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WP1. Ecological, technical, social and economic characteristics of discarding fisheries.
Deliverable 1.9 Spatial overlap discards / habitats

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GIS maps showing the spatial overlap between high discard rate areas and habitats in case study areas

1. Background

Unwanted catch (UWC) is a widespread and critical problem of world fisheries (Kelleher 2005). It represents the fraction of the catch returned to the sea, and essentially includes undersized (under the minimum legal size), over quota or damaged specimens of commercial species, commercial species with low market value, and non-marketable species. The amount of the unwanted catch depends mainly on the exploited fishing ground (geographic area and habitat) and the fishing gears adopted, being bottom trawling the fishing practice which produces the highest discard rates. Other factors that influence the production of unwanted catch include technical characteristics of the vessels, fishing strategies, fishing season, environmental conditions. Nonetheless, ultimately, the choice of discarding the entire or part of the catch back to the sea is up to the fishermen, and is induced by economic reasons or compliance with fishing regulations (for instance, until recently, it was expressly forbidden to land undersize individuals in Mediterranean coasts).

The discard level produced by bottom trawlers in the European Atlantic regions is about 60% of total catch, reaching levels as high as 90% in some areas for specific fisheries (STECF 2006). Indeed, high amount of catches subject to quotas results in discarding of smaller individuals, even when they are above the minimum legal size (Catchpole et al. 2005).

Discard rates in the Mediterranean seem to be lower than in the Atlantic because a wider size range of fish is routinely marketed and no quota system is in place (STECF/SGMOS 2008; Lleonart and Maynou 2003; Condie et al. 2013). In the Mediterranean, estimates of annual discards rates range between 13.3 and 26.8% of total catches (Tsagarakis et al., 2014). According to Sanchez et al. (2004), estimated discards in bottom trawl fisheries in the north western Mediterranean is around 1/3 of total catch in biomass.

Under the current trawl selection pattern, undersized individuals predominate in the catches of some species such as European hake and red mullet in the Mediterranean, especially during the recruitment period (Sala and Lucchetti 2011).

The recent introduction of the “landings obligation” by the reform of the Common Fisheries Policy (EU Reg. n. 1380/2013) has the objective to reduce the wasteful practice of discarding unwanted catch at sea. While promoting the introduction of technical measures aimed at reducing and discouraging the capture of undersized specimens, at the same time it requires fishermen to land all the catch. According to the new CFP this obligation is introduced gradually, following a specific schedule. The landed discards will be limited to purposes other than human consumption (meals and fish oils, animal feed, cosmetics, pharmaceuticals and food additives) and exceptions (*de minimis*) from the obligation to land (Council of the European Union, 2013) are also introduced. Given the specific characteristics of each region, local management plans are needed as solutions to set up the best measure in a regional context. Finally, at present it is still unclear the potential use of the unwanted catches under landings obligation as well as the protocol for its preservation and storage.

2. Objectives

Under the framework of the Task 1.3 ("Characterization of habitats where case-study fisheries producing unwanted catches take place"), the main goal of Deliverable 1.9 was to produce GIS maps showing the spatial overlap between high discard rate areas and habitats in case study areas. Figure 1 shows the location of each case study involved in the present deliverable.

The databases and results were intended to serve as knowledge base for the development of GIS and modelling tools under WP3.

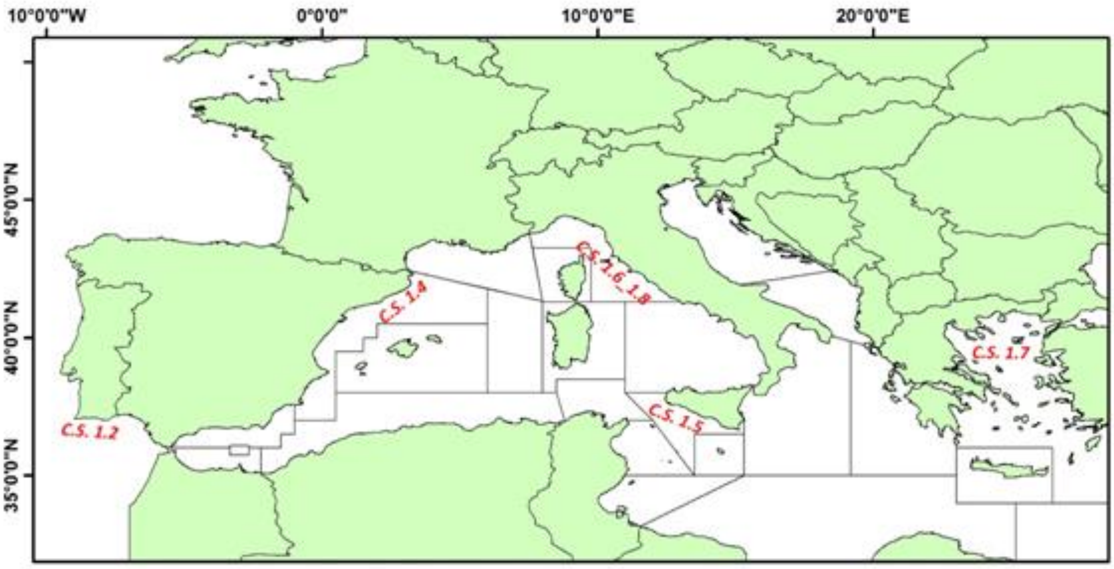

Figure 1 Spatial location of different Case Studies.

3. Description of the datasets available

In order to fulfil the project milestones and deliverables, an exploratory survey of the data available for each case study was performed. Different main source of data were identified: i) national scientific bottom trawl surveys in Case Study 1.2 ii) the International scientific trawl surveys (MEDITS) in Case Studies 1.4, 1.5, 1.6, 1.8 and iii) the unwanted catch info from on board sampling in Case Study and 1.7.

The Portuguese International Bottom Trawl Survey (PT-IBTS) is part of the IBTS programme and consists in a number of bottom trawl surveys with the aim of improving standardisation and collaboration between surveys in different countries. Starting in 1989 with a sampling design based in 97 locations stratified by depth strata and covering 12 sectors along the Portuguese coast, was latter modified in 2005 with fixed and random trawl positions and the Autumn groundfish and the Winter groundfish surveys were introduced. These surveys have different main objectives, the Autumn is to monitor abundance and distribution of hake and horse mackerel recruitment and the Winter to monitor the abundance and distribution of hake in the spawning season, additionally both these surveys also estimate abundance indices and biomass of the most important commercial species among other biological parameters and biodiversity indicators. The Autumn groundfish survey plan, which were the one used in this report, comprises 96 fishing stations, 66 at fixed (grid) positions and 30 at random. The tow duration is 30 min, with a trawl speed of 3.5 knots, during day light using a Norwegian Campell Trawl 1800/96 NCT with a 20mm codend mesh size.

The spatial information gathered from these projects covered the fishing grounds typically used by the trawl fleet using the common fishing procedures of commercial vessels, which allowed the mapping of areas of potential unwanted catches.

The Mediterranean International bottom trawl survey (MEDITS) is routinely carried out in the Mediterranean with the primary aim of monitoring and assessing fisheries resources status. Data from MEDITS surveys provide an accurate picture of the population structure and spatial distribution of species. The main drawback is that the surveys cover a single season during the year, which is mostly during summertime, and use a cod-end net with a smaller mesh size than the commercial mesh size permitted. These two aspects make the MEDITS data not entirely comparable to the mapping that would be obtained from using high-resolution discards data from the commercial fishery, which is generally not available on a continuous basis. However, the MEDITS data permit to produce density index maps of unwanted catches species without MCRS over a long time period (started in 1994 in most areas).

National commercial sampling programs are aimed at collecting data on discards and discarding practices from commercial fisheries. Usually, sampling activities are carried out throughout the year, providing accurate information on the spatial and temporal dynamics of discards. However, national discards sampling programs are not standardized at the European level (Uhlmann et al., 2013) and exhibit differences in the methodology of discards sampling and the level of detail of biological data (e.g. taxonomic identification, recording of abundance and biomass, etc.) and are not generally available at large spatial or temporal scales.

Data provided by the Vessel Monitoring System (VMS), the main geo-positioning device currently used to track the fishing activity of the European fleet (Regulation EC No 2371/2002), were used to produce estimate of fishing pressure in the case study areas. Since 2005, the VMS is mandatory for all the fishing vessels with length-over-all (LOA) ≥ 15 m.

Habitat maps have been downloaded from the MESH project ("Mapping European Seabed Habitats", currently available through the EMODNET portal:

http://www.emodnet-seabedhabitats.eu) and the MEDISEH project (Giannoulaki et al., 2013).

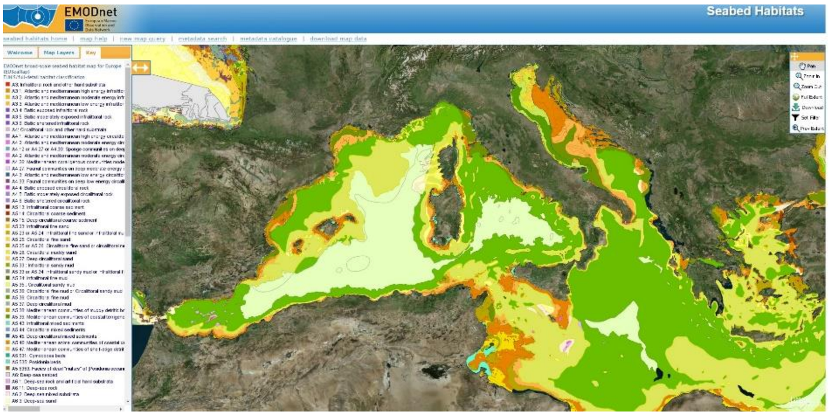

Figure 2 EMODNET portal: http://www.emodnet-seabedhabitats.eu

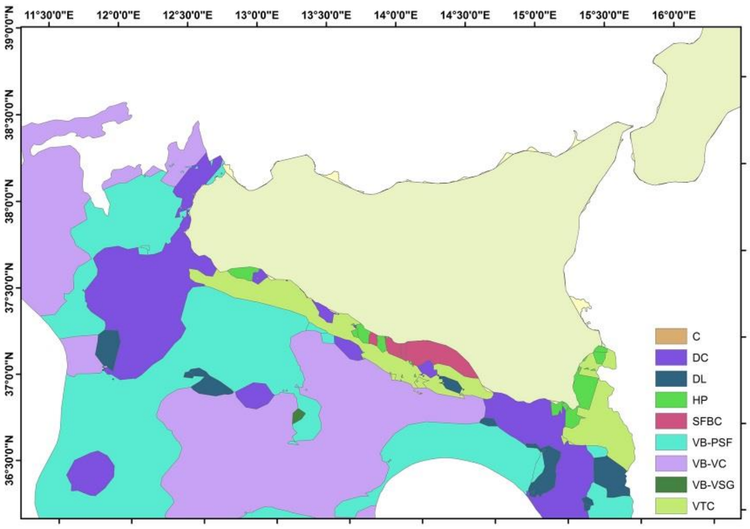

Figure 3 Habitat map of the Strait of Sicily: C=Coralligenous, DC=Coastal Detritus, DL=Open-Sea Detritus bottoms, HP=*Posidonia oceanica* meadows, SFBC=Well-graded fine sand, VB-PSF= Soft muds with fluid surface film, VB-VC=Compacted muds, VB-VSG=Sandy muds with gravels, VTC= Coastal terrigenous mud (redrawn from Garofalo et al., 2004).

4. Methodology used in each case study and results:

1.2 –Algarve (SW Portugal)

In order to display the amount of potential total discard (PTD) produced by fisheries in this case study, the raster file of unwanted catches (computed from International Bottom Trawl Survey (IBTS) data was combined and multiplied with the raster file of VMS data from crustaceans trawlers (Figure 4) representing the fisheries effort in the same zone. The two-raster file were obtained using the same temporal range (2009, 2010 and 2011).

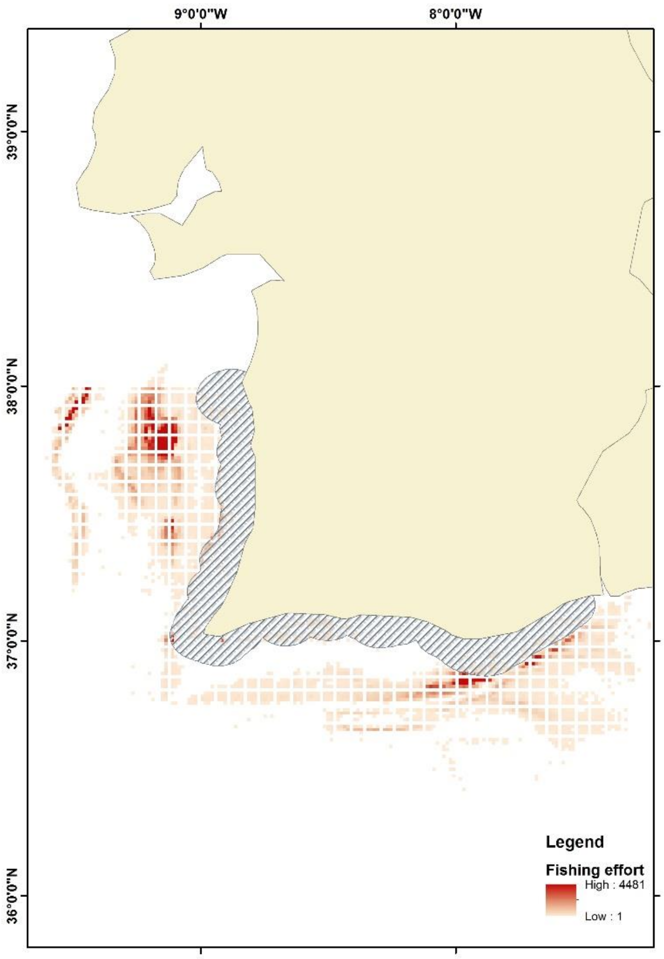

Figure 4 Fishing effort distribution in the case study area 1.2

The spatial analysis of PTD was performed using geostatistical methods (variogram analysis and kriging) whose fundamentals may be found in Goovaerts (1997) and Petitgas (1996).

Different exploratory plots (contour plots, scatter plots of density indices versus geographical components, normal q-q plots) were examined to check for significant deviations from stationarity and normality (the basic assumptions of linear geostatistics).

The successive step was to characterize the spatial structure of PTD data through variogram analysis. The experimental variograms were computed and fitted using asymptotic models such as spherical, exponential or Gaussian models. Anisotropy was not analyzed because data were insufficient to characterize the possible directionality in spatial correlation. Following estimation of variogram parameters (range, nugget, sill), ordinary kriging was applied for estimating undersized specimens densities at not sampled locations and mapping their distribution. Grids were constructed using 1×1 km cells. Cross-validation procedures were applied to check the goodness of fit of selected variogram models and the choice of kriging parameters.

Density hot spots (Figure 4) were outlined on the kriging maps using a threshold calculated on the basis of the cumulative distribution of the PTD. This analysis has been performed in ArcMap using Hot Spot Analysis (Getis-Ord Gi*) tool. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). Z-score, p-value, and confidence level bin (Gi_Bin) are the final results of the analysis. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant. The Getis' G statistic with a 0.95 significance level was selected among the local methods for spatial hot-spot identification in order to identify and locate spatial clusters of PTD with significantly higher production.

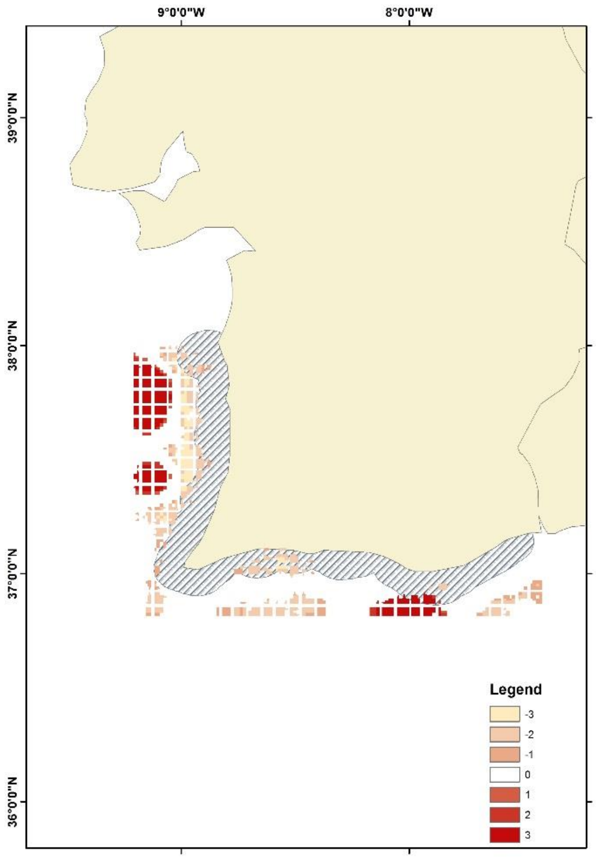

Figure 5 HotSpot maps showing the zones with the highest level of potential total discard production.

The habitat composition present in the HotSpot zones has been described using habitat map downloaded from the EMODNET portal. In particular the two maps were overlaid and the area occupied by each biocenosis was computed as percentage. Table 1 shows the results for case study 1.2.

Table 1

Sea-bed Habitats	Percentage of HotSpot surface
Deep-Sea Mud	73.6 %
Deep Circalittoral Mud	13.8 %
Deep-Sea Bed	6.2 %
Deep-Sea Rock	3.2 %
Others	3.2 %

1.4 – Catalan sea

In order to display the amount of potential total discard (PTD) produced by fisheries in this case study, the raster file of unwanted catches computed from data of the Mediterranean International bottom trawl survey (MEDITS) was combined and multiplied with the raster file of VMS data (Figure 6) representing the fisheries bottom trawl effort in the same zone. The two-raster file were obtained using the same temporal range (2013 and 2014).

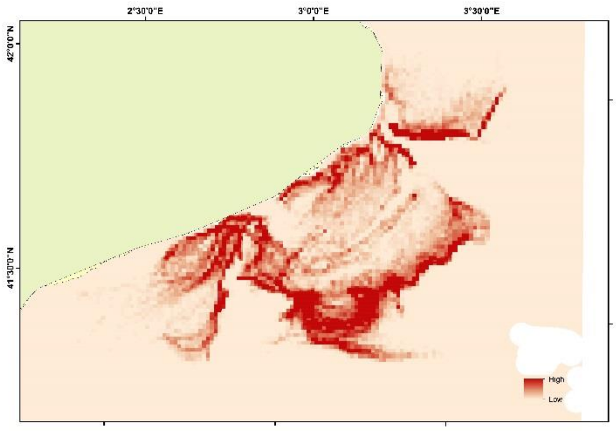

Figure 6 Fishing effort distribution in the case study area 1.4

The spatial analysis of PTD was performed using geostatistical methods (variogram analysis and kriging) whose fundamentals may be found in Goovaerts (1997) and Petitgas (1996).

Different exploratory plots (contour plots, scatter plots of density indices versus geographical components, normal q-q plots) were examined to check for significant deviations from stationarity and normality (the basic assumptions of linear geostatistics).

The successive step was to characterize the spatial structure of PTD data through variogram analysis. The experimental variograms were computed and fitted using asymptotic models such as spherical, exponential or Gaussian models. Anisotropy was not analysed because data were insufficient to characterize the possible directionality in spatial correlation. Following estimation of variogram parameters (range, nugget, sill), ordinary kriging was applied for estimating undersized specimens densities at not sampled locations and mapping their distribution. Grids were constructed using 1×1 km cells. Cross-validation procedures were applied to check the goodness of fit of selected variogram models and the choice of kriging parameters.

Density hot spots were outlined on the kriging maps using a threshold calculated on the basis of the cumulative distribution of the PTD. This analysis has been performed in ArcMap using Hot Spot Analysis (Getis-Ord Gi*) tool. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). Z-score, p-value, and confidence level bin (Gi_Bin) are the final results of the analysis. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant. The Getis' G statistic with a 0.95 significance level was selected among the local methods for spatial hot-spot identification in order to identify and locate spatial clusters of PTD with significantly higher production.

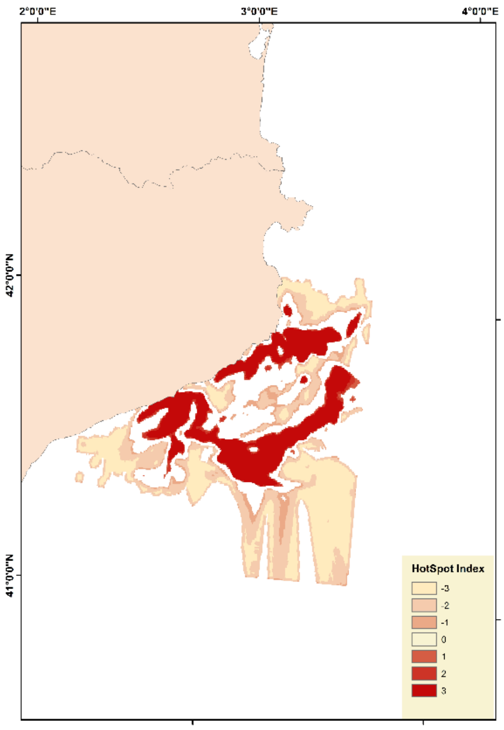

Figure 7 HotSpot maps showing the zones with the highest level of potential total discard production.

The habitat composition present in the HotSpot zones has been described using habitat map downloaded from the EMODNET portal. In particular the two maps were overlaid and the area occupied by each biocenosis was computed as percentage. Table 2 shows the results for case study 1.4.

Table 2

Sea-bed Habitats	Percentage of HotSpot surface
Deep-Sea Muddy Sand	38 %
Mediterranean communities of shelf-edge detritic bottoms	36 %
Mediterranean biocoenosis of coastal detritic bottoms	13.6 %
Mediterranean biocoenosis of coastal terrigenous muds	12.4 %

1.5 –Strait of Sicily

In order to display the amount of potential total discard (PTD) produced by fisheries in this case study, the raster file of unwanted catches (Milisenda et al., 2016a, 2016b) computed from data of the Mediterranean International bottom trawl survey (MEDITS) was combined and multiplied with the raster file of VMS data representing the fisheries effort in the same zone. The two raster file were obtained using the same temporal range (2009, 2010, 2011, 2012 and 2013).

The spatial analysis of PTD was performed using geostatistical methods (variogram analysis and kriging) whose fundamentals may be found in Goovaerts (1997) and Petitgas (1996).

Different exploratory plots (contour plots, scatter plots of density indices versus geographical components, normal q-q plots) were examined to check for significant deviations from stationarity and normality (the basic assumptions of linear geostatistics).

The successive step was to characterize the spatial structure of PTD data through variogram analysis. The experimental variograms were computed and fitted using asymptotic models such as spherical, exponential or Gaussian models. Anisotropy was not analysed because data were insufficient to characterize the possible directionality in spatial correlation. Following estimation of variogram parameters (range, nugget, sill), ordinary kriging was applied for estimating undersized specimens densities at not sampled locations and mapping their distribution. Grids were constructed using 1×1 km cells. Cross-validation procedures were applied to check the goodness of fit of selected variogram models and the choice of kriging parameters.

Density hot spots were outlined on the kriging maps using a threshold calculated on the basis of the cumulative distribution of the PTD. This analysis has been performed in ArcMap using Hot Spot Analysis (Getis-Ord Gi*) tool. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). Z-score, p-value, and confidence level bin (Gi_Bin) are the final results of the analysis. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant. The Getis' G statistic with a 0.95 significance level was selected among the local methods for spatial hot-spot identification in order to identify and locate spatial clusters of PTD with significantly higher production.

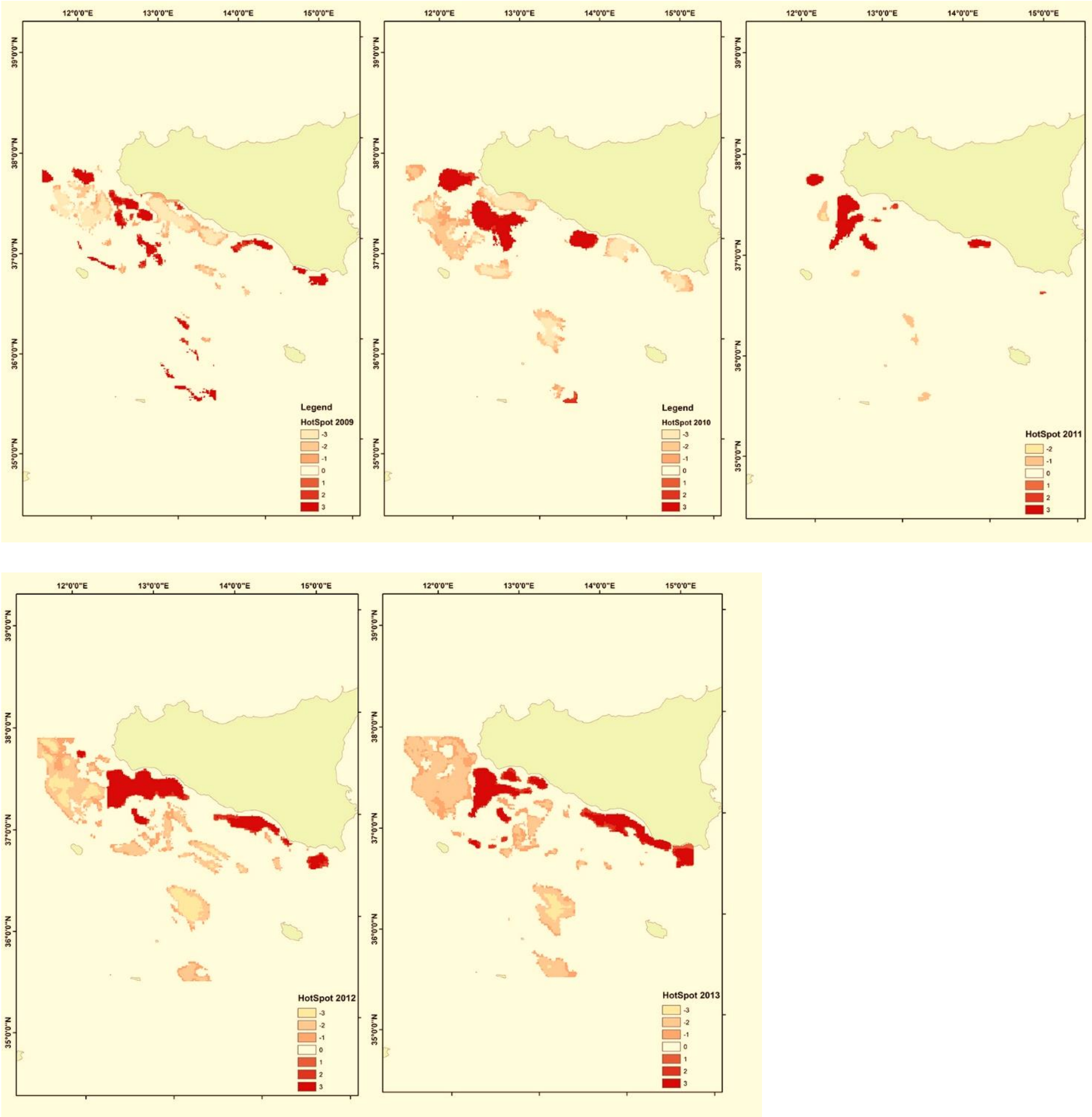

Figure 8 HotSpot maps showing the zones with the highest level of potential total discard production.

A persistent zone of undersized organisms was defined as an area consistently occupied by the highest density of PTD, hence it was identified by means of GIS tools, extracting the area where the overlap of hot spots occurred over time. The overlap rate for each grid cell was quantified and named the index of persistence (PI) (Fiorentino et al., 2003; Colloca et al., 2009), measuring the relative persistence of cell i as an annual potential zone of undersized organisms. This index was obtained as a percentage ratio of the number of times that a given area was classified as a hot spot to the total number of years according to the formula:

$$PI_i = 100 * \frac{1}{n}\sum_{j=1}^{n}\delta_{ij}$$

where $\delta_{ij} = 1$ when grid cell i is included in a hot-spot in year j and $\delta_{ij} = 0$ otherwise, and n is the number of years. The PI decreases to zero where density hot spots have never been observed, while it increases to 100% where density hot spots occur year-by-year throughout the time series. Results were plotted in the maps of persistence reporting a scale of different persistence classes.

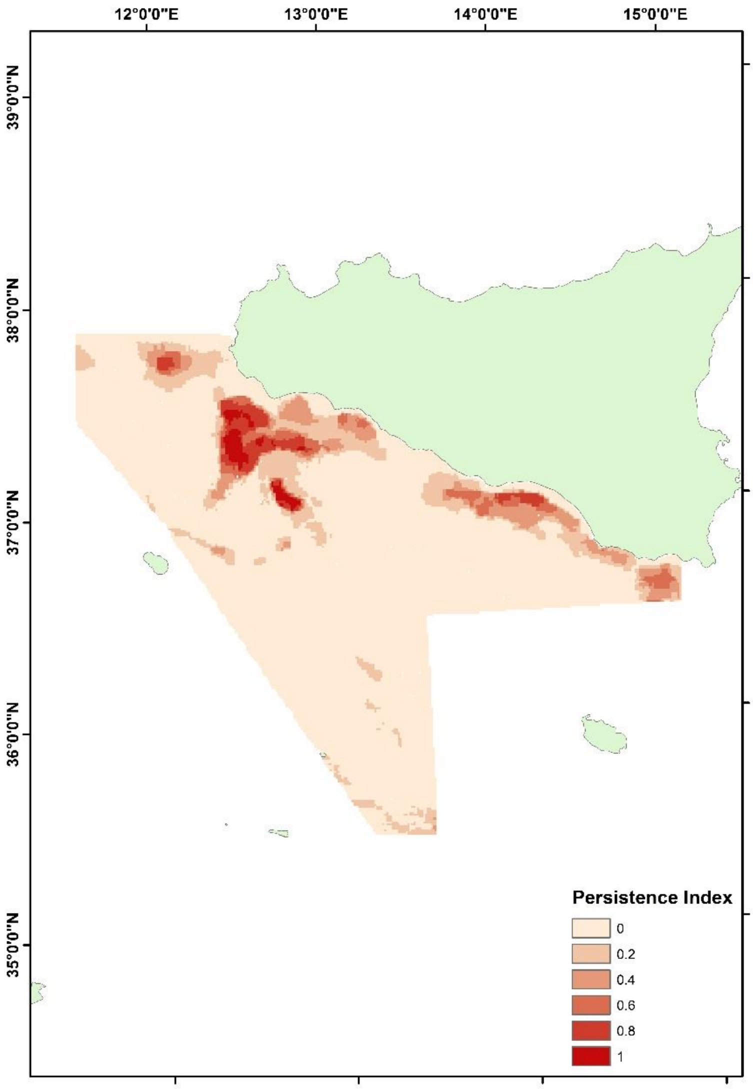

Figure 9 Persistence index maps showing the zones with the highest level of persistence of total discard production.

The habitat composition present in the zones with a value of persistence index ranging from to 0.8 to 1 has been described using habitat map available for the case study area (Garofalo et al., 2004). In particular the two maps were overlaid and the area occupied by each biocenosis was computed as percentage. Table 3 shows the results for case study 1.5.

Table 3

Sea-bed Habitats	Percentage of HotSpot surface
Soft muds with fluid surface film	68.2 %
Coastal detritus	18.3 %
Well-graded fine sand	10 %
Coastal terrigenous mud	3.5 %

1.6 – 1.8 - Ligurian and North Tyrrhenian sea

In order to display the amount of potential total discard (PTD) produced by fisheries in this case study, the raster file of unwanted catches (Milisenda et al., 2016a, 2016b) computed from data of the Mediterranean International bottom trawl survey (MEDITS) was combined and multiplied with the raster file of AIS (automatic identification system, fig.10) data representing the fisheries effort in the same zone. The two raster file were obtained using the same temporal range (summer period).

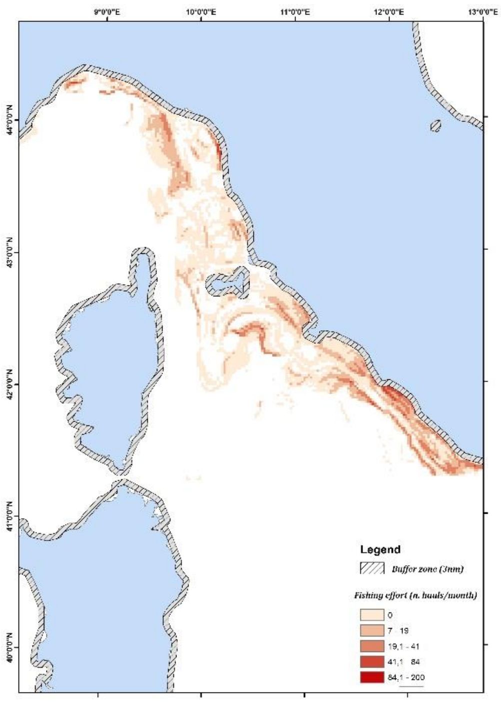

Figure 10. Fishing effort in the case study 1.6 – 1.8

The spatial analysis of PTD was performed using geostatistical methods (variogram analysis and kriging) whose fundamentals may be found in Goovaerts (1997) and Petitgas (1996).

Different exploratory plots (contour plots, scatter plots of density indices versus geographical components, normal q-q plots) were examined to check for significant deviations from stationarity and normality (the basic assumptions of linear geostatistics).

The successive step was to characterize the spatial structure of PTD data through variogram analysis. The experimental variograms were computed and fitted using asymptotic models such as spherical, exponential or Gaussian models. Anisotropy was not analysed because data were insufficient to characterize the possible directionality in spatial correlation. Following estimation of variogram parameters (range, nugget, sill), ordinary kriging was applied for estimating undersized specimens densities at not sampled locations and mapping their distribution. Grids were constructed using 1×1 km cells. Cross-validation procedures were applied to check the goodness of fit of selected variogram models and the choice of kriging parameters.

Density hot spots were outlined on the kriging maps using a threshold calculated on the basis of the cumulative distribution of the PTD. This analysis has been performed in ArcMap using Hot Spot Analysis (Getis-Ord Gi*) tool. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). Z-score, p-value, and confidence level bin (Gi_Bin) are the final results of the analysis. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant. The Getis' G statistic with a 0.95 significance level was selected among the local methods for spatial hot-spot identification in order to identify and locate spatial clusters of PTD with significantly higher production.

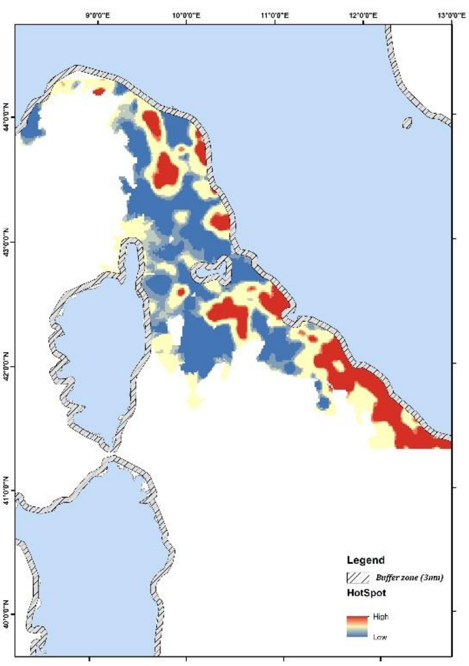

Figure 10 HotSpot map showing the zones with the highest level of seasonal potential total discard production.

The habitat composition present in the zones with high HotSpot index (bin value equal to 3) has been described using habitat map downloaded from the EMODNET portal. In particular the two maps were overlaid and the area occupied by each biocenosis was computed as percentage. Table 4 shows the results for case study 1.6 – 1.8.

Table 4

Sea-bed Habitats	Percentage of HotSpot surface
Deep circalittoral mud	45 %
Deep-sea mud	30 %
Deep circalittoral mixed sediment	10 %
Others	15 %

1.7 – Aegean Sea

In order to display the amount of potential total discard (PTD) for species with established minimum landing size as produced by fisheries in this case study, we used the discard amount coming from commercial data and on board sampling. Data from this case study were elaborated directly by HCMR. The time series considered ranged from 2003 to 2008 and 2013 to 2014. Data have been analyzed considering three different seasons: spring, autumn and winter as summer period is closed for the bottom trawl fishery in territorial Greek waters.

Biomass of species with established minimum landing size (MLS) was modeled along with satellite environmental parameters, season and haul duration by means of Generalized Additive Models.

For each sampling station several types of information such as date and time of sampling, longitude and latitude, swept area, haul duration and species composition were recorded. In total over 1300 sampling stations were recorded covering most of the Greek part of Aegean Sea. The raw biomass data were divided by species into UWDI and landings at each sampling station and subsequently the biomass was standardized and estimated as total kilograms per hour for three different groups: potential total discards (PTD), potential total fish discard (PTFD) and potential total crustacea discard (PTCD).

In order to address the spatial dimension of UWDI reduction over the wider Aegean Sea we modeled the spatial distribution of each group along with satellite environmental parameters, season and haul duration by means of Generalized Additive Models (GAMs) which employ non-linear and non-parametric techniques for regression modeling (Hastie & Tibshirani, 1990). This allowed us to identify areas that are most likely to show high biomass of potential unwanted catch. Final model selection was made on a stepwise forward approach. Data were log transformed and modeled using a Gaussian error distribution or a Gamma error distribution and an identity link function depending on the group analyzed and the inspection of the residual fit and the lack of trend in the residual vs predictor plots (i.e. residuals vs fitted values, QQ-plots, residual vs original explanatory variables). The minimization of the Restricted Maximum Likelihood (REML) and the level of Deviance Explained (DE) led to the selection of the model that fitted best the response variable.

To avoid over-fitting and to simplify the interpretation of the results, the degree of smoothing was chosen based on the restricted maximum likelihood while the maximum degrees of freedom allowed to the smoothing functions were limited to the main effects at k = 5 and, for the first-order interaction effects, at k = 15. Only statistical significant parameters, with p-value < 0.05, were retained in the final models.

Based on the final model selected we obtained seasonal mean maps showing potential areas with increased discards biomass for the study period (Figs 11-13).

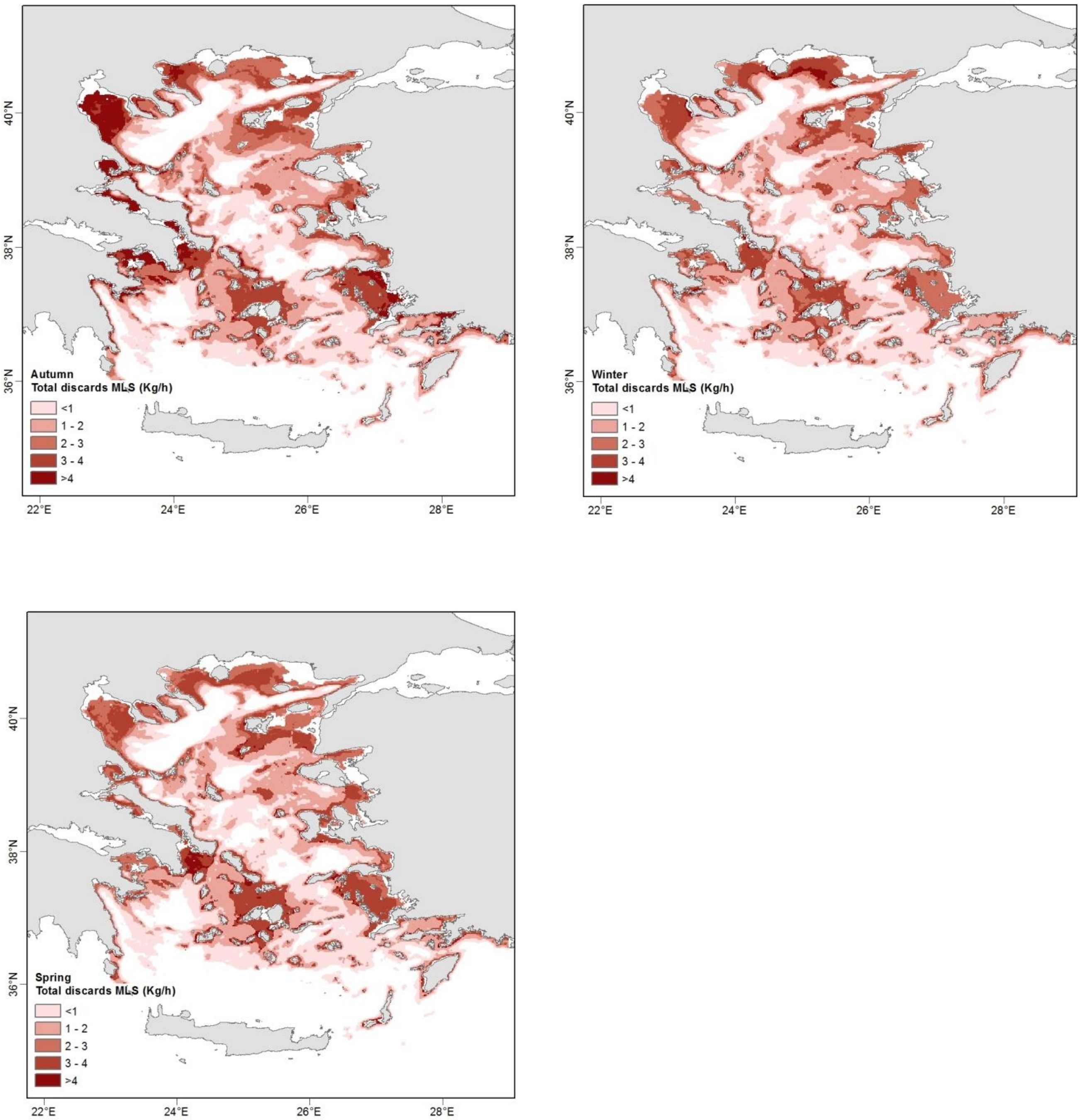

Figure 11 Mean seasonal maps of potential total discard production for species with MLS.

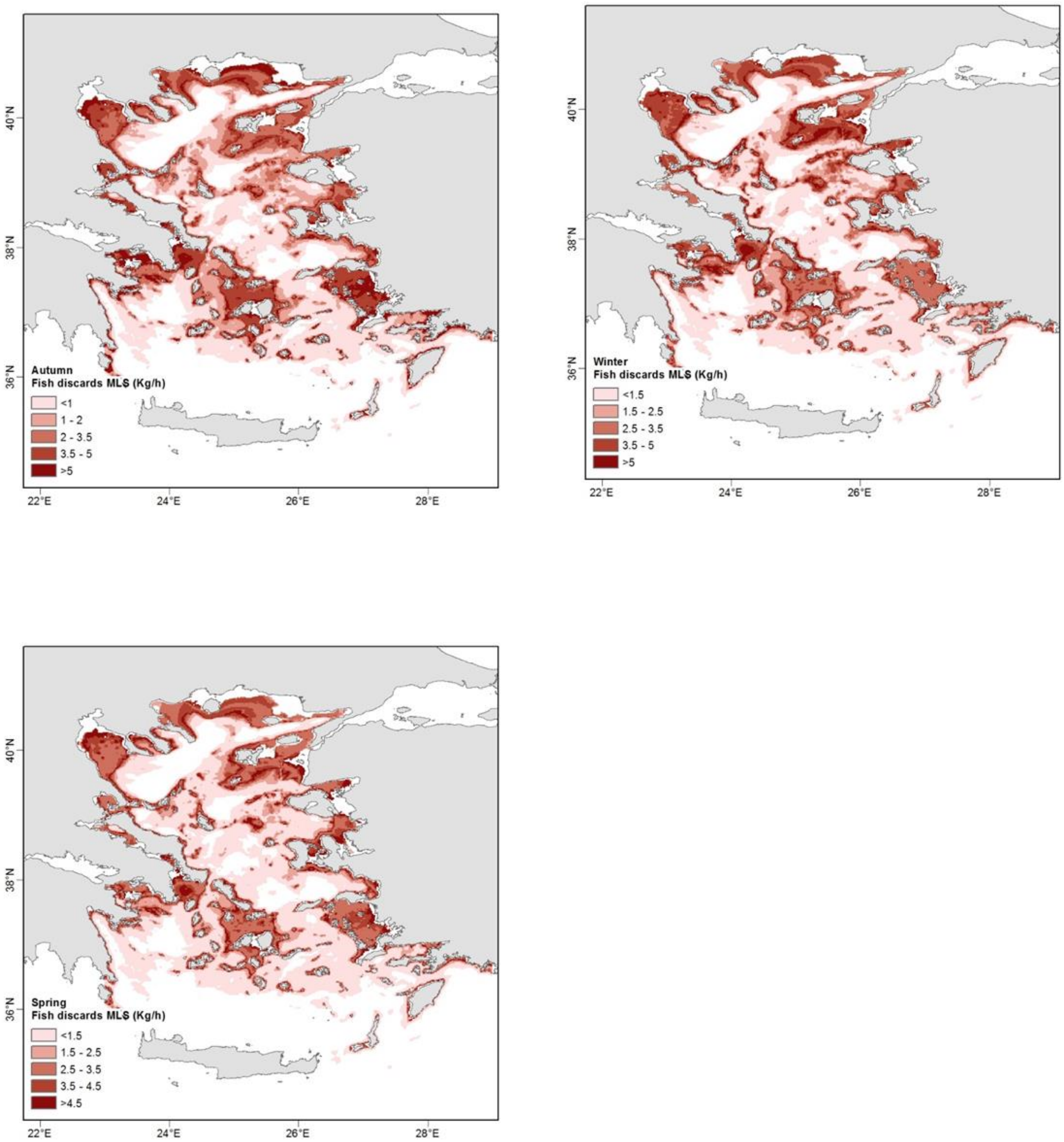

Figure 12 Mean seasonal maps of potential total Fish discard production for species with MLS.

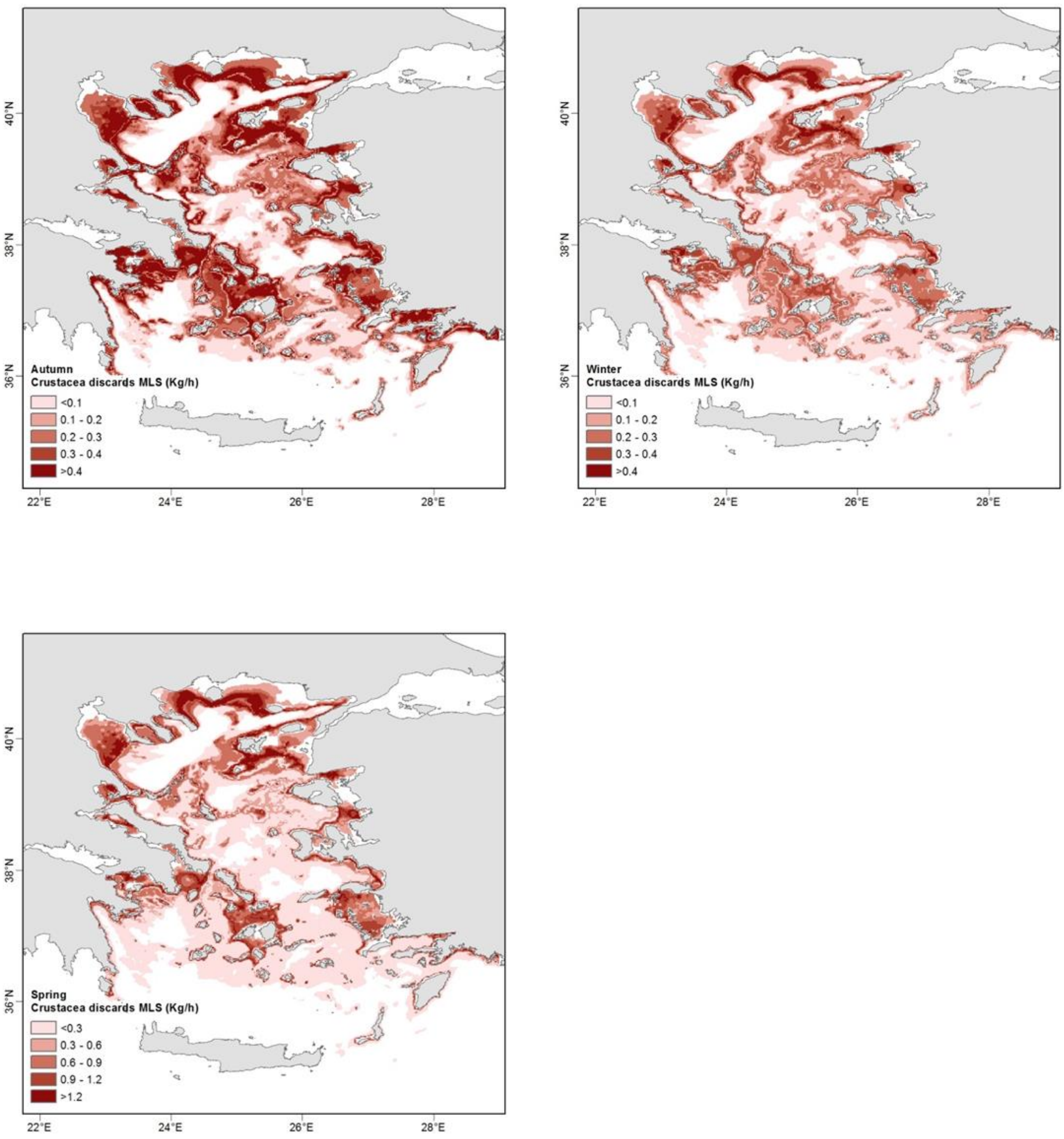

Figure 13 Mean seasonal maps of potential total Crustacea discard production for species with MLS.

The persistent zone of undersized discarded organisms was defined as an area consistently occupied by the higher biomass values of PTD. Hence it was identified by means of GIS tools, extracting the area where the overlap of hot spots occurred over time. The overlap rate for each grid cell was quantified and named the index of persistence (PI) (Fiorentino et al., 2003; Colloca et al., 2009), measuring the relative persistence of cell i as an annual potential zone of undersized organisms. This index was obtained as a percentage ratio of the number of times that a given area was classified as a hot spot to the total number of years according to the formula:

$$PI_i = 100 * \frac{1}{n} \sum_{j=1}^{n} \delta_{ij}$$

where $\delta_{ij} = 1$ when grid cell i is included in a hot-spot in year j and $\delta_{ij} = 0$ otherwise, and n is the number of years. The PI decreases to zero where density hot spots have never been observed, while it increases to 100% where density hot spots occur year-by-year throughout the time series. Concerning CS 1.7, hot spots are the potential total discard grounds with biomass values exceeding the 75% of the cumulative distribution of the PTD for each year and season. Results were plotted in the maps of persistence reporting a scale of different persistence classes (Fig 14).

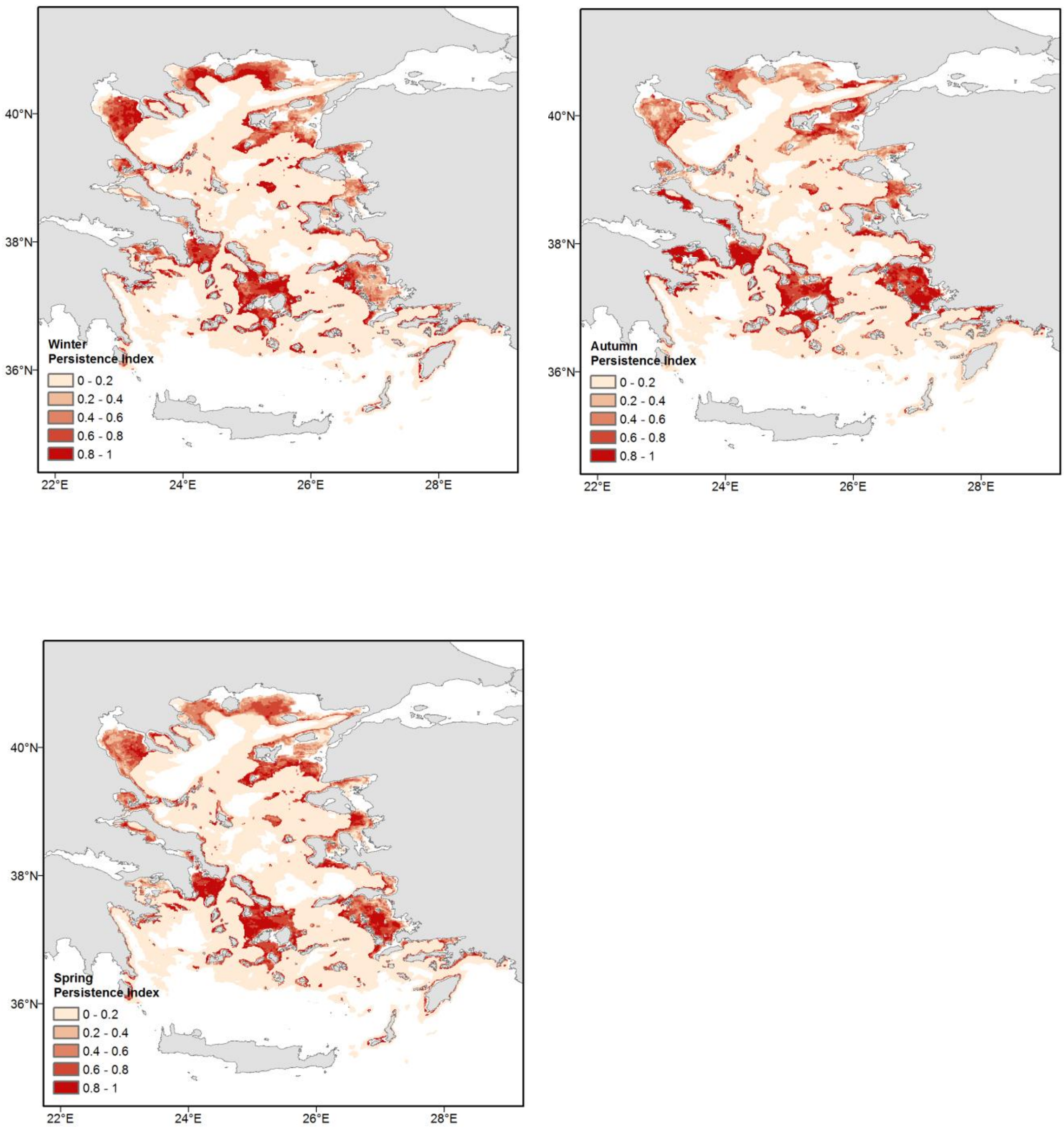

Figure 14 Persistence index maps showing the zones with the highest level of persistence of total discard production for each season.

The habitat composition present in the zones with a value of persistence index ranging from to 0.75 to 1 has been described using habitat map downloaded from the EMODNET portal. In particular the two maps were overlaid and the area occupied by each biocenosis was computed as percentage. Table 5 shows the results for CS 1.7.

Table 5

Sea-bed Habitats	Percentage of HotSpot surface		
	Spring	Winter	Autumn
Coarse sediment	24.4%	23.7%	19.7%
Fine mud	3.3%	4.7%	6.8%
Mixed sediment	2.5%	6.6%	2.3%
Rock or other hard substrata	35.7%	27.7%	33.5%
Sand	12.0%	15.4%	18.3%
Sandy mud to muddy sand	21.7%	21.6%	19.2%
Other	0.4%	0.4%	0.1%

Finally, the overlapping between sensitive habitats (Posidonia meadows, coralligenous and maerl formations) as estimated in the MEDISEH project (Giannoulaki et al., 2013, Martin et al., 2014) and the total discard zones in seasonal basis is presented in Figures 15 to 17.

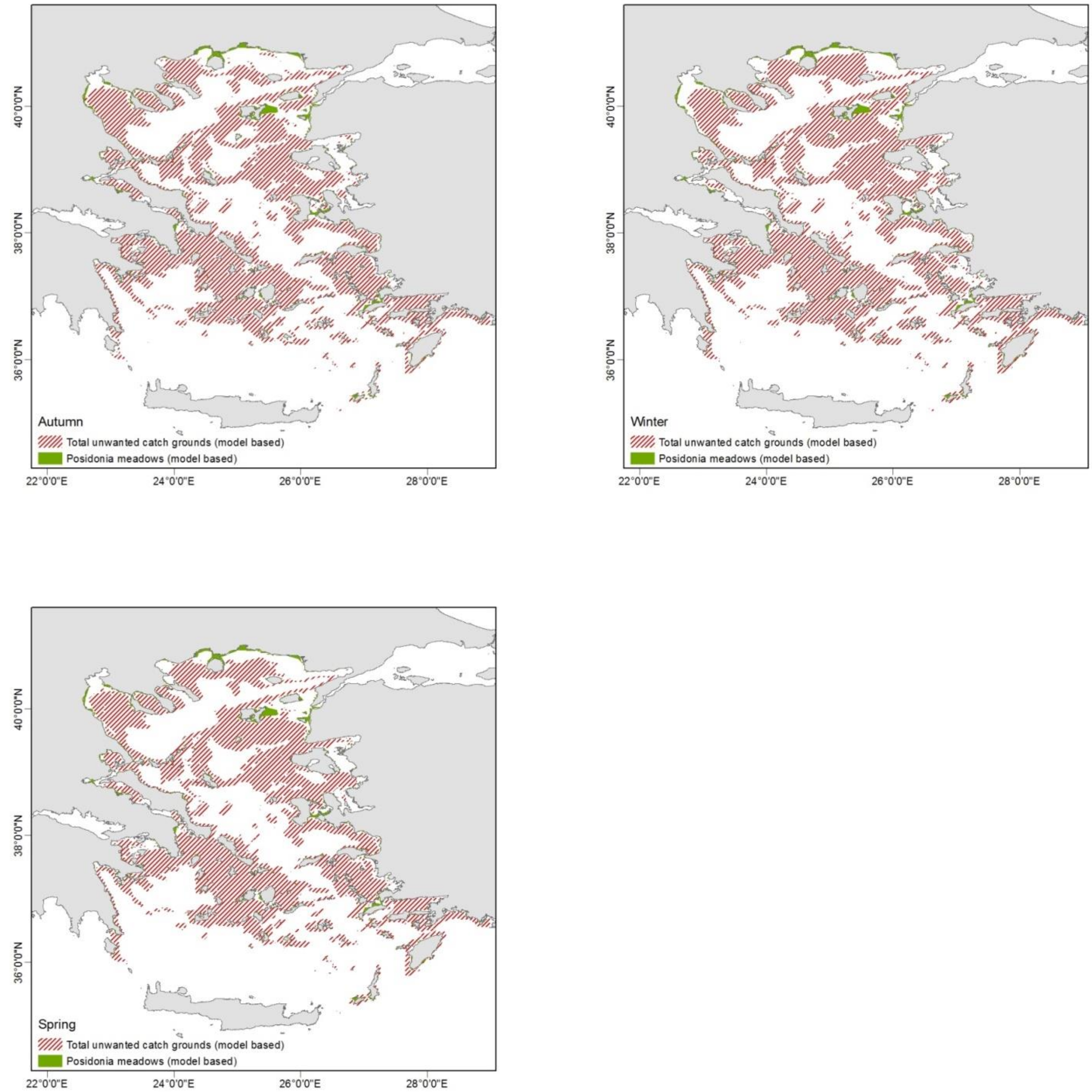

Figure 15 Overlapping between Posidonia meadows (as estimated in the MEDISEH project, Giannoulaki et al., 2013) and the total discard zones (estimated within D1.9) in a seasonal basis.

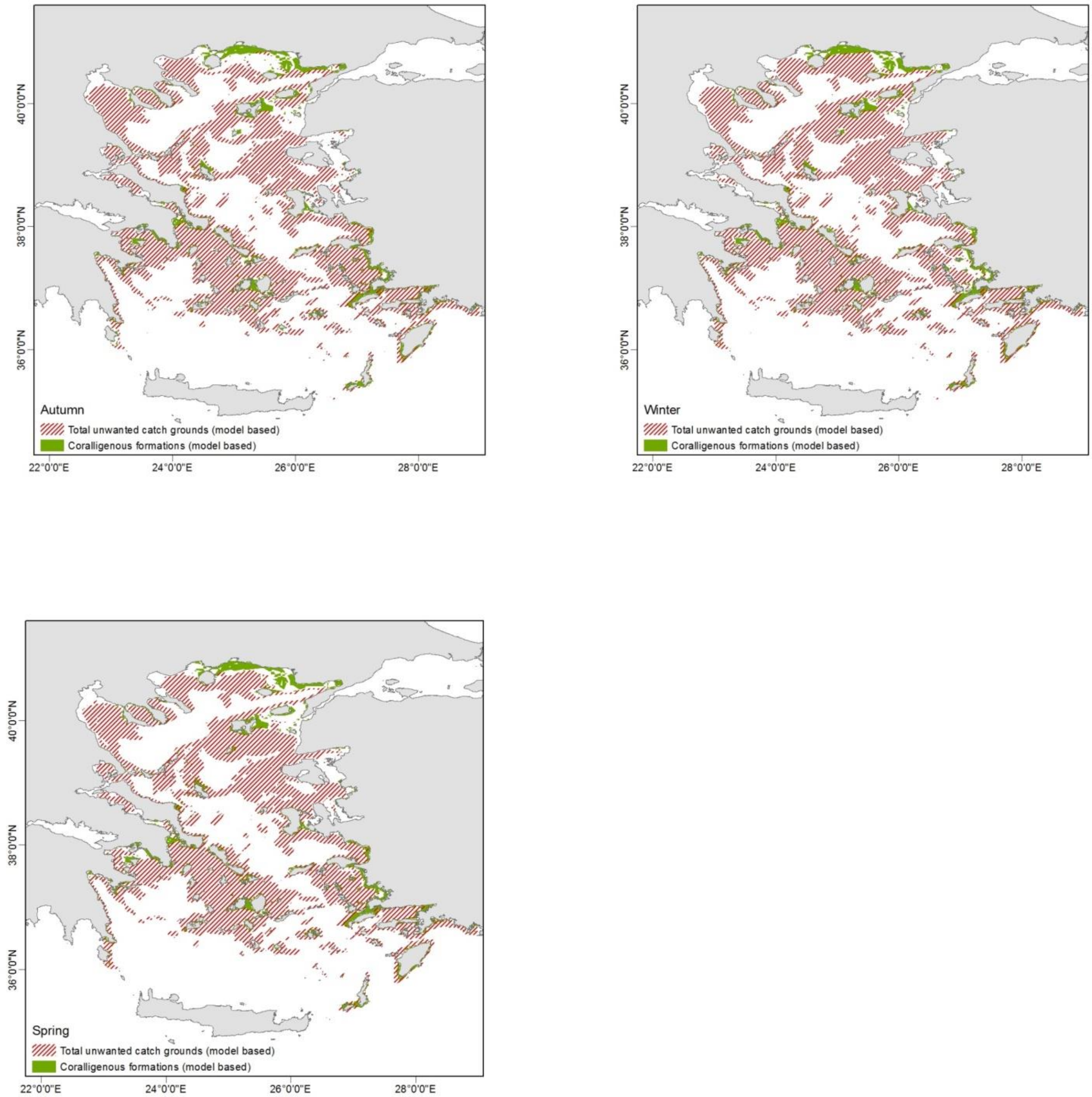

Figure 16 Overlapping between Coralligenous formations (as estimated in the MEDISEH project, Martin et al., 2014) and the total discard zones (estimated within D1.9) in a seasonal basis.

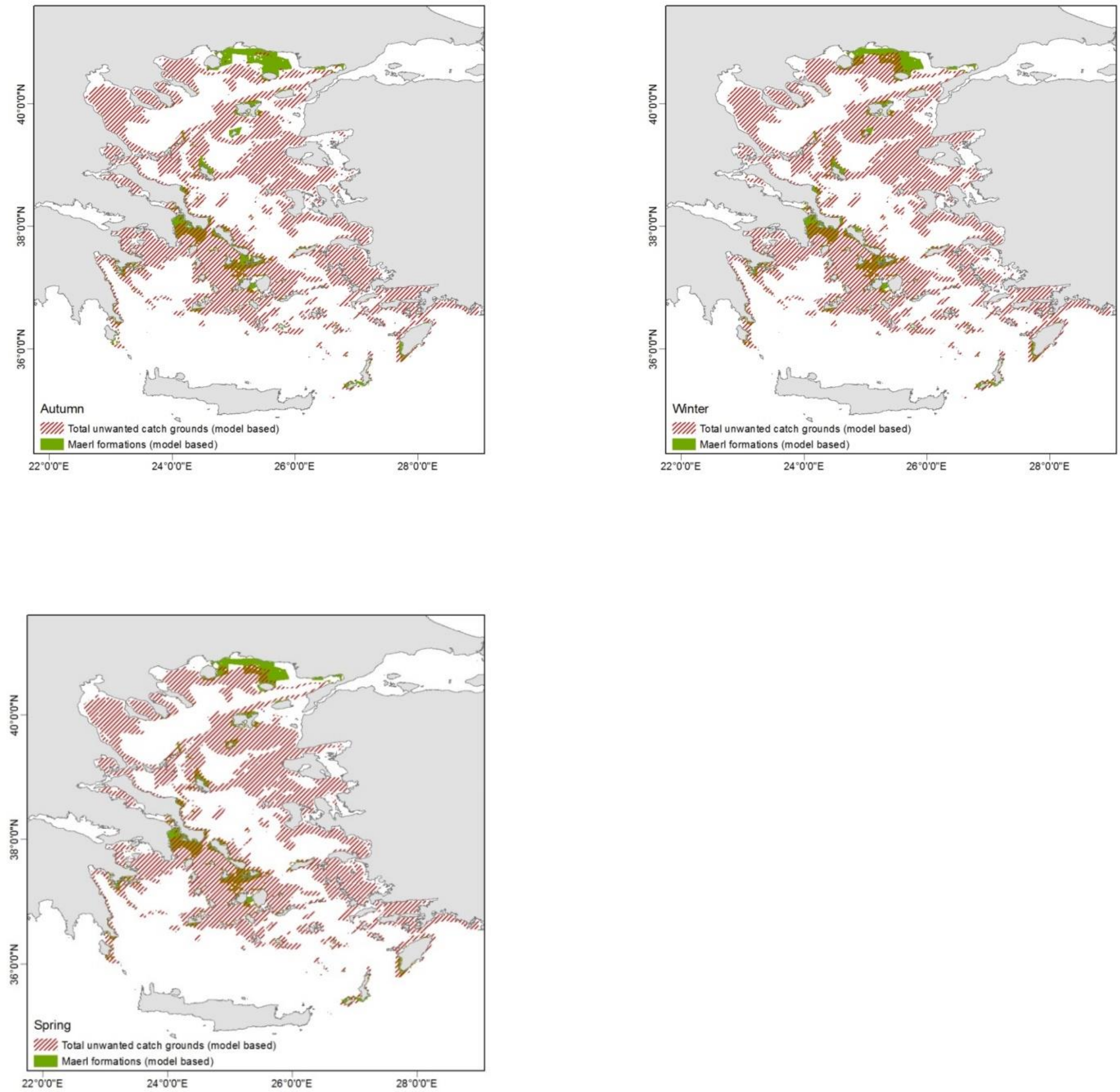

Figure 17 Overlapping between maerl formations (as estimated in the MEDISEH project, Martin et al., 2014) and the total discard zones (estimated within D1.9) in a seasonal basis.

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