concern possible changes in the natural distribution and abundance of populations due to OWF, as well as the displacement of fisheries. These can be assessed through dynamic simulation models and will be estimated in subsequent activities of BEYOND (Activity 2.2).

For this preliminary analysis, the direct and indirect potential effects of OWF on fisheries and aquaculture are assessed by analysing various sources of information. Given the difficulties in conducting a comprehensive analysis of all effects, the analysis focuses on four areas.

The analyses aim to understand different aspects and therefore relate to four areas:

1. essential fish habitats (EFH) for main commercial species, presented, analysed and discussed in Section 2;
2. fishing grounds derived from fishing vessel activities, presented in Section 3;
3. estimated catches at high resolution by combining species and effort distribution, as detailed in Section 4;
4. aquaculture farms and their overlap with OWF, discussed in Section 5.

These areas of investigation are analysed in separate sections, each using the best available information to provide highly detailed and accurate estimates of the impacts of OWF on regional seafood production. The analyses involving commercial species are necessarily species-specific and were therefore conducted for the most important species in Adriatic Sea fisheries: European hake (*Merluccius merluccius*), European anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), red mullet (*Mullus barbatus*), deep-water rose shrimp (*Parapenaeus longirostris*), giant red shrimp (*Aristaeomorpha foliacea*), horse mackerel (*Trachurus trachurus*), and southern shortfin squid (*Illex coindetii*). Together, these species comprise more than 70% of the total commercial landings in the Adriatic Sea (FAO, 2023).

Impact is estimated by analysing the overlap between OWF and indicators of fishing and aquaculture activities. Although the exact impact is not known, this analysis should serve as a preliminary assessment of the impacts of OWF in the four regions on marine seafood production in the Adriatic Sea.

# 2. Essential Fish Habitats (EFH) for main commercial species

Indirect possible effects of OWF on fisheries are also determined by the potential impacts that OWF has on habitats crucial for marine populations. These include habitats essential for completing the life cycle of species, such as spawning and nursery areas—areas where an impact causes substantial and continuous effects on the species' life cycle, thereby affecting their abundance at sea and, consequently, fisheries. These Essential Fish Habitats (EFH) are specific to each species and can be identified from scientific trawl surveys (fishery-independent data).

## 2.1. Approach used: objective, data, method

Data from the Mediterranean International Trawl Survey (MEDITS; Spedicato et al., 2019), conducted in GSA 17 and 18 (Northern and Southern Adriatic Sea), were used to identify the most important fish habitats for commercially exploited species, following a procedure previously applied in many studies (Zorica et al., 2020; Von Schuckmann et al., 2021; Panzeri et al., 2024). The main objective was to identify hotspots with high biomass throughout the basin, particularly within the BEYOND area in the Istria, Apulia, Split and Veneto regions.

The data, obtained from the independent fisheries survey MEDITS, include two types of information: kilograms or number of individuals caught. To improve the method, both types of data were used to determine whether the area studied could be important and involved in the BEYOND area for juveniles, spawning, and biomass of the species analysed. The eight species selected as the most important commercial species in the area are: European hake (*Merluccius merluccius*), European anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), red mullet (*Mullus barbatus*), deep-water rose shrimp (*Parapenaeus longirostris*), giant red shrimp (*Aristaeomorpha foliacea*), horse mackerel (*Trachurus trachurus*), and southern shortfin squid (*Illex coindetii*).

To determine the spatial and temporal distribution of species, averaged over years, we used the species distribution model approach, focusing in particular on the generalised additive mixed model, which includes a fixed and a random effect (see Eq. 1).

$$\log(E[Y_{s,t}]) = \beta_0 + X_{s,t}\beta + \omega_s + v_t \quad \text{eq 1.}$$

The $\log(E[Y_{(s,t)}])$ is the expected mean of the response variable, $\beta_0$ is the intercept, $X_{(s,t)}$ is the covariate matrix with its corresponding coefficient β. The terms $\omega_s$ and $v_t$ represent the spatial and spatiotemporal random effects of the process. The coordinates refer to the MEDITS samples

Environmental covariates are derived from the Copernicus Marine Service dataset (marine.copernicus.eu) considering in particular the reanalysis from the physical and biogeochemical models (Cossarini et al. 2021). Covariates were used as the fixed effect and include two of the main species drivers. The covariates are the bottom temperature for demersal species and the surface temperature for pelagic species, as well as depth of the haul for both. In addition, we include spatial covariance as a random effect (see Eq. 1), which integrates the random covariance between density and life stage (e.g. juveniles and adults) of the analysed species. For the spatial and temporal outcome in terms of number of individuals or kilogrammes per square kilometre, we identify the autocorrelation (in terms of hot spot, high aggregation area) using the Gi* statistic (Getis star index; Getis and Ord, 1982). The Gi* index is a spatial moving average and indicates the degree of aggregation of data: high values indicates overaggregation and low values indicates very sparse distribution. We choose to highlight the values of Gi* greater than the third quartile to define the main hot spot areas for each species and life stage following a procedure defined previously (Panzeri et al., 2024). Then we show the overlap between such hotpots and the foreseen OWF areas in the four regions.

## 2.2. Results of the EFH analysis for the Adriatic Sea

The following presents the hot spots for each species and life stage, overlaid with the OWF foreseen in BEYOND for the four areas (represented as black shapes in each figure). Only hot spots (Gi* greater than the third quartile) are shown as EFH, although Gi* values in these areas are also reported to highlight the most important sites. EFH areas are presented for anchovy and sardine (Figure 2.2.1), for red mullet and hake (Figure 2.2.2), for Rose shrimp and Deep red shrimp (Figure 2.2.3) and for horse mackerel and southern shortfin squid (Figure 2.2.4).

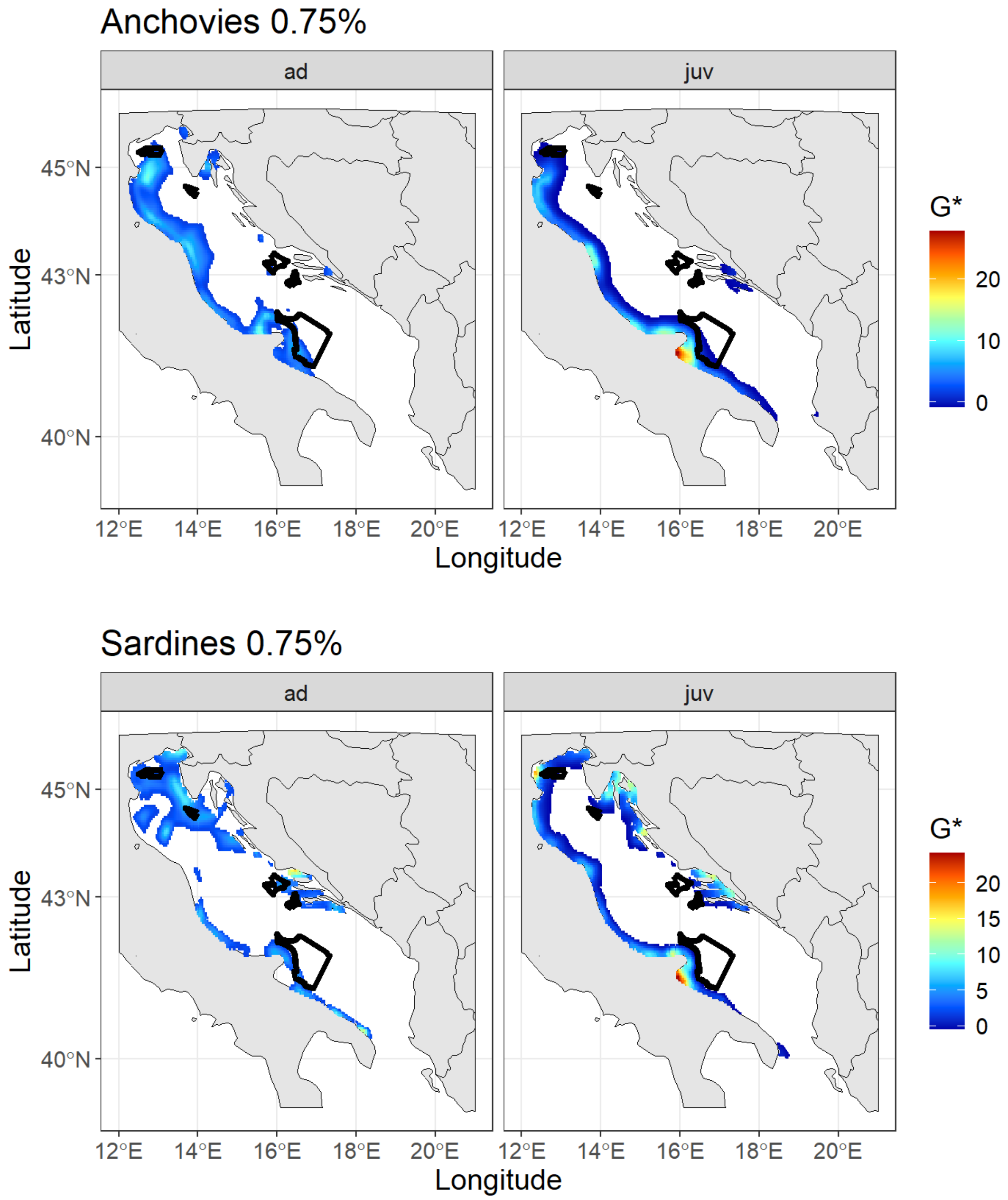
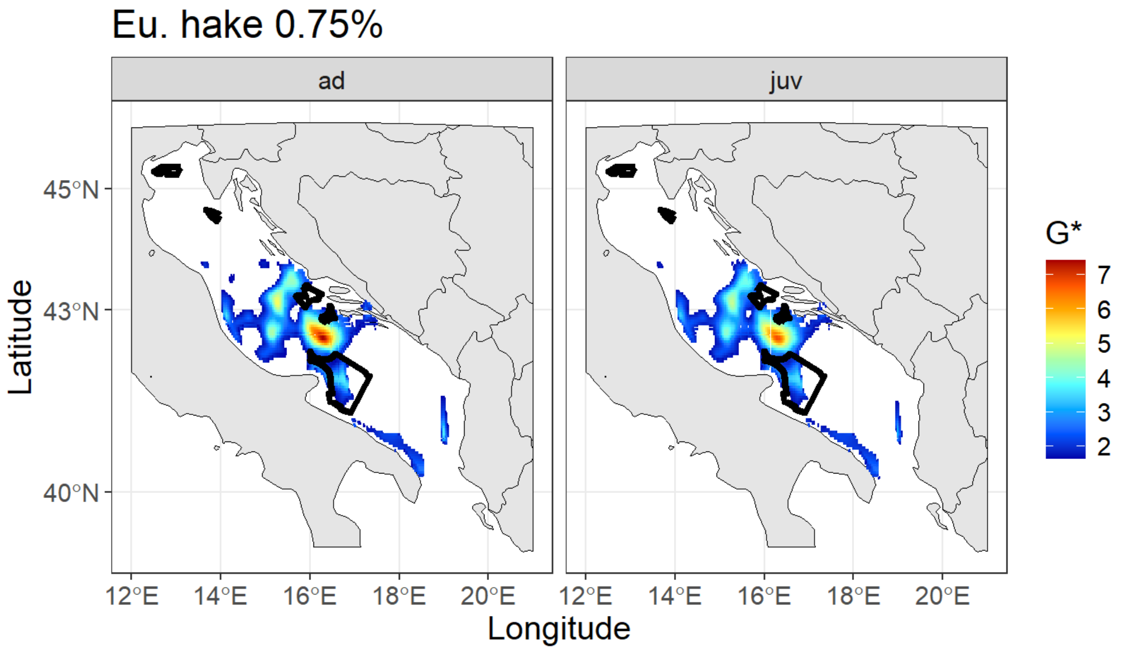



*Figure 2.2.1. Essential fish habitat for adults and juveniles of European anchovy (Engraulis encrasicolus) and sardine (Sardina pilchardus). EFH is estimated as the hotspots of aggregation, i.e., where Gi* is above the third quartile (all coloured areas). OWF areas in the four regions are also shown on the map (black contour).*



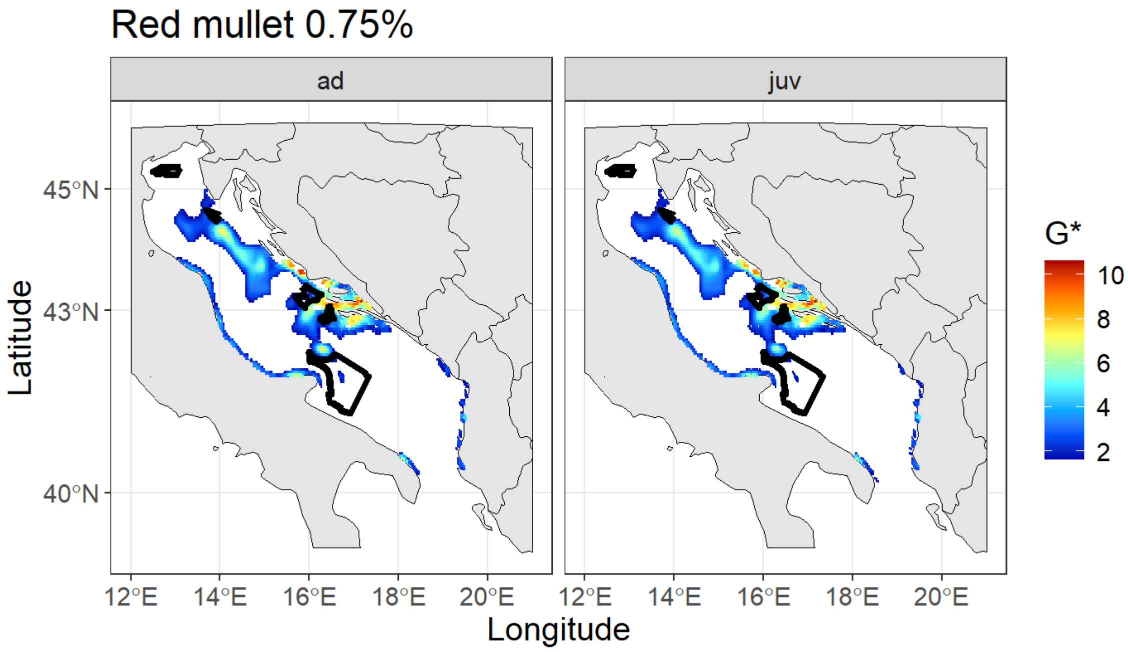




*Figure 2.2.2. Essential fish habitat for adults and juveniles of red mullet (Mullus barbatus) and European hake (Merluccius merluccius). EFH is estimated as the hotspots of aggregation, i.e., where Gi* is above the third quartile (all coloured areas). OWF areas in the four regions are also shown on the map (black contour).*

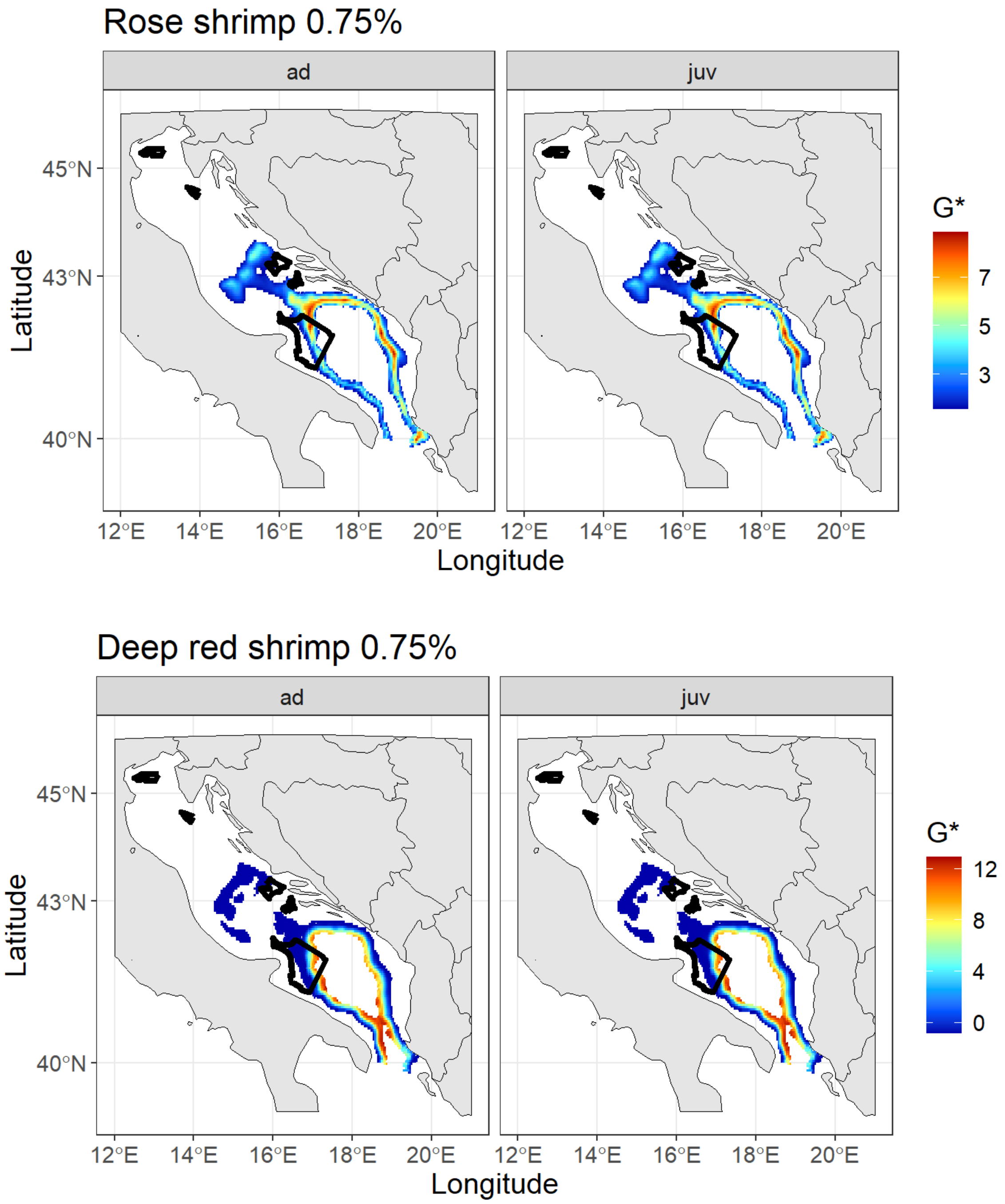



*Figure 2.2.3. Essential fish habitat for adults and juveniles of Deep-water rose shrimp (Parapenaeus longirostris) and Giant red shrimp (Aristaeomorpha foliacea). EFH is estimated as the hotspots of aggregation, i.e., where Gi* is above the third quartile (all coloured areas). OWF areas in the four regions are also shown on the map (black contour).*

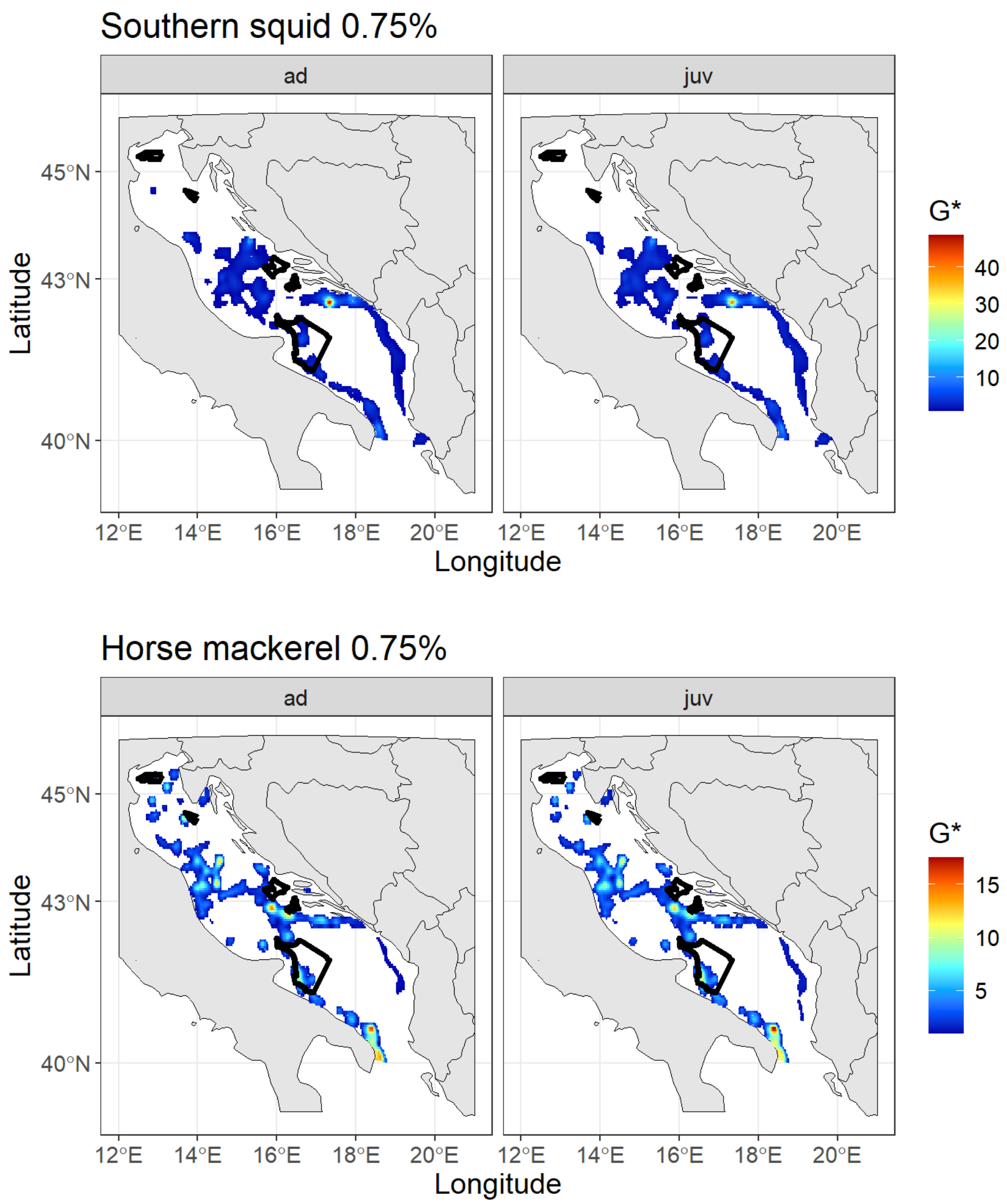



*Figure 2.2.4. Essential fish habitat for adults and juveniles of horse mackerel (Trachurus trachurus) and southern shortfin squid (Illex coindetii). EFH is estimated as the hotspots of aggregation, i.e., where Gi* is above the third quartile (all coloured areas). OWF areas in the four regions are also shown on the map (black contour).*

Species such as the anchovy are particularly concentrated in the western part of the Adriatic basin and overlap with the OWF areas in Veneto and the Apulia region. Sardine EFH is quite widespread; thus, the overlap between EFH for sardine and OWF occurs on both sides of the basin, but especially in the Split region (Fig. 2.2.1).

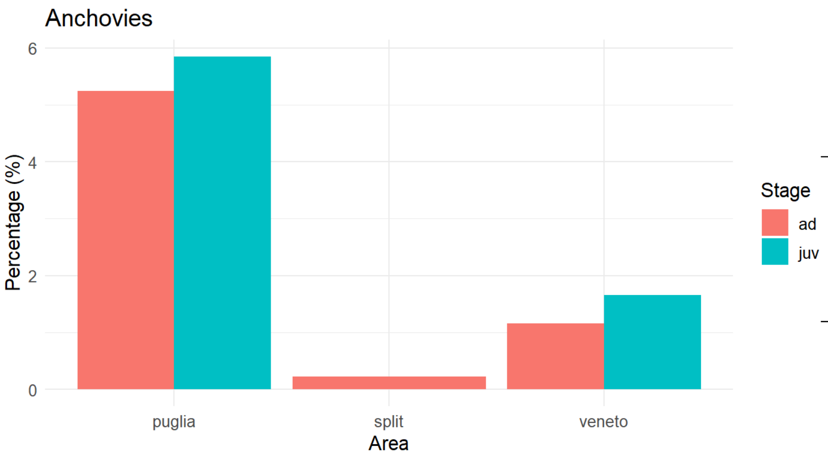
The EFH for European hake overlaps mainly with OWF foreseen in Split-Dalmatia and Apulia regions, where the EFH of both life stages of the species is common (Fig. 2.2.2). The EFH for the red mullet (Fig. 2.2.2), a species that occurs mainly in the shelf area and on the coast of the basin, show wide overlaps with the foreseen OWF areas mainly within the Split-Dalmatia, Istra and Apulia regions, the latter especially in the upper part of the BEYOND area, near the Bari canyon.

The Rose shrimp is a species mainly present in the deeper areas in the Southern part of the Adriatic Sea thus its EFH overlaps with planned OWF areas only in the Apulian region (Fig. 2.2.3). The same applies to the Giant Red Shrimp (Fig. 2.2.3).

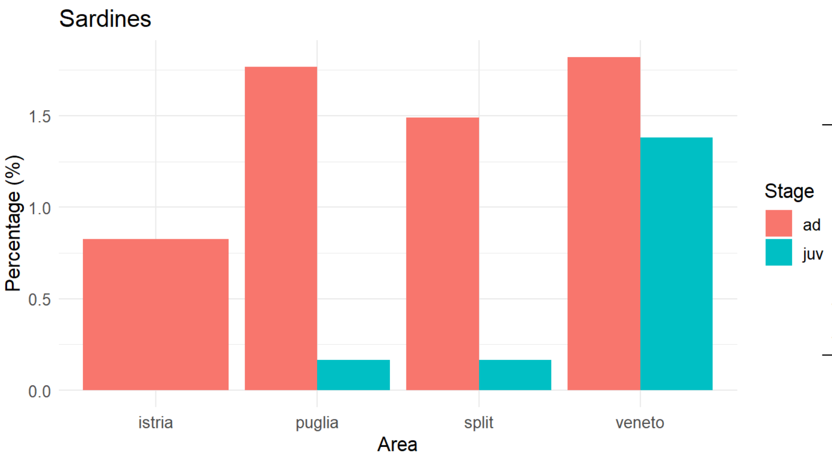
The EFH for southern shortfin squid are mainly located in the central and southern part of the Adriatic Sea (Fig. 2.2.4) thus there is overlap with OWF areas in the Apulia and Split regions only. The EFH for the horse mackerel (Fig. 2.2.4) resulted quite scattered both for juveniles and adults: the estimated EFH overlaps with the OWF planned in three regions: Split-Dalmatia, Apulia and Istria.

## 2.3. Synthesis and discussion on overlap between EFH and OWF

To quantitatively assess the importance of EFH affected by the planned OWF, the proportion and number of EFH grid cells for each species and life stage within the planned OWF were calculated. These values are reported by life stage and species in the following figures. Species such as anchovy have no EFH overlapping with the Istra region, but EFH overlap occurs in decreasing proportions in the Apulia region (~6%), especially for juveniles, and in Veneto and the Split area at approximately 1.5% and 0.2%, respectively (Fig. 2.3.1). For sardines (Fig. 2.3.1), the proportion of EFH and OWF overlap ranges from 0.16% in Apulia to 1.8% in the Veneto region (adults).



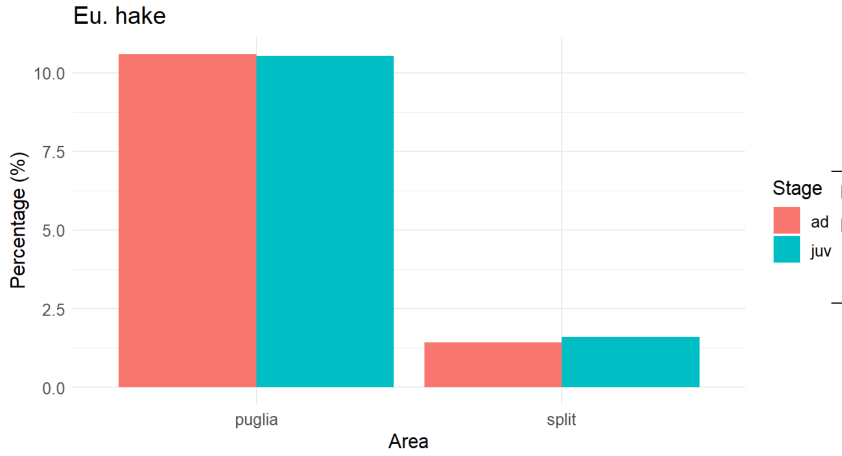

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 95 | 1812 | 5.2428256 |
| puglia | juv | 106 | 1812 | 5.8498896 |
| split | ad | 4 | 1812 | 0.2207506 |
| veneto | ad | 21 | 1812 | 1.1589404 |
| veneto | juv | 30 | 1812 | 1.6556291 |



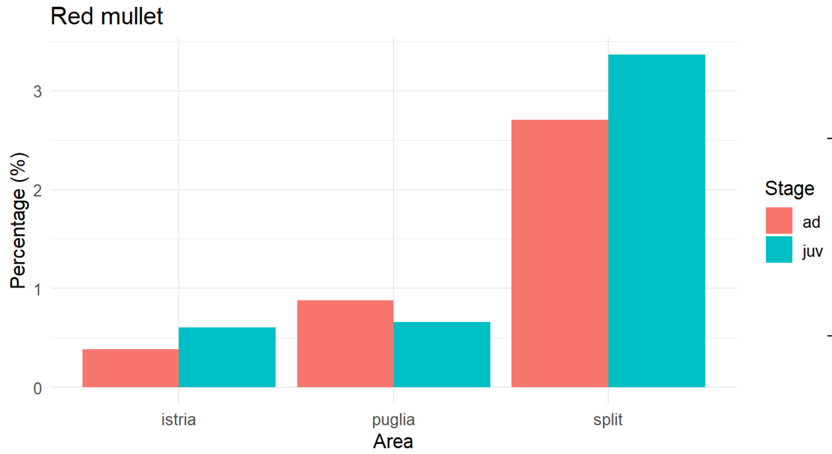

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| istria | ad | 15 | 1812 | 0.8278146 |
| puglia | ad | 32 | 1812 | 1.7660044 |
| puglia | juv | 3 | 1812 | 0.1655629 |
| split | ad | 27 | 1812 | 1.4900662 |
| split | juv | 3 | 1812 | 0.1655629 |
| veneto | ad | 33 | 1812 | 1.8211921 |
| veneto | juv | 25 | 1812 | 1.3796909 |

*Fig. 2.3.1: Proportion of the EFH for adults and juveniles of anchovy and sardine in the Adriatic Sea interested by the planned OWF in the four regions. Table also report number of grid cells, total and proportion.*

For European hake EFH and OWF overlaps mainly in the Apulia region, where the EFH falling into OWF areas accounts for more than 10 % for both life stages (Fig. 2.3.2). The proportion of red mullet EFH that overlaps with OWF is 2.7% and 3.36 % for adults and juveniles, respectively in the OWF in Split-Dalmatia region and is <1% in Istra and Puglia OWF areas (Fig. 2.3.2).



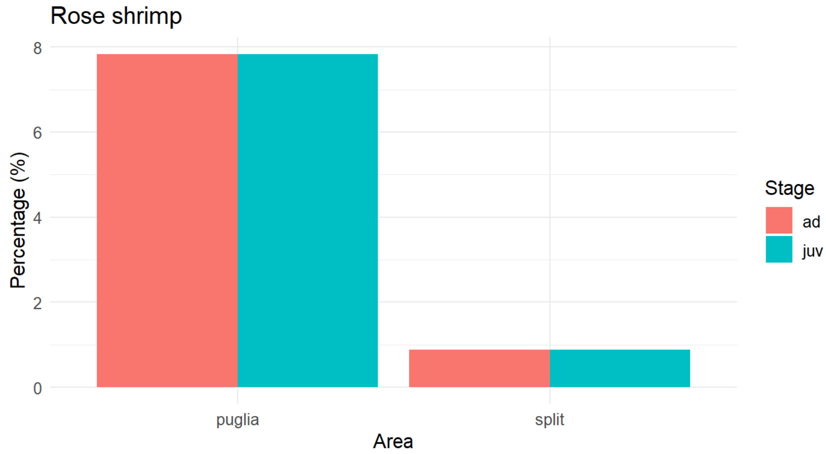

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 192 | 1812 | 10.596026 |
| puglia | juv | 191 | 1812 | 10.540839 |
| split | ad | 26 | 1812 | 1.434879 |
| split | juv | 29 | 1812 | 1.600442 |



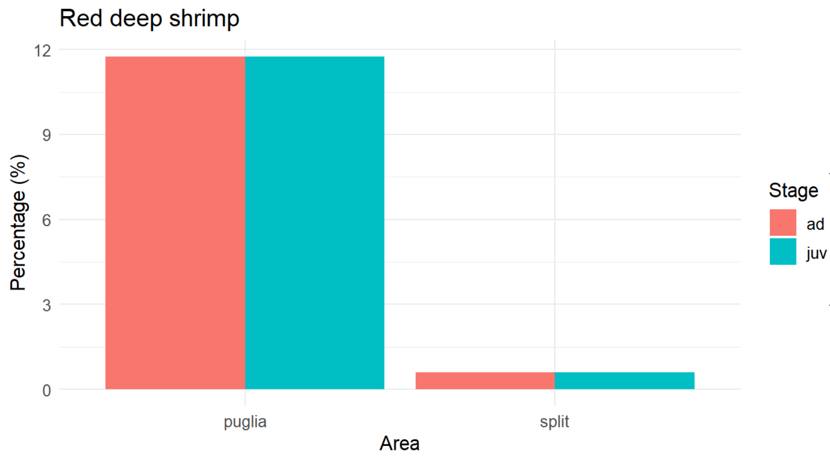

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| istria | ad | 7 | 1812 | 0.3863135 |
| istria | juv | 11 | 1812 | 0.6070640 |
| puglia | ad | 16 | 1812 | 0.8830022 |
| puglia | juv | 12 | 1812 | 0.6622517 |
| split | ad | 49 | 1812 | 2.7041943 |
| split | juv | 61 | 1812 | 3.3664459 |

*Fig. 2.3.2: Proportion of the EFH for adults and juveniles of hake and red mullet in the Adriatic Sea interested by the planned OWF in the four regions. Table also report number of grid cells, total and proportion.*

The EFH for Deep rose shrimp and Giant Red shrimp overlaps with the OWF mainly in the Apulian region with a proportion that is ~7.5 % and 11% of the EFH fall of the Adriatic fall in the OWF, respectively. Minimal overlap exists for both species with the OWF placed in Split-Dalmatia region (Fig. 2.3.3).



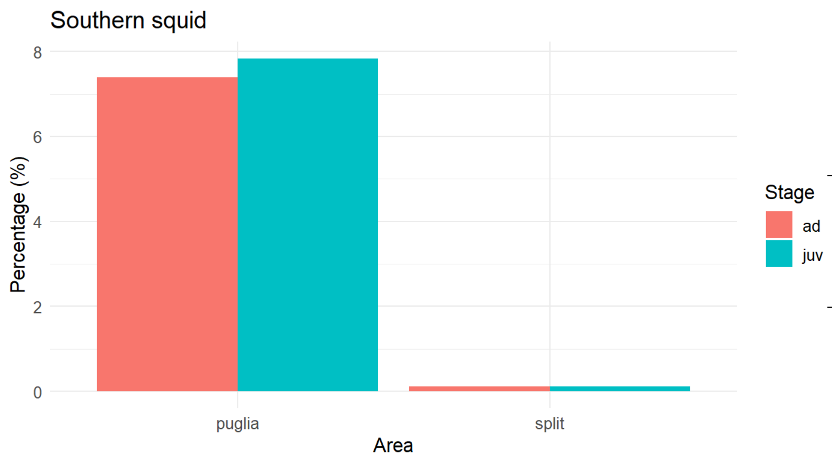

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 142 | 1812 | 7.8366446 |
| puglia | juv | 142 | 1812 | 7.8366446 |
| split | ad | 16 | 1812 | 0.8830022 |
| split | juv | 16 | 1812 | 0.8830022 |



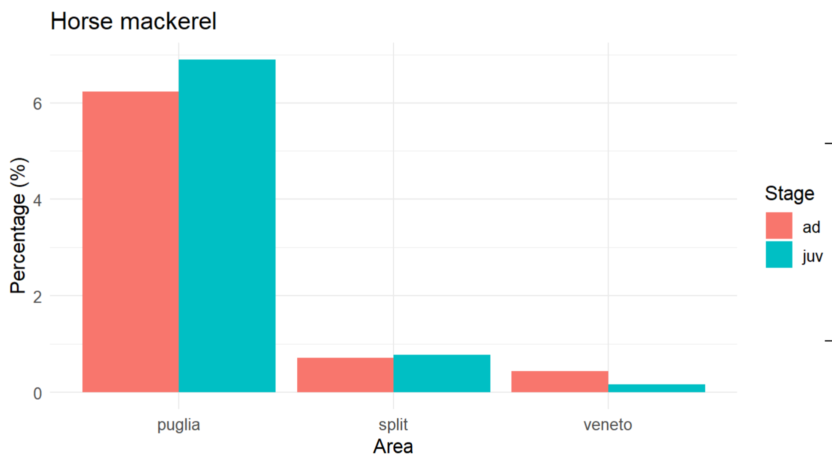

| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 213 | 1812 | 11.754967 |
| puglia | juv | 213 | 1812 | 11.754967 |
| split | ad | 11 | 1812 | 0.607064 |
| split | juv | 11 | 1812 | 0.607064 |

*Fig. 2.3.3: Proportion of the EFH for adults and juveniles of Deep Rose Shrimp and Red Giant Shrimp in the Adriatic Sea interested by the planned OWF in the four regions. Table also report number of grid cells, total and proportion.*

The EFH of the southern squid overlaps only with the OWF planned in the Apulia region: 7.5% of the EFH in the Adriatic is expected to fall within this OWF area. Finally, EFH for horse mackerel overlaps with OWF planned in the Apulia region, Split-Dalmatia, and Veneto region, with moderate proportions of approximately 6.2%, 0.7%, and 0.44%, respectively (Fig. 2.3.4).




| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 134 | 1812 | 7.3951435 |
| puglia | juv | 142 | 1812 | 7.8366446 |
| split | ad | 2 | 1812 | 0.1103753 |
| split | juv | 2 | 1812 | 0.1103753 |




| area | age | in_zone | total | perc |
|---|---|---|---|---|
| puglia | ad | 113 | 1812 | 6.2362031 |
| puglia | juv | 125 | 1812 | 6.8984547 |
| split | ad | 13 | 1812 | 0.7174393 |
| split | juv | 14 | 1812 | 0.7726269 |
| veneto | ad | 8 | 1812 | 0.4415011 |
| veneto | juv | 3 | 1812 | 0.1655629 |

*Fig. 2.3.4: Proportion of the EFH for adults and juveniles of Southern shortfin Squid and Horse Mackerel in the Adriatic Sea interested by the planned OWF in the four regions. Table also report number of grid cells, total and proportion.*

Overall the results highlight a moderate overlap between EFH and OWF planned. It has to be considered that the high proportion of EFH impacted in the Puglia region are also related to the large surface considered for the planned OWF.

# 3. Analysis of fishing activity

The impact of OWF on fisheries can also be established by understanding how the proposed OWF in the four regions will fall within the actual fishing grounds. Thus in this section an analysis of the spatial distribution of fishing effort is proposed and it is estimated the overlap between the fishing grounds of fleets operating in the Adriatic Sea and the planned OWF in the four regions.

## 3.1. Introduction, data used and methods

The analysis is conducted by using the Automatic Information System (AIS), a device installed onboard of all vessels which pings a vessel position on average every minute. Global Fishing Watch (GFW; https://globalfishingwatch.org/) processes raw AIS messages, sourced by Spire and Orbcomm provider (Kroodsma et al. 2018). In particular, AIS messages for fishing vessels are processed through two different convolutional neural networks (CNN) to predict when the vessel is active in fishing operations. One classifies the vessel type and predicts vessel characteristics such as length, tonnage and engine power while a second one classifies every AIS position as either fishing or non-fishing (Kroodsma et al., 2018). Notably this approach is specific for each fishing gear and the GFW is reporting the estimated "apparent fishing effort" distinguished into 10 different fishing gears:

- Dredges
- Drifting longline
- Fixed gears
- Gillnets
- Other mixed small fisheries
- Purse seiners
- Other seiners
- Set longline
- Trawlers
- Others (inconclusive)

All these gears are active in the Adriatic sea and thus the data were considered.

## 3.2. Results of fishing activities operating in OWF planned areas

Data of AIS are available at grid cells of 0.2 decimal degrees horizontal resolution (~ 22 $Km^2$) and were elaborated to estimate apparent fishing activity (using CNN) to estimate the hours spent fishing within each grid cell. The data for the year 2022 were used to identify the fishing grounds and for calculating the proportion of effort within the OWF.

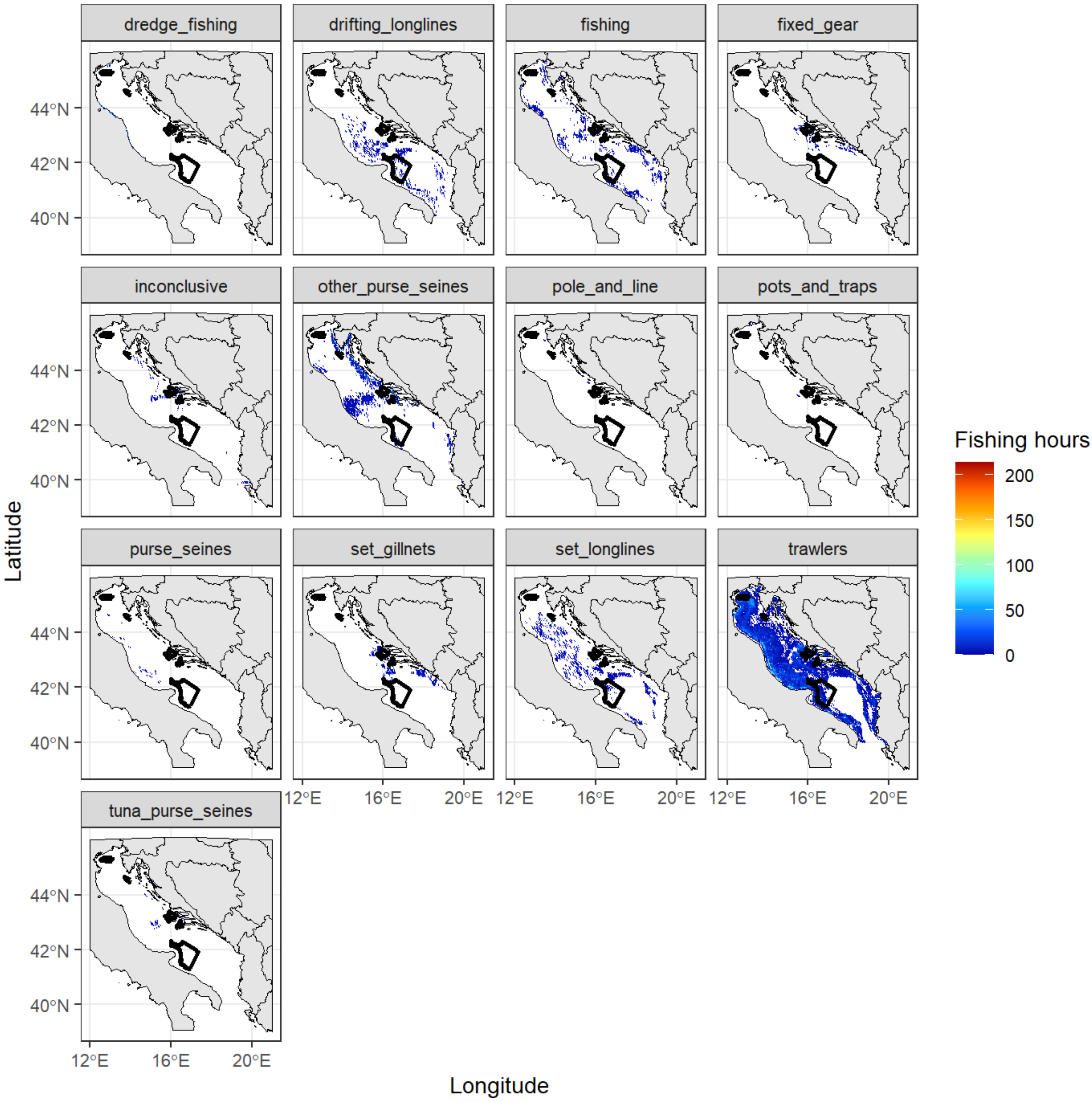



*Fig. 3.2.1. Apparent fishing effort (in hours per grid cell) by gear for the year 2022.*

### 3.3. Synthesis of results and discussion on overlap between fisheries and OWF

Very small proportions of apparent fishing effort from AIS were located within planned OWF areas. In particular, only trawlers were found to be active in all four areas affected by planned OWF. Nevertheless, the annual effort (2022) within the OWF ranged from 0.033% for the Veneto region, 0.024% for the Istra region, 0.019% for Apulia, and 0.011% for the Split-Dalmatia region (Fig. 3.3.1). For longlines (drifting and set), the OWF in the Apulia region was mostly affected, but with a very modest proportion of the effort: 0.306% and 0.162% for drifting and set longlines, respectively. Set gillnets overlapped with the planned OWF only in the Split-Dalmatia region (0.553%). Overall, the results indicate that the OWF areas planned in the four regions affect the fishing grounds of all Adriatic fisheries to a very minor extent.

AIS data are the most abundant and frequent source for tracking vessels, and methods for understanding fishing activity are well established (Natale et al., 2015; Kroodsma et al., 2018; Russo et al., 2019; Paolo et al., 2024). Although AIS is considered the most reliable and continuous source of information on fishing activities (see also https://globalfishingwatch.org/), there are some limitations.

Minor errors may occur in the identification of fishing vessels, and there can be inaccuracies regarding the gear used by each vessel. Although the gear type is recorded through the registered licence, errors may arise if the same vessel uses different gear according to the season. Furthermore, only vessels with a length overall (LOA) greater than 15 metres are required to have AIS installed; therefore, AIS data represent large vessels from industrial activities (typically trawlers) well, but have limited capability for other fishing activities, especially coastal small-scale fishing, which is usually carried out with small vessels (LOA < 12 m) (Russo et al., 2019).

New approaches have been developed for identifying fishing vessels and activities from satellite, for example, using satellite data from Synthetic Aperture Radar (SAR; e.g., Marsaglia et al., 2025). However, these approaches have limitations, such as a lack of high-frequency observation and still poor resolution. Furthermore, comparison between different data sources has shown that for many areas in the northern Mediterranean Sea, including the Adriatic Sea, the representation of AIS data is fully confirmed by SAR information (Marsaglia et al., 2025) .

Thus, overall, AIS data are currently considered the best available dataset for detecting fishing activities of large vessels and, therefore, for industrial fisheries worldwide (Paolo et al., 2024). Nevertheless, given the lack of coverage for small vessels and inevitable errors in AIS (such as accidental or voluntary deactivation of AIS on board), it is recommended to conduct detailed and local analyses (including questionnaires, interview with fishermen, tracking vessels, checking catches) for a definitive assessment of the importance of planned OWF areas for fisheries.

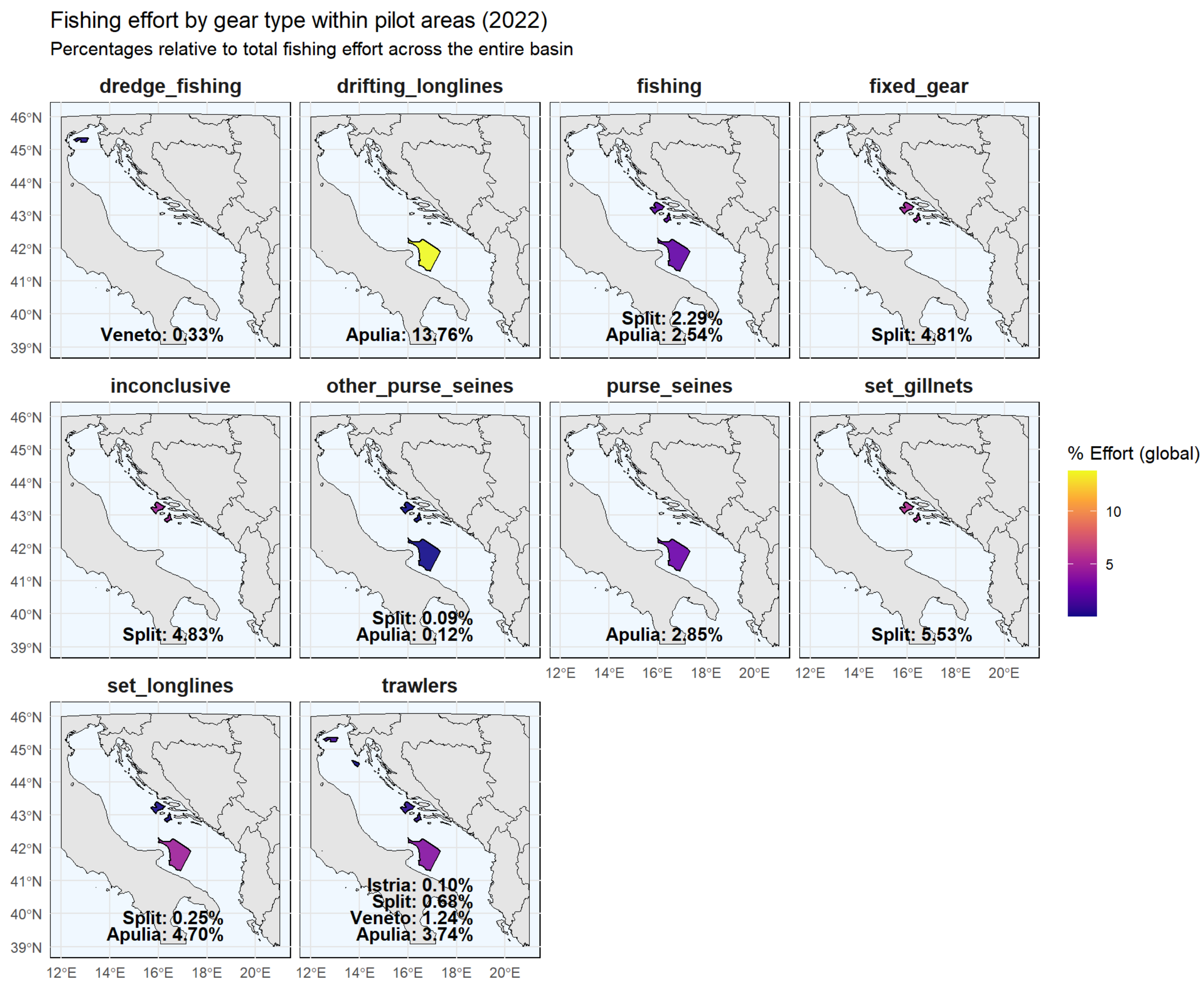



*Fig. 3.3.1. Proportion of apparent fishing effort by gear for year 2022 falling within the planned OWF.*

## 4. Estimating catches in areas interested by OWF

Estimating catches potentially affected by planned OWFs is not a straightforward task. The main problem lies in the fact that catch statistics are often not linked to precise spatial fishing locations. Fisheries catch statistics are generally available in three forms:

1. Aggregated landings by country, species, and large FAO areas (catch statistics, e.g., from FAO FishstatJ; EU Data Collection Fishery);
2. Logbook data by fishing vessel, reporting detailed catches, sometimes with coordinates but more often with general catch areas;
3. Port sampling and detailed landing records, where verified catches can be georeferenced to fishing areas.

Given that the possible spatial identification of exact points where catches occur inevitably needs to be estimated by integrating other datasets, such as:

1. Automatic Identification System (AIS);
2. Vessel Monitoring System (VMS);
3. On-board observers.

An approach to combine AIS and logbook data, for example, was developed by Russo et al. (2014); an alternative approach is to develop spatio-temporal ecosystem models to simulate resource and fisheries distribution and estimate catches (De Mutsert et al., 2024). While the ecosystem approach will be used in the next phase of the project (Activity 2.2, project BEYOND), in this deliverable the preliminary analysis of catches from potential OWF areas is identified by combining information on the best distribution of species, as determined in Section 2, and the AIS data on fishing effort used in Section 3.

### 4.1. Introduction: method, data, estimated catches

The approach implemented by combining best known distribution of species and effort is based on the assumption that the catch is the product of the probability of encounter between fisheries and the species.

The probability of the species presence is determined by the estimated best distribution from the spatial and temporal model that is fit for the biomass index in kg/km$^2$. The result is an index of biomass density for each species and year, which, when divided by the total biomass estimated in the basin, yields the spatio-temporal distribution of the probability of encountering each species. The biomass index was estimated using a model approach described in Section 2 thus implementing the biomass estimates obtained from Mediterranean International Trawl Survey (MEDITS; Spedicato et al., 2019), conducted in GSA 17 and 18 (Northern and Southern Adriatic Sea) . Biomass index were estimated at 1/24 degree resolution (approximately 4 km grid cell).

The fishing effort is then considered as the other factor for calculating spatialized catches, by using spatialized yearly relative fishing effort (i.e., for each grid cell we divided the apparent AIS effort from the total effort of the gear). Apparent realized effort was taken from elaborated Automatic Information System (AIS) data available at the Global Fishing Watch (GFW; https://globalfishingwatch.org/) available at grid cells of 0.2 decimal degrees horizontal resolution (~ 22 Km$^2$) (see Section 3).

By multiplying relative effort distribution by relative biomass index for each species we obtain the specific probability of having catches . Multiplying such probability by the total catches in the basin of each species we obtain spatialized catches. These calculations are expressed in the following equation:

$$C'_i = \frac{\frac{y_i}{\sum_{i=1}^{n} y_i} * \frac{eff_i}{\sum_{i=1}^{n} eff_i}}{\sum_{i=1}^{n}\left(\frac{y_i}{\sum_{i=1}^{n} y_i} * \frac{eff_i}{\sum_{i=1}^{n} eff_i}\right)} \qquad \text{(Eq. 1)}$$

Where the relative catch per grid cell ($C'_i$) is estimated using the relative biomass index $y'_i$ equal to $\frac{y_i}{\sum_{i=1}^{n} y_i}$ that is the ration between the biomass index in the cell i (kg/km$^2$) divided by the sum of all biomasses in the domain and has values comprised between 0 and 1. Similarly the relative effort, $eff'_i$ is equal to $\frac{eff_i}{\sum_{i=1}^{n} eff_i}$, which result from the ratio between the effort of each grid cell ($eff_i$) to the total effort in the domain. The relative biomass and the relative effort by cell are considered as two independent probabilities to have biomass and fisheries in the cell. Therefore their product is assumed proportional to the probability of catches.

By dividing the combined weight of a single element (i) by the sum of all combined weights, the normalized catches are obtained with values ranging between 0 and 1. In other words, it is a way of calculating the relative importance of each element, taking into account both the biomass as probability to encounter the species and the "*eff*" as the probability to having fisheries in that cell.

Multiplying the values of relative catches (C'i) by the total catches in the basin for each species one obtain the spatialized estimates of catches in the Adriatic Sea. The data used for the catches by species were taken from the EU Fisheries Dependent Information (EU FDI; https://stecf.ec.europa.eu/data-dissemination/fdi_en).

## 4.2. Estimated catches for main commercial species

The approach described above was used for all years for which data of effort (2014-2024) and biomass (1994-2022) are both available, i.e., estimates of spatialized catches were obtained from 2014 to 2022. Data at the spatial resolution of 1/24 degree were obtained for European anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), European hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), deep-water rose shrimp (*Parapenaeus longirostris*), giant red shrimp (*Aristaeomorpha foliacea*), horse mackerel (*Trachurus trachurus*), and southern shortfin squid (*Illex coindetii*) in Figure 4.2.1-4.2.8 , respectively.

Purse seines effort and catches from GFW and EU FDI, respectively, were used for estimating spatialized small pelagic catches. Trawler effort and trawlers catches from GFW and EU FDI were used for all other demersal species. These gears were considered as the most important in the basin for representing the catches of these target species. Although the analysis can be done also taking into account other fishing gears, the results of this analysis still represent major indications for the effects of OWF on fisheries.

The maps shows the distribution of catches in the whole Adriatic basin, on which are overimposed the possible OWF considered in the 4 regions Istra, Split-Dalmatia, Veneto and Apuglia. Results has to be intended as estimates (not real catches) although the approach is the most reliable for basin wide estimates. Clearly local data are necessary to test and increase accuracy of estimates.

However, it should be noted the scant grid cell with estimated catches for anchovy and sardine. This is the result especially of poorly distributed information on effort of purse seiners (see Section 3) that were used to estimate the catches. Sardine and anchovy are target especially of two kind of gears: the purse seines and the pelagic trawlers. Nevertheless the effort data cannot permit to distinguish benthic/demersal trawlers from pelagic ones: therefore in the analysis for reconstructing catches only the purse seine effort was used (Fig. 4.2.1 and 4.2.2). Given the poor capacity of representing effort for all fleets targeting small pelagics, results in terms of spatialized catches for these species need to be considered with care.

Th estimated spatial catches for other species, instead, appear quite consistent with ecological and fisheries knowledge and gives preliminary vision of possible catches in planned OWF areas.

Notably future work is needed to verify the accuracy of such results, for example confronting with the scant information available on spatialized catches from logbook and interviews or with poor resolution spatial catches available from EU Data Collection of Fisheries.

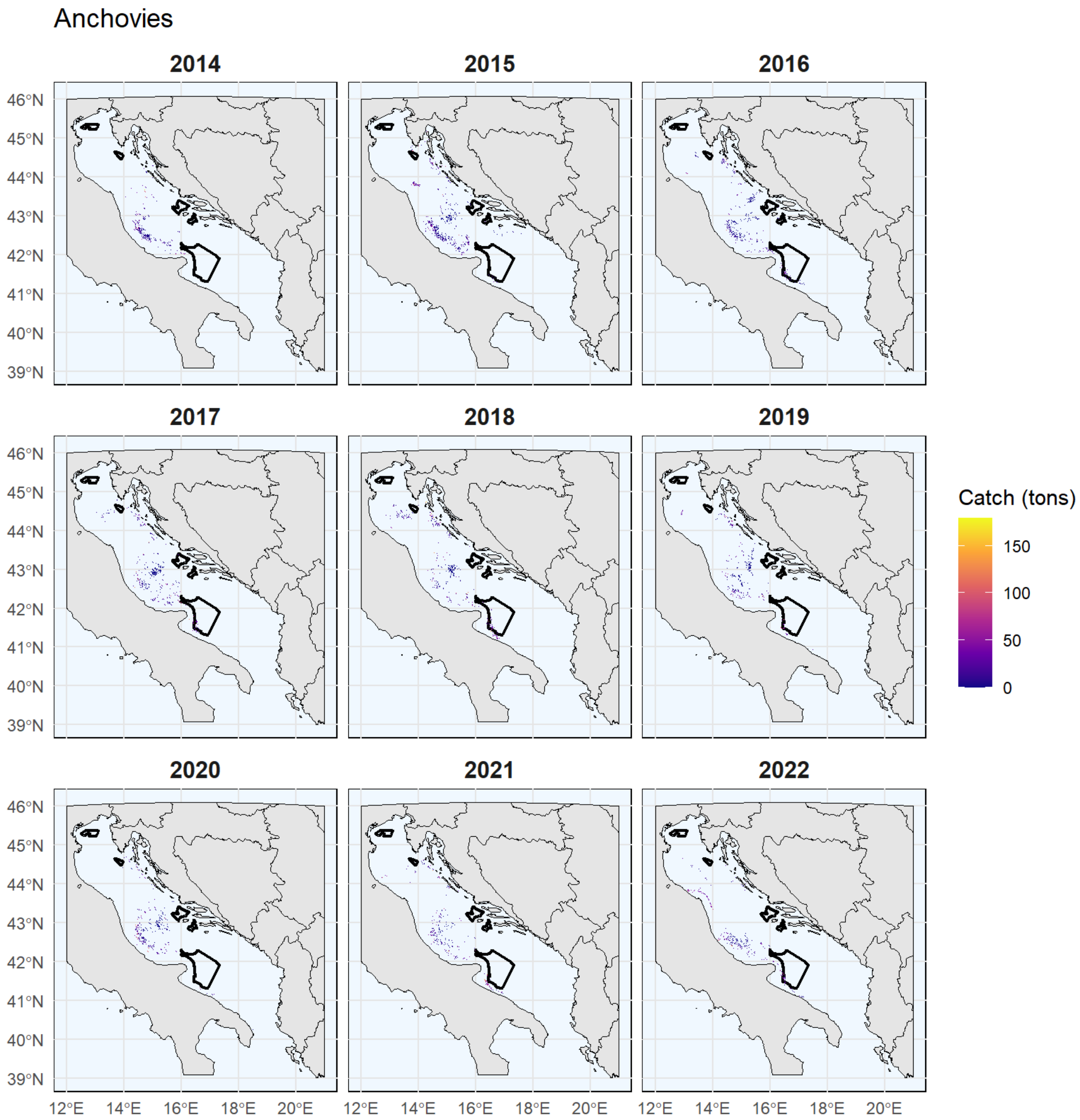



*Fig. 4.2.1. Spatialized estimated catches for Anchovy in the Adriatic Sea obtained by considering biomass and effort distribution of purse seiners.*

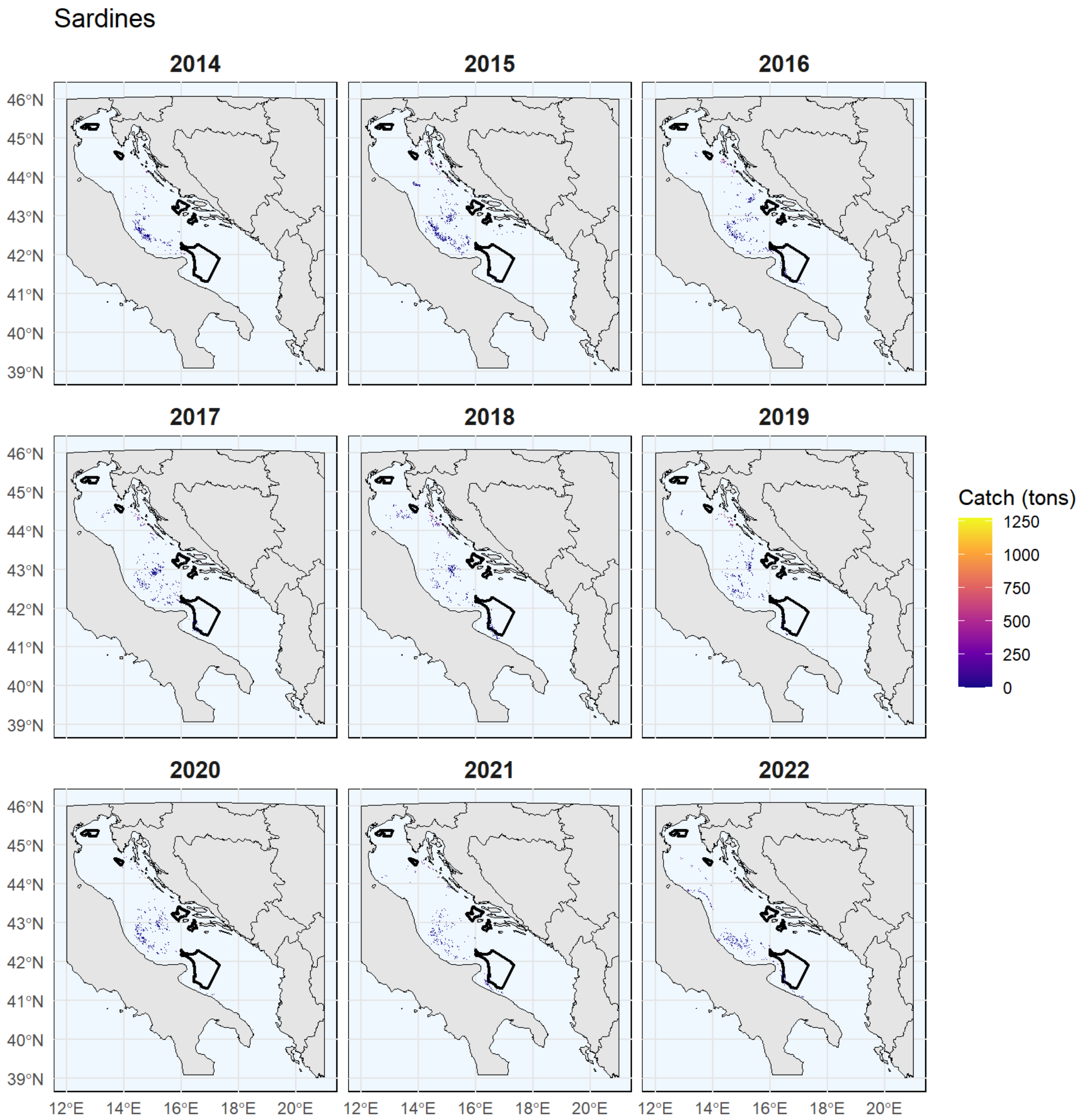



*Fig. 4.2.2. Spatialized estimated catches for Sardine in the Adriatic Sea obtained by considering biomass and effort distribution of purse seiners.*

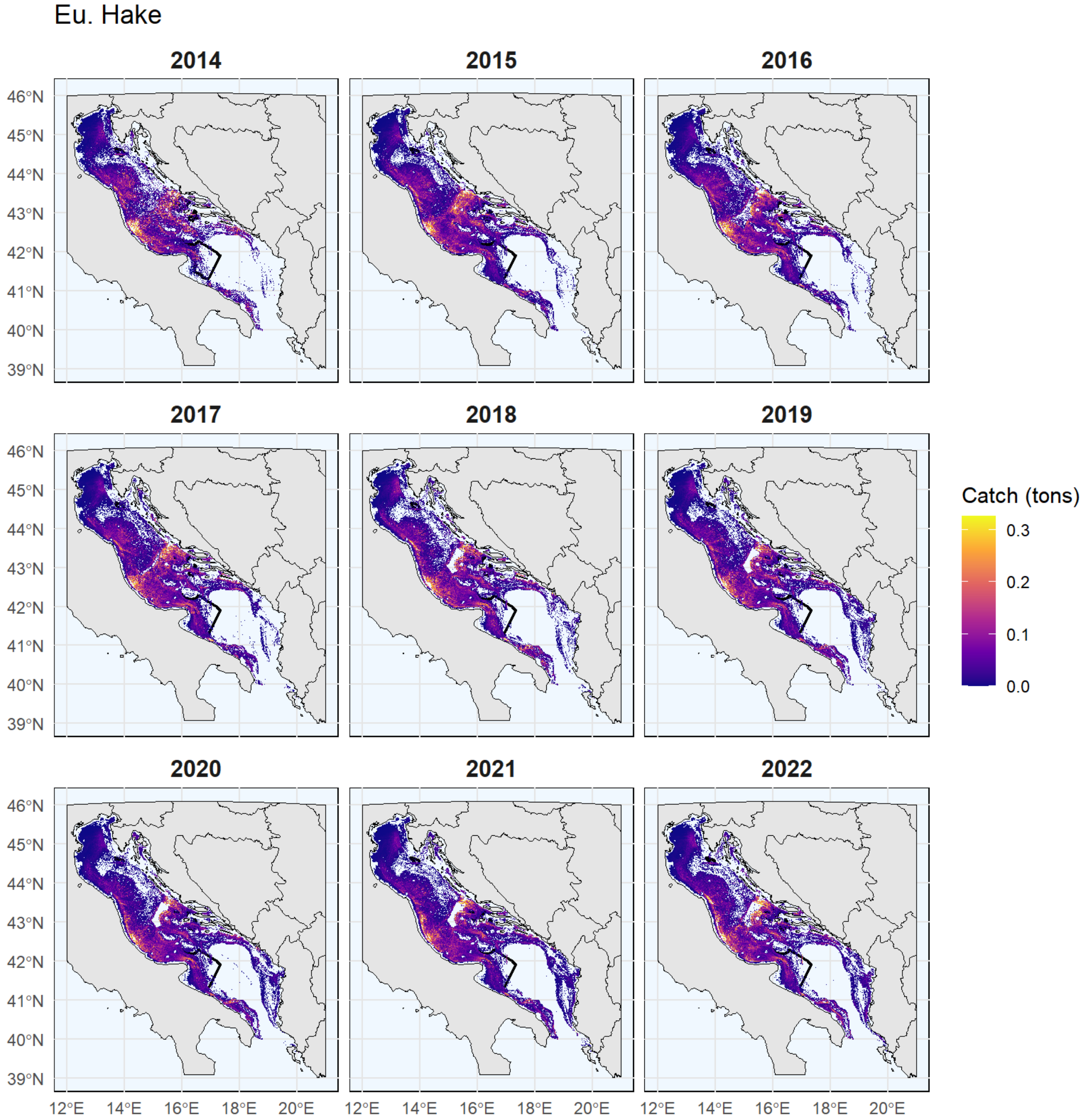



*Fig. 4.2.3. Spatialized estimated catches for Hake in the Adriatic Sea obtained by considering biomass and effort distribution.*

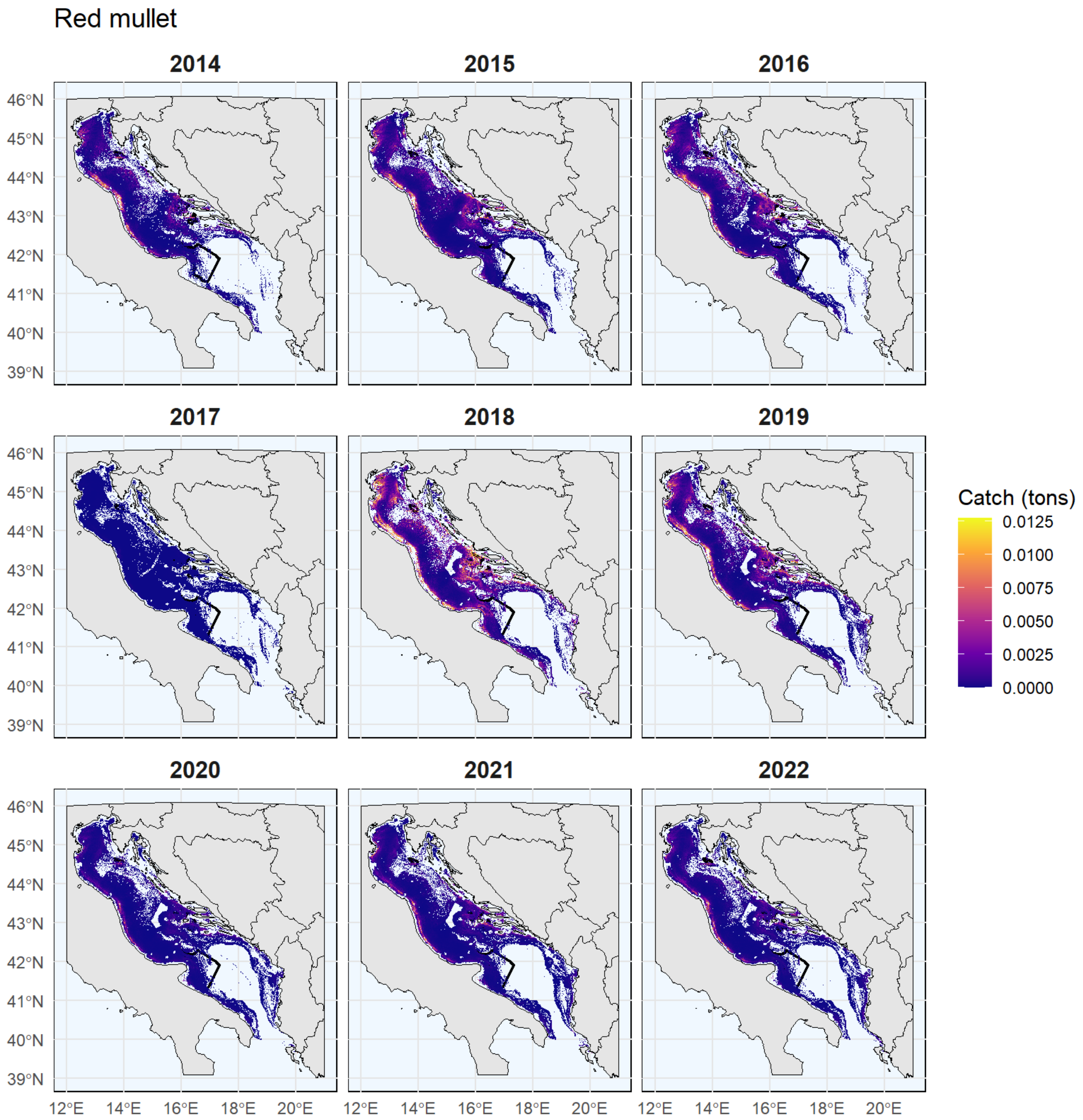



*Fig. 4.2.4. Spatialized estimated catches for Red mullet in the Adriatic Sea obtained by considering biomass and effort distribution.*

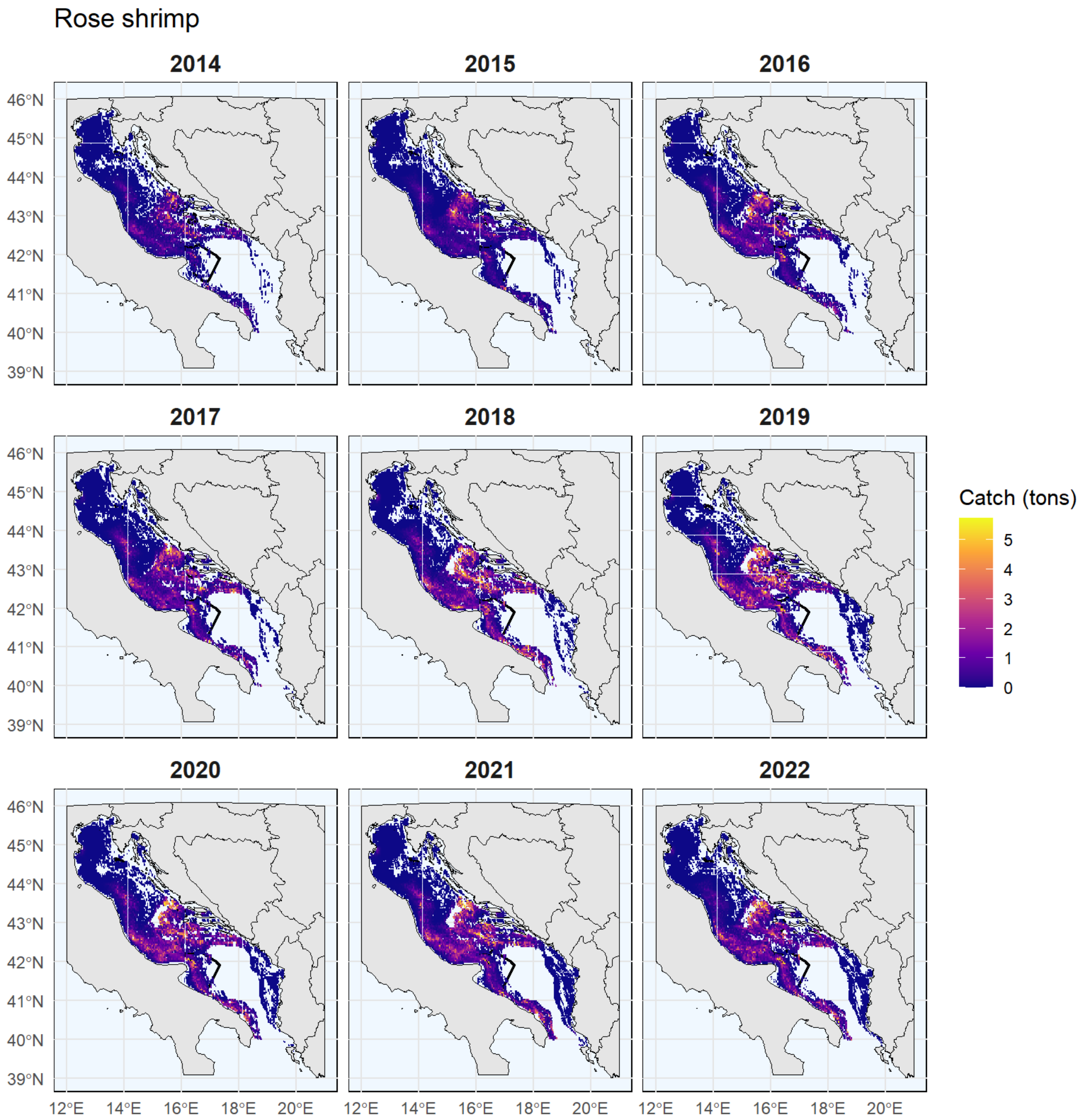



*Fig. 4.2.5.. Spatialized estimated catches for Deep Rose Shrimp in the Adriatic Sea obtained by considering biomass and effort distribution.*

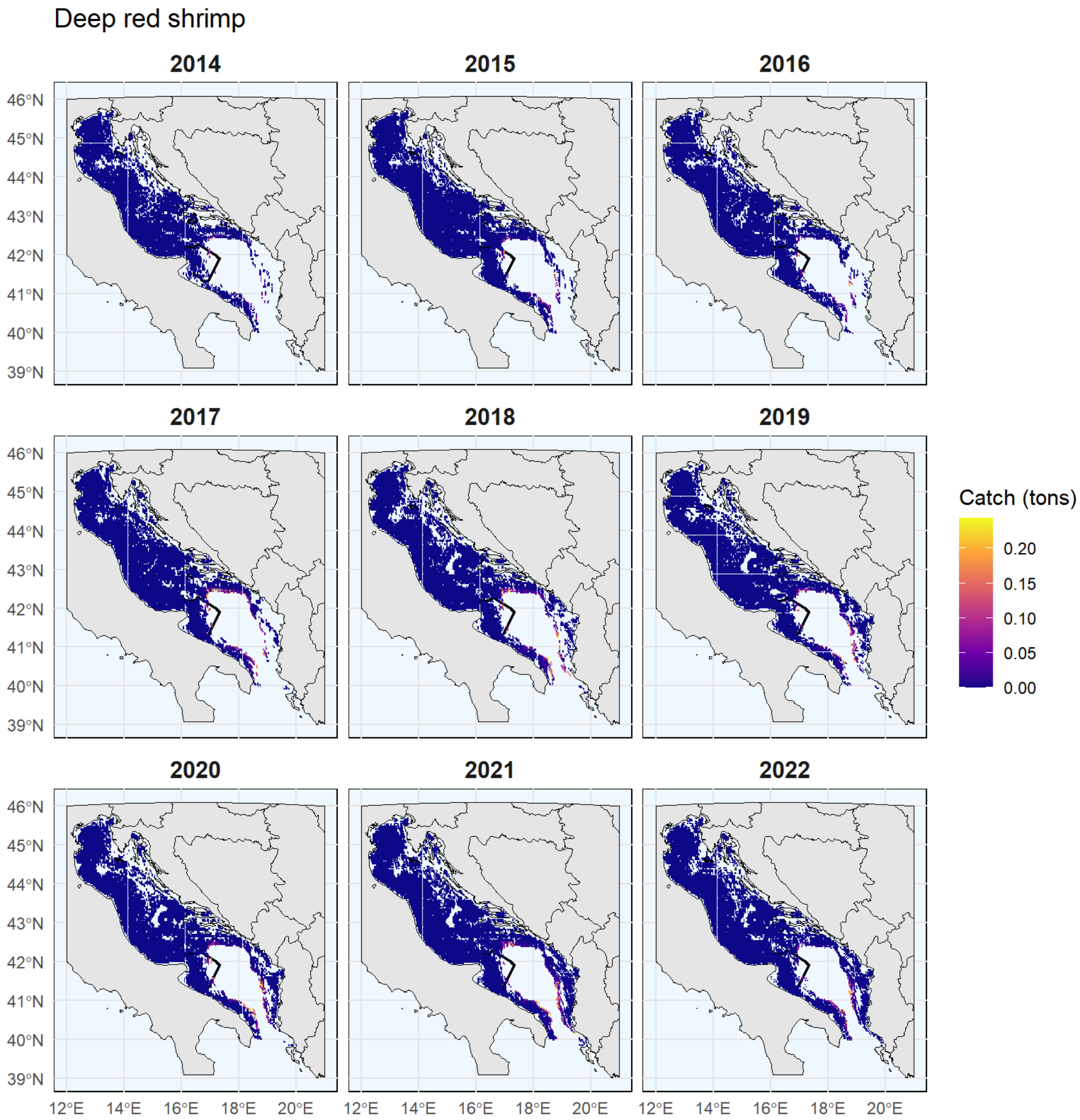



*Fig. 4.2.6. Spatialized estimated catches for Giant Red Shrimp in the Adriatic Sea obtained by considering biomass and effort distribution.*

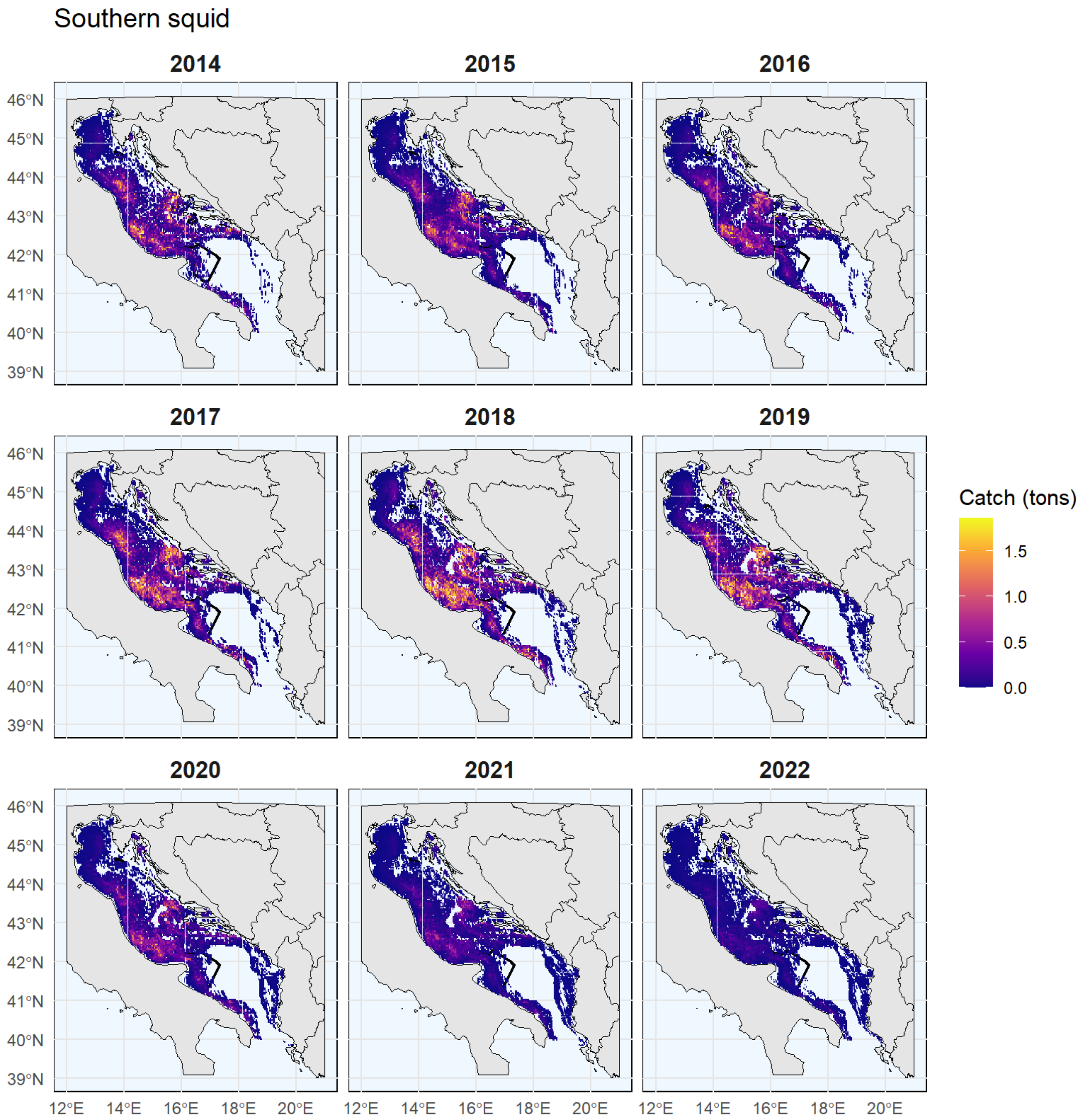



*Fig. 4.2.7. Spatialized estimated catches for Southern Squid in the Adriatic Sea obtained by considering biomass and effort distribution.*

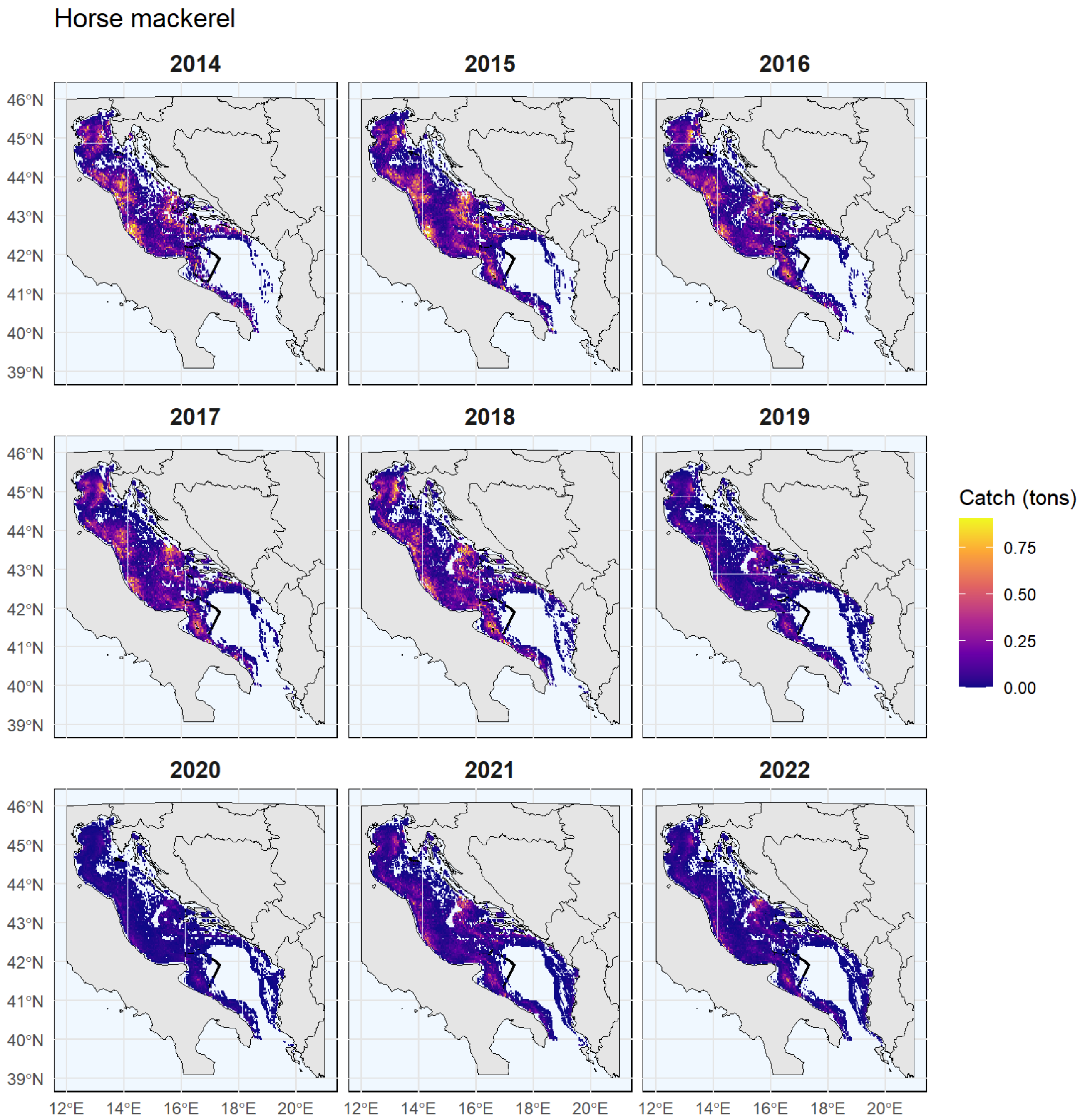



*Fig. 4.2.8. Spatialized estimated catches for Horse mackerel in the Adriatic Sea obtained by considering biomass and effort distribution.*

## 4.3. Synthesis of estimated catches in OWF areas

In order to report synthetically the results obtained for the spatialization of the catches, it was estimated the amount of catches in absolute (tonnes) and relative proportions (%) for each species in all the OWF planned.

Results shows that only the OWF in the Apulia region is potentially including catches of Anchovy and Sardine (Fig. 4.3.1 and 4.3.2): clearly this is due to the fact that only purse seiners were considered because of the lack of disentangling demersal from pelagic trawlers in the effort database (GFW) . Overall, the OWF in the Apulia Region are estimated to be caught in 2022, 862 and 721 tonnes of anchovy and sardine respectively.

All areas planned for OWF are interested by catches of hake (Fig. 4.3.3): with catches estimated in 4, 52, 2 and 147 ton/year respectively for Istra, Split-Dalmatia, Veneto and Apulia pilot OWF. Although apparently low, these catches amount approximately 4.78% of the total hake catches in the Adriatic Sea.

For red mullet (Fig. 4.3.4) the situation is very similar, although for this species is the Split-Dalmatia pilot area for OWF that retain the higher proportion of catches (Istra: 0.04%, Veneto: 0.67%) and Apulia : 1.15%). Total proportion of the catches of the four pilots amount to 4.54% of total red mullet catches.

Deep Rose shrimp (Fig. 4.3.5) have relevant catches only in Split-Dalmatia and Apulia pilot areas where trawlers are estimated to catch 68 and 127 tonn/year respectively. These catches amount to 7.43% of the total catches in the basin.

Red Giant Shrimp catches allowed estimating relevant catches only in the Apulia pilot OWF region as much as 3 ton/year equal to approximately 7% of total catches of this species (Fig. 4.3.6).

Horse mackerel estimates (Fig. 4.3.7) allow to quantify catches in the order of 0.04%, 0.85 %, 0.48% and 6.94% for Istra, Split-Dalmatia, Veneto and Apulia, respectively.

For Southern squid (Fig. 4.3.8) catches are estimated as much as 0.01%, 1.49%, 0.03% and 4.13% of the total catches for Istra, Split-Dalmatia, Veneto and Apulia, respectively.

It can be noticed the quite specific situation of each species resulting from the integration of effort (purse seine or trawlers) and species distribution. Nevertheless, it emerges the very relevant role of the Apulia pilot OWF site for many species: this result is partially due to the large surface of the area possibly dedicated to OWF. Conversely Istra pilot region seems less relevant for the 8 commercial species analysed here: this result is possibly suffering the limitations of using only trawlers and purse seiners for measuring effort.

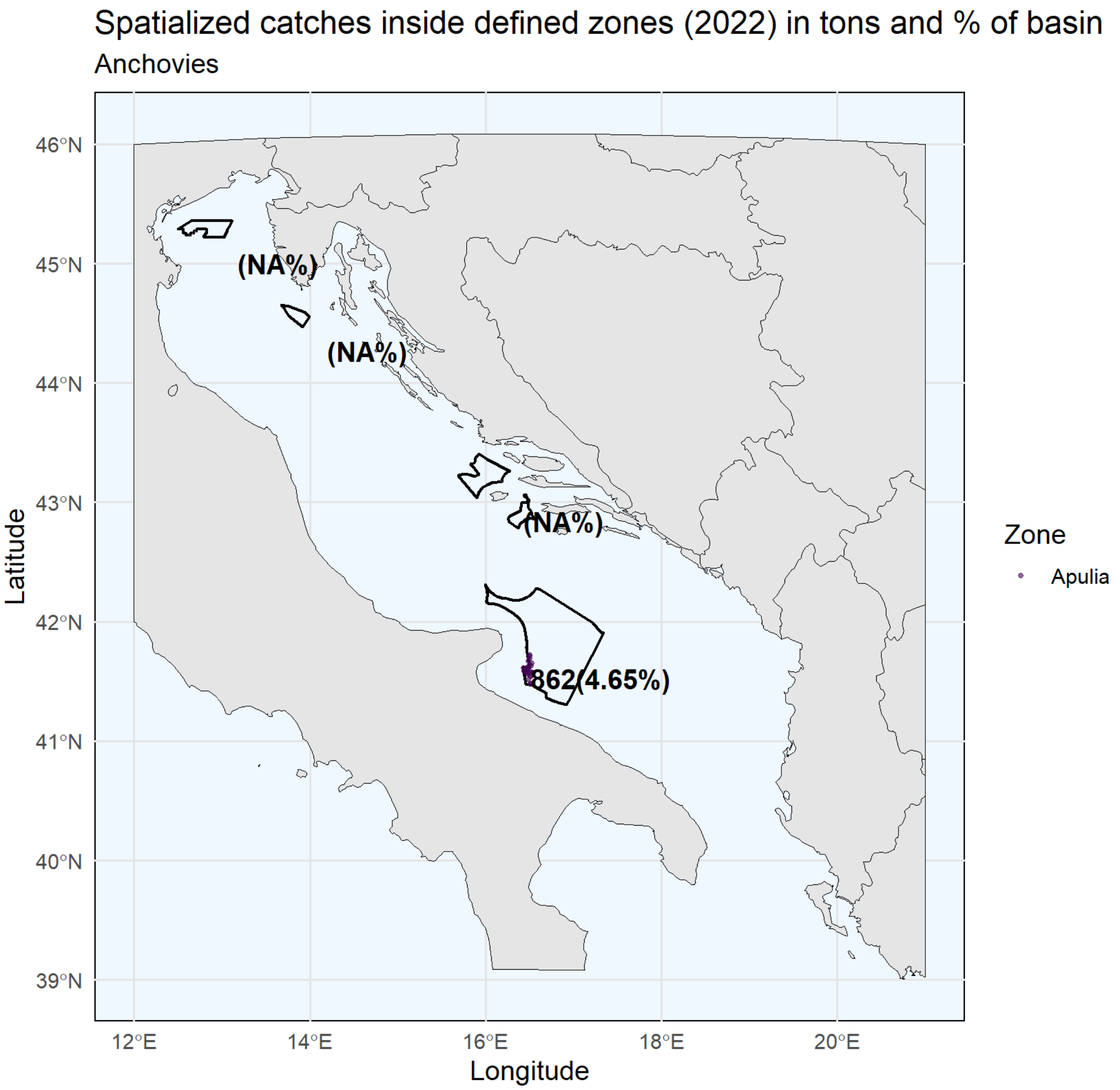



*Fig. 4.3.1.Amount of Anchovy catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

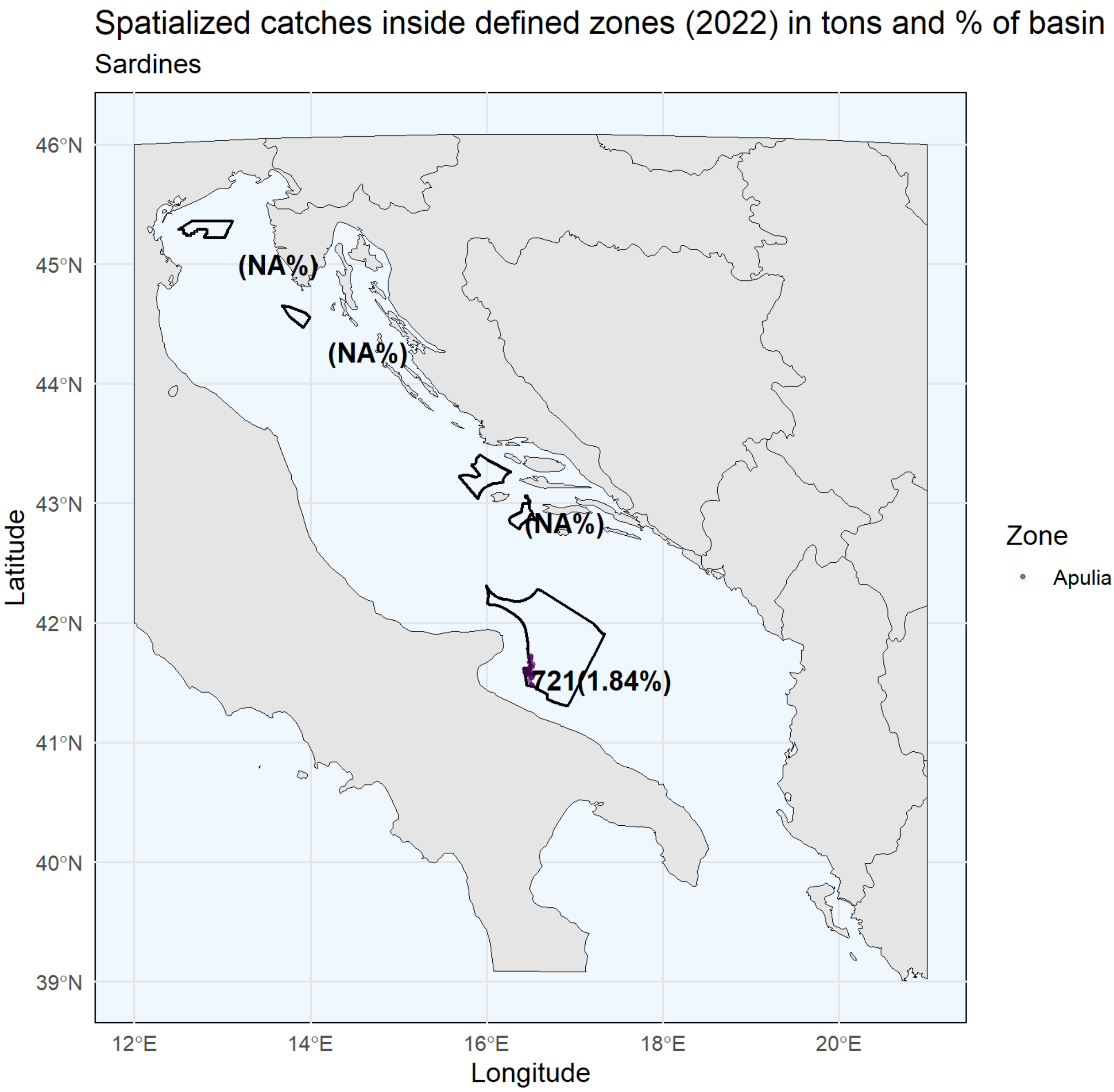



*Fig. 4.3.2. Amount of Sardine catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

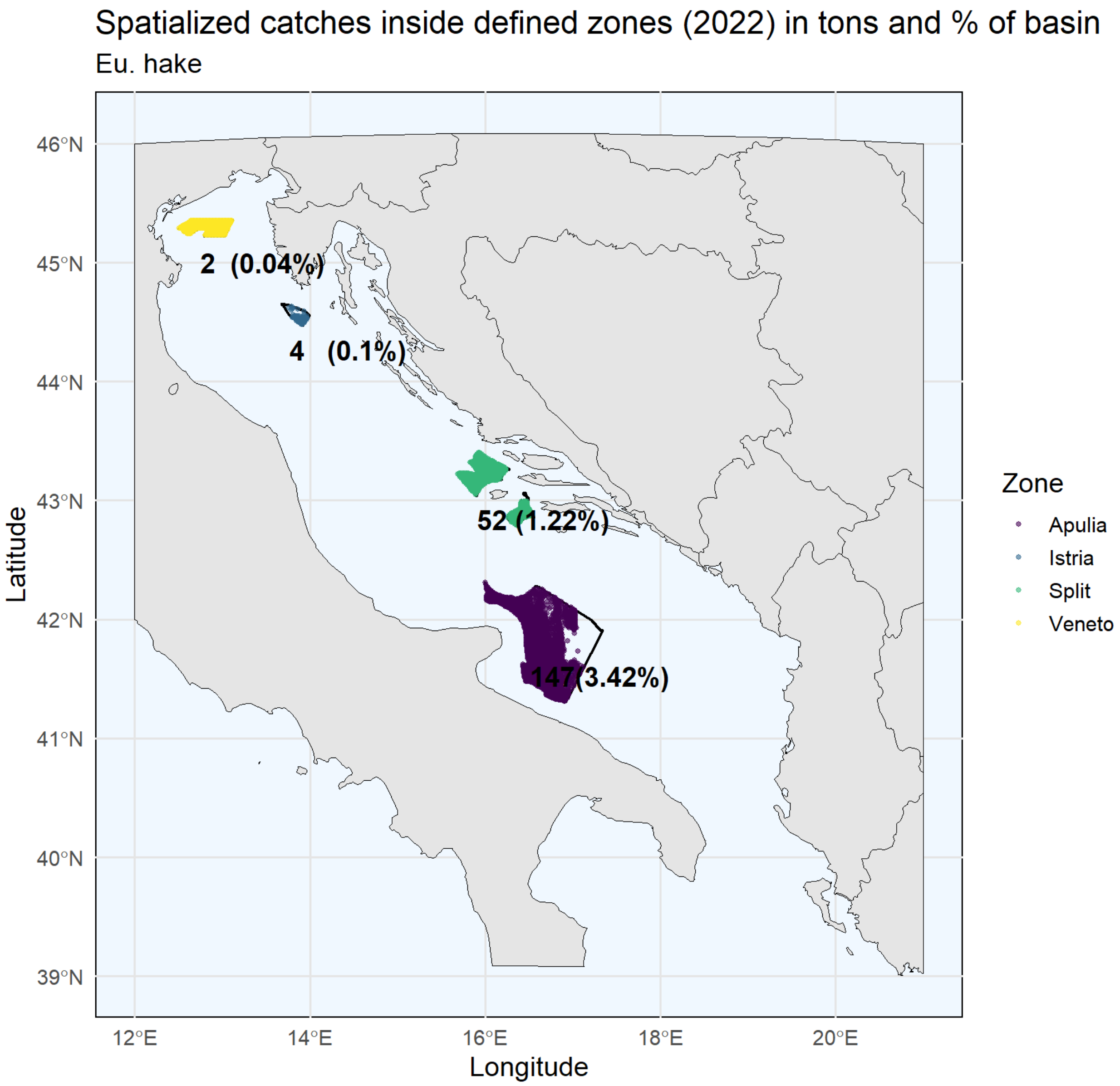



*Fig. 4.3.3. Amount of Hake catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

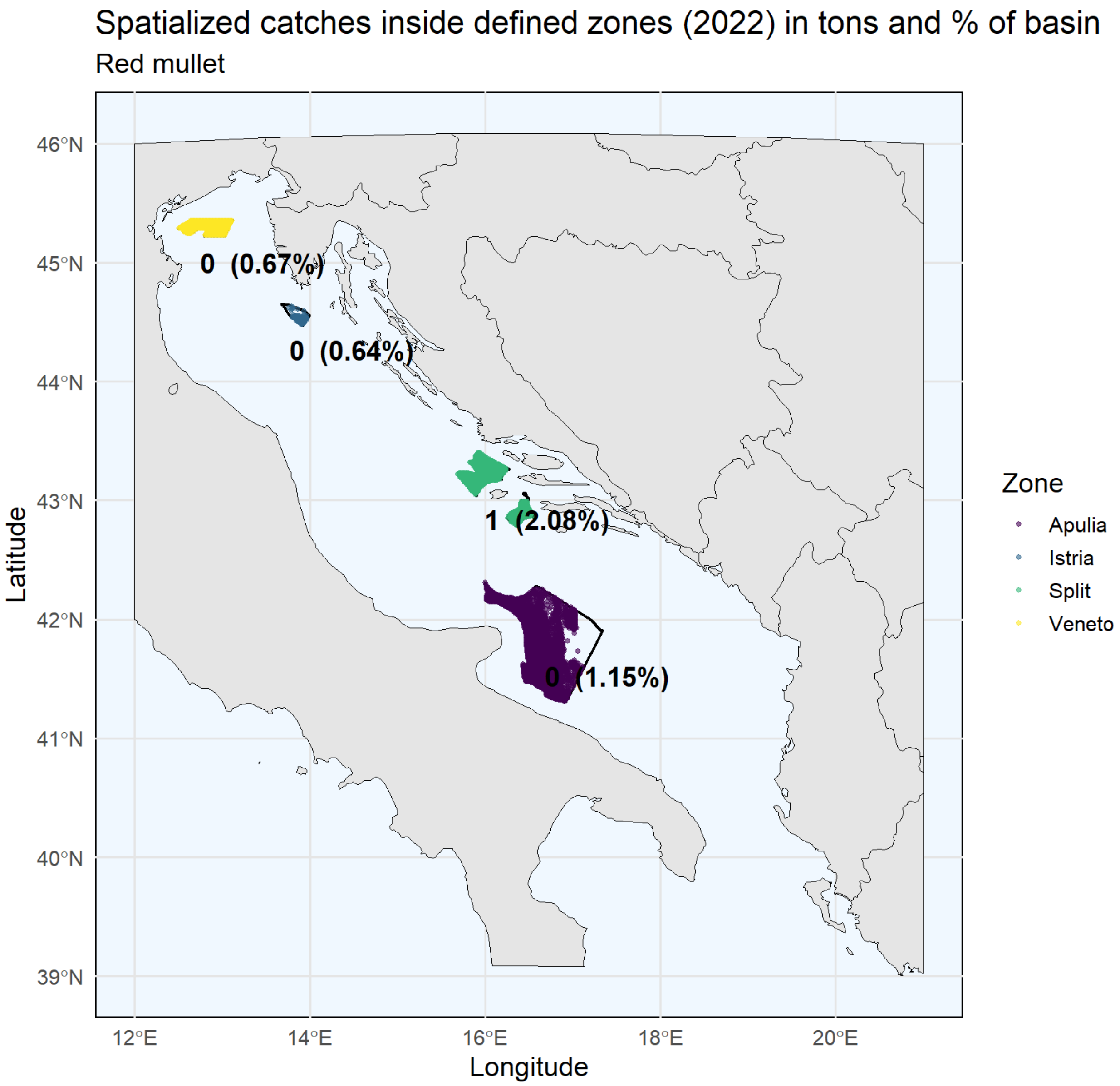



*Fig. 4.3.4. Amount of Red mullet catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

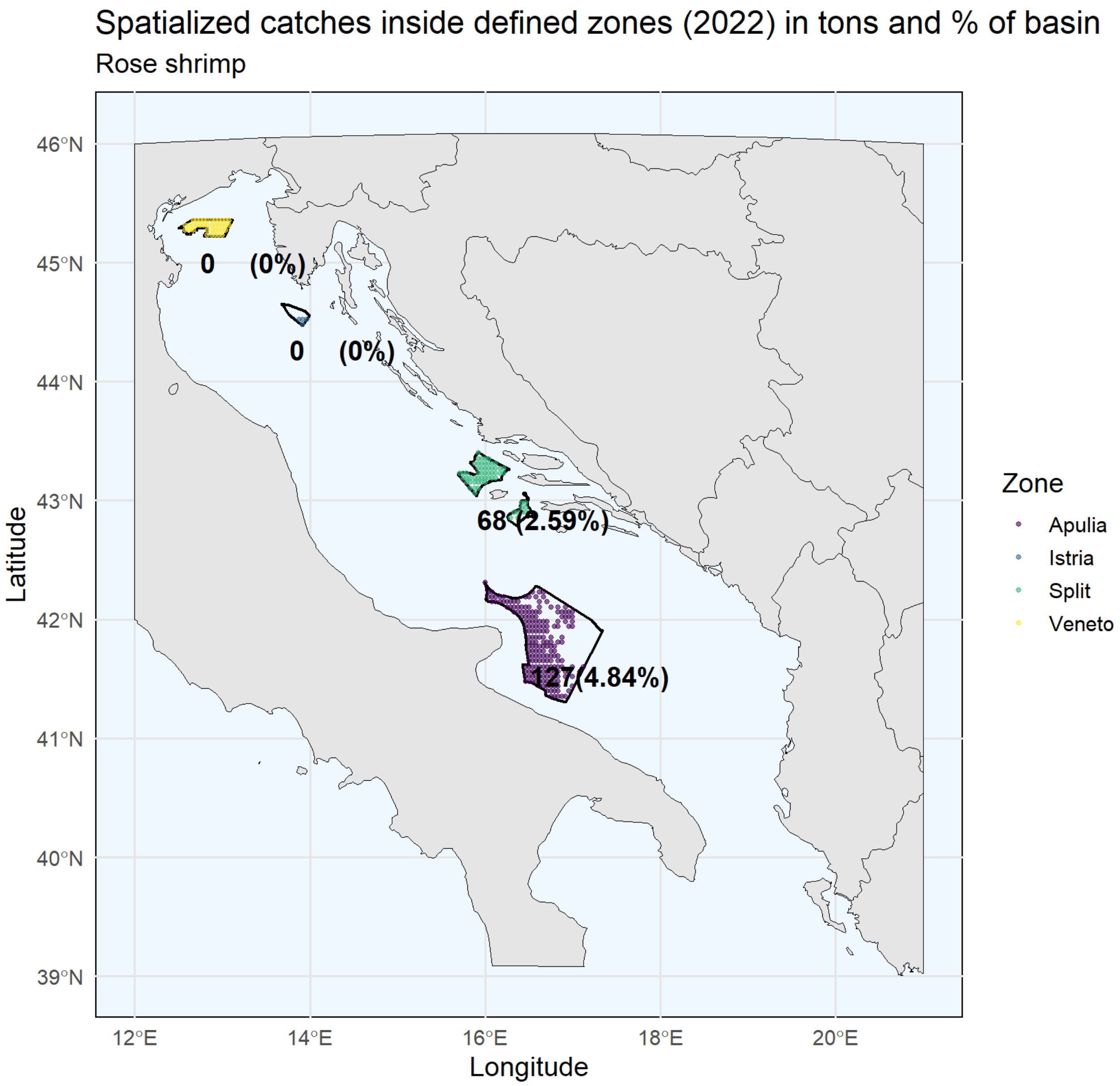



*Fig. 4.3.5. Amount of Deep Rose Shrimp catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

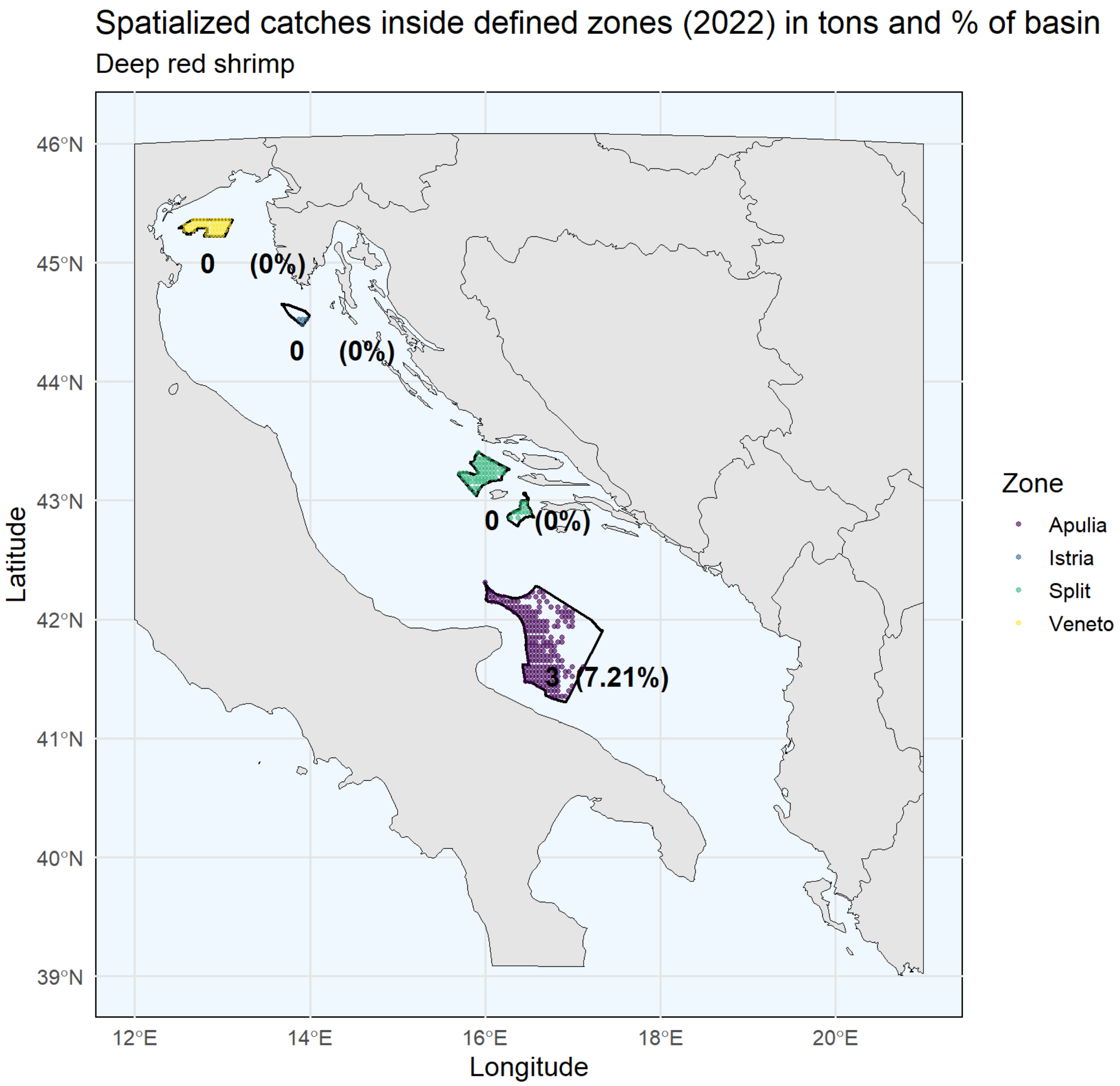



*Fig. 4.3.5. Amount of Deep Giant Red Shrimp catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

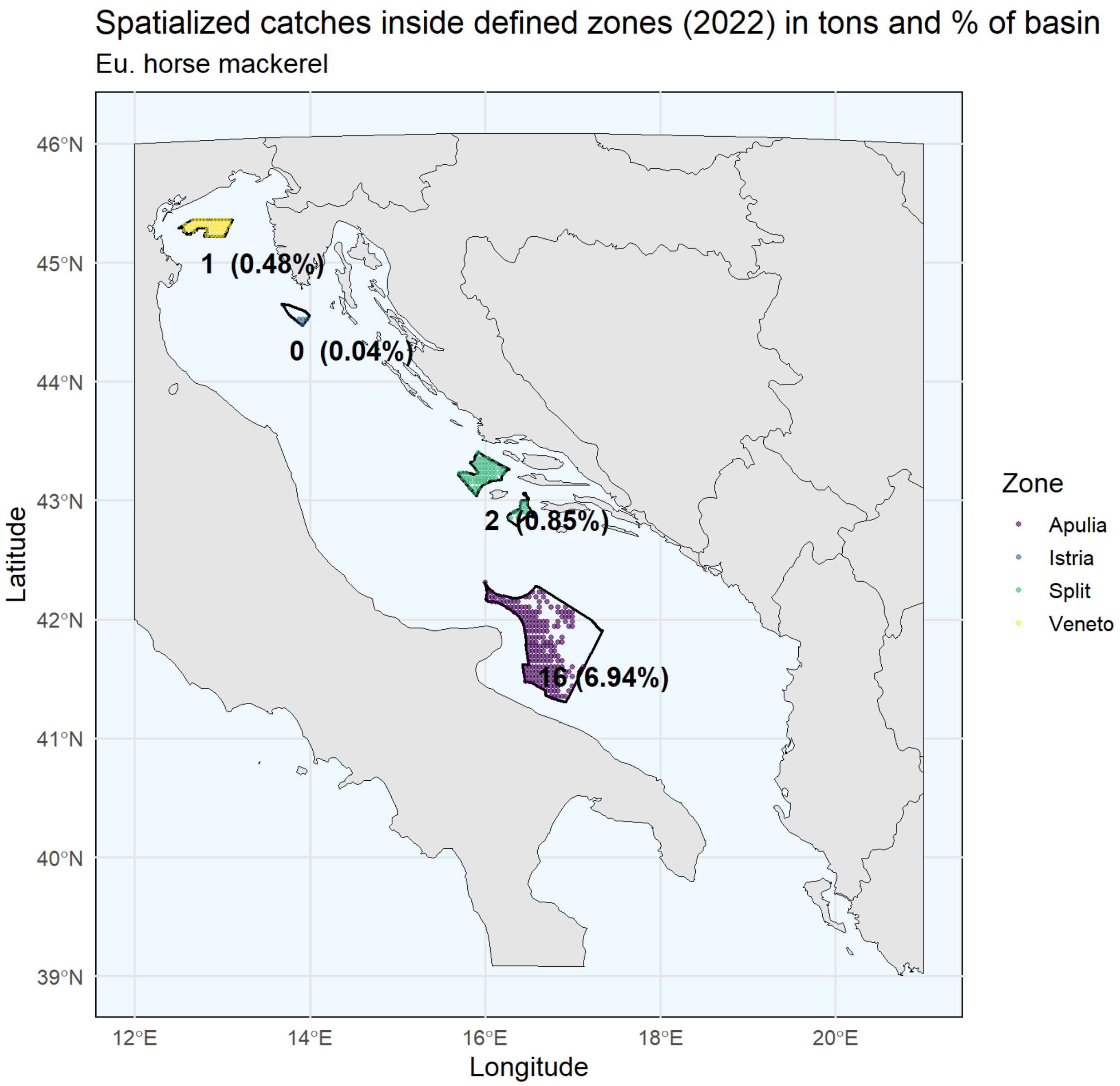



*Fig. 4.3.6. Amount of Horse mackerel catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

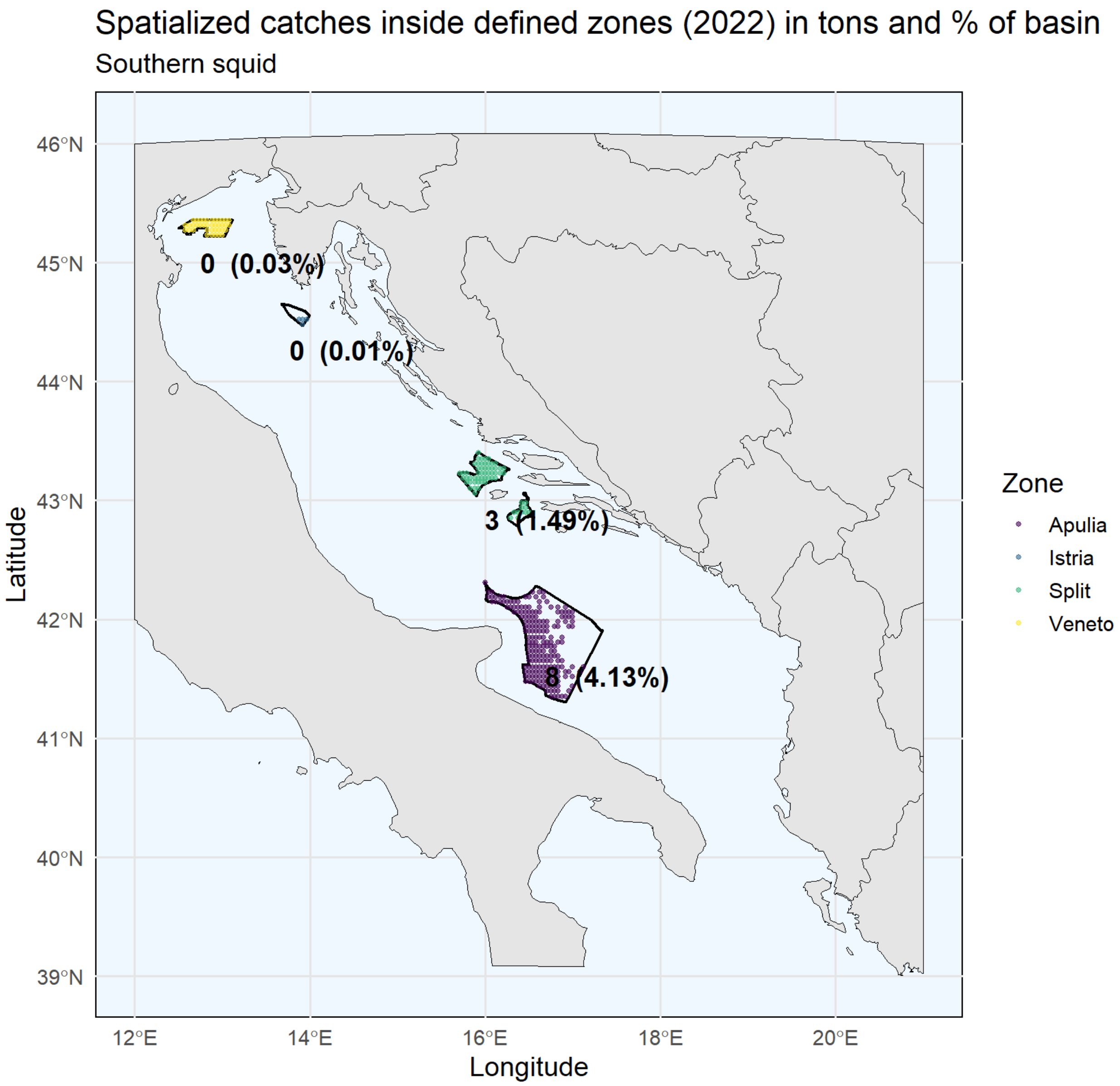



*Fig. 4.3.5. Amount of Southern squid catches estimated to occur in planned OWF in the four regions. Absolute values (tonnes/year) and relative (proportion with respect to total catches) are reported for year 2022.*

Although estimates appear quite minimal, the catches included in the OWF pilot areas range from 1.84% (sardine) to 8.31% (mackerel) of total catches for purse seine and trawlers. These gears are the key for pelagic and demersal species respectively and although not completely representing total catches, the proportion into the OWF estimated can be considered as indicative for all the gears.

Therefore Table 4.3.1 synthesize the overall economic value of the catches within the OWF for the 8 key species.

| | anchovy | sardine | hake | red mullet |
|---|---|---|---|---|
| **Istra** | 0.00% | 0.00% | 0.10% | 0.64% |
| **Split-Dalmatia** | 0.00% | 0.00% | 1.22% | 2.08% |
| **Veneto** | 0.00% | 0.00% | 0.04% | 0.67% |
| **Apulia** | 4.65% | 1.84% | 3.42% | 1.15% |
| Adriatic total catches | 28030.568 | 49783.794 | 4907.528 | 2368.099 |
| Adriatic total value | 72,167,163.03 € | 34,410,632.45 € | 28,453,734.80 € | 9,020,595.90 € |
| mean value (euro/kg) | 2.57 € | 0.69 € | 5.80 € | 3.81 € |
| **total catches in OWF** | **4.65%** | **1.84%** | **4.78%** | **4.54%** |
| **economic value per year** | **3,355,773 €** | **633,156 €** | **1,360,089 €** | **409,535 €** |

| | rose shrimp | red giant shrimp | horse mackerel | southern squid |
|---|---|---|---|---|
| **Istra** | 0.00% | 0.00% | 0.04% | 0.01% |
| **Split-Dalmatia** | 2.59% | 0.00% | 0.85% | 1.49% |
| **Veneto** | 0.00% | 0.00% | 0.48% | 0.03% |
| **Apulia** | 4.84% | 7.21% | 6.94% | 4.13% |
| Adriatic total catches | 2627.483 | 42.512 | 446.444 | 188.82 |
| Adriatic total value | 12,866,689.66 € | 1,070,647.51 € | 797,650.21 € | 929,086.95 € |
| mean value (euro/kg) | 4.90 € | 25.18 € | 1.79 € | 4.92 € |
| **total catches in OWF** | **7.43%** | **7.21%** | **8.31%** | **5.66%** |
| **economic value per year** | **955,995 €** | **77,194 €** | **66,285 €** | **52,586 €** |

*Table. 4.3.1. Synthesis of amount of catches estimated to occur in planned OWF in the four regions for the 8 key commercial species of the Adriatic Sea. Absolute values (tonnes/year), relative catches (proportion with respect to total catches), and values (in Euro) are reported for year 2022.*

## 5. Aquaculture

The aquaculture sector in the Adriatic Sea EU countries (Slovenia, Croatia and Italy) has a production with a value that was 19 mil euro in 2010 that steadily grew up to 41 mil euros/year in 2023 (data from FAO FishstatJ, Global fisheries and aquaculture production, 2025). The main species farmed are mussels (*Mytilus galloprovincialis*), that is an historical farmed species slightly declining in the last decades (see Fig. 5.1.1). Increasingly important farmed species are also seabass (*Dichentrarchus labrax*) and seabream (*Sparus auratus*). A growing production of the last decade is also represented by the farming of Atlantic Bluefin tuna (*Thunnus thynnus*) which is a key economic resource mainly for Croatia farming sector. Today, mariculture and marine farming is a highly strategic sector of the Croatian economy, supporting coastal and islands communities (see Milosevic et al., 2024).

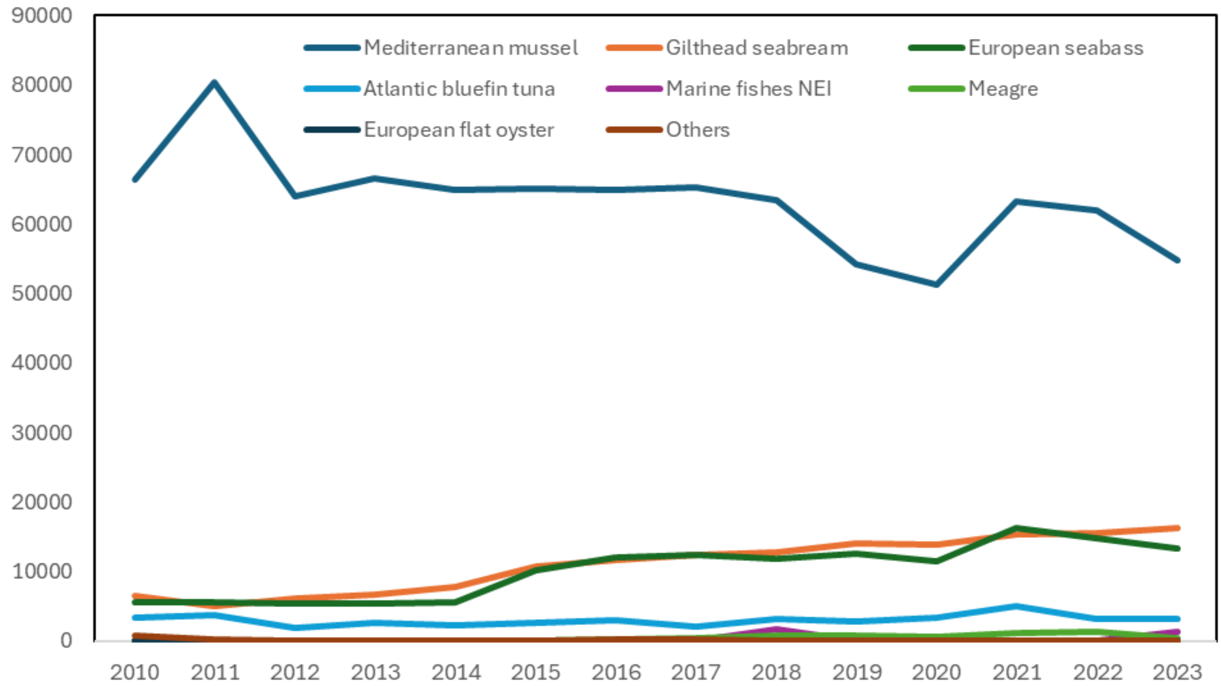



*Fig. 5.1.1. Volume in tonnes of the main farmed marine species in the Adriatic Sea (Croatia, Slovenia and Italy) from 2010 to 2023. Data extracted from the FAO FishstatJ (FAO Global Fisheries and Aquaculture Production Statistics – 2025).*

## 5.1. Data used and approach implemented

Aquaculture production economic and volume data for Slovenia, Italy and Croatia were taken from FAO FishstatJ (FAO Global Fisheries and Aquaculture Production Statistics – update 2025). Data regards the period from 1984 to 2023. For simplicity only data from 2010 to 2023 were analysed.

Data for the analysis also regarded the detailed mapping of aquaculture sites in the Adriatic Sea. The shape files of all concessions dedicated to farming were take from Adriplan website (http://data.adriplan.eu:80/geoserver/wfs?format_options=charset%3AUTF-8&typename=geonode%3Abs_marinefarm_pl_2&outputFormat=SHAPE-ZIP&version=1.0.0&service=WFS&request=GetFeature).

## 5.2. Analysis

The inspection of aquaculture farms mapping showed that there is no overlap between planned OWF and existing aquaculture sites (see Fig. 5.2.1). Even considering eventual buffer zone around planned OWF there is no overlap because they are quite far from the coast, while all farming sites are usually within the first 3-4 nautical miles from the coast (Brigolin et al., 2017; Milosevic et al., 2024).

Given the above it is considered that OWF is not affecting current aquaculture sites and productions.

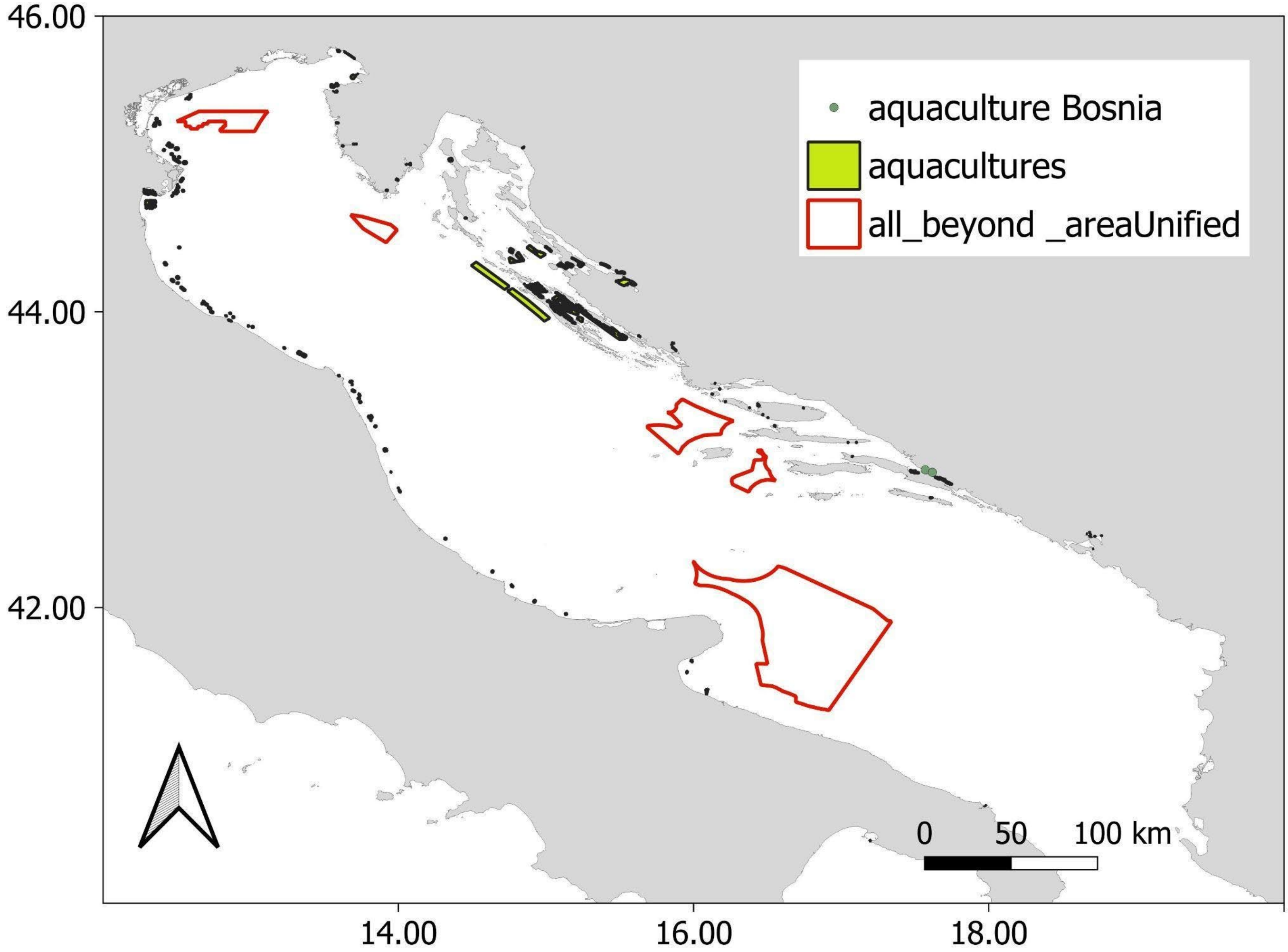



*Fig. 5.2.1. Location of all the concessions in Italy, Slovenia and Croatia for aquaculture and fish farming. Data obtained from Adriplan website. The map represents also the proposed Offshore Wind Farms areas in the fours regions.*

## 6. Concluding remarks and discussion

The analysis carried out showed to be quite simple for understanding the role of aquaculture and OWF interaction, which is basically very limited with current farming activities and planned OWF in the four identified pilot sites.

Conversely the situation is a little bit more complicated for understanding the interaction between OWF and fisheries. First because direct impacts of OWF on critical Essential Fish Habitats (EFH) might affect the population dynamics of commercial species. Therefore an analysis of overlap between OWF and sensitive EFH is proposed in section 2. Results indicate that especially the OWF in the Apulia pilot region overlap with proportions from 1 to 10% of the key EFH for 8 selected commercial species. This result is quite relevant: although the indirect impacts cannot be estimated with the current approach it is recommended to consider with care this aspect as the proportion of EFH impacted is potentially relevant.

Effort distribution allowed  understanding the direct impacts of OWF on fisheries assuming complete ban. The approach didn't consider any buffer area, but yet highlighted a sensitive proportion of effort within the OWF: for the 10 gears for which the effort was available proportions included in the OWF were generally very low. Exceptionally high proportion of drifting longline effort in 2022 (approximately 13%) was falling Apulia OWF. More concern regards the approximately 4% of trawlers effort in Apulia OWF suggesting caution or evaluating possibilities to use only part of the defined area as OWF.

Finally reconstruction of spatialized catches for 8 key commercial species allowed to estimate that a proportion of catches between 1.84 and 8.31 % was caught within the planned OWF areas in 2022. Only for these 8 species, therefore, these proportions sum up to a value of approximately 5 mil euros per year.

## 7 Acknowledgements

The authors wish to thank all participants in the MEDITS survey, which is funded by the European Union through the European Maritime Fisheries and Aquaculture Fund (EMFAF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

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