REPORT ABOUT SEABIRD AND FISHERIES INTERACTION: EXPLORATIVE BYCATCH RISK ANALYSES

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Association Biom (BirdLife Croatia)

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Action C.4: At-sea distribution of seabird species and spatio-temporal overlap with fisheries

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REPORT ABOUT SEABIRD AND FISHERIES INTERACTION: EXPLORATIVE BYCATCH RISK ANALYSIS

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Data Beneficiary

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Front cover illustration: Scopoli's shearwaters in front of a fisherman's boat. Rita Matos.

This report is part of Action C.4: At-sea distribution of seabird species and spatio-temporal overlap with fisheries

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Background

Bycatch is among the major threats facing pelagic birds at sea (Dias et al., 2019). The purpose of this analysis is to explore the spatial distribution of possible areas with an elevated risk of seabird bycatch in the Croatian Adriatic. It is not intended as a conclusive or comprehensive risk assessment for seabird bycatch, but rather as an exploratory analysis to inform decision makers on possible priorities in bycatch mitigation, and as a template for further analysis by conservation practitioners.

The focus of this explorative study is on three seabird species which are globally and/ or regionally endangered (IUCN Red List; Tutiš et al. 2013) and breed almost exclusively in the Mediterranean Sea (incl. the Adriatic), namely Yelkouan shearwater *Puffinus yelkouan*, Scopoli's shearwater *Calonectris diomedea* and Audouin's gull *Larus audouinii*. In terms of bycatch, among the riskiest fishing method for these three species is long line fishing (Genovart et al. 2017).

Methodology

Species

In the scope of the LIFE Artina project (LIFE17 NAT/HR/000594), GPS tracking was performed on three species of seabird (Yelkouan shearwaters, Scopoli's shearwaters and Audouin's gulls) and analyzed in order to identify important bird and biodiversity areas (IBAs) at sea (Zec et al., 2023). The same data is used in this analysis to try to estimate seabird bycatch risk.

Geographical scope

id	iso3	label
5673	HRV	Croatia
50167	HRV	Joint regime area Croatia / Slovenia

The Croatian exclusive economic zone (EEZ code 5673) was included in this analysis. The joint regime area with Slovenia (EEZ code 50167) was not.

Input data

Fishing effort

This analysis used both VMS data provided by the national competent authority and the AIS "Apparent Fishing Effort" dataset provided by Global Fishing Watch https://globalfishingwatch.org/.

VMS (Vessel Monitoring System)

The VMS data provided for this analysis was limited in several important regards, specifically: * includes only vessels using drifting longlines * the spatial extent of the data is limited (see map) * the data included all vessel movement, with no explicit way to filter only locations where fishing activity was performed (Figure 1).

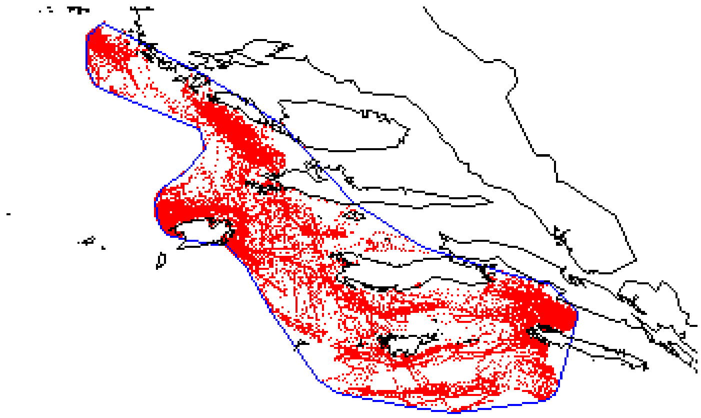


Figure 1: VMS longlines, all locations

In order to filter out location points that likely don't correspond to fishing activity (i.e. vessel movement, anchoring, mooring), a coarse speed filter was applied, removing points with a recorded speed below 1 knot and above 10 knots (Figure 2). Following this, the points were rasterized by counting location points per grid cell. Finally, the raster values were clamped to the 99.5 percentile value to remove extreme outliers that tend to appear in ports.

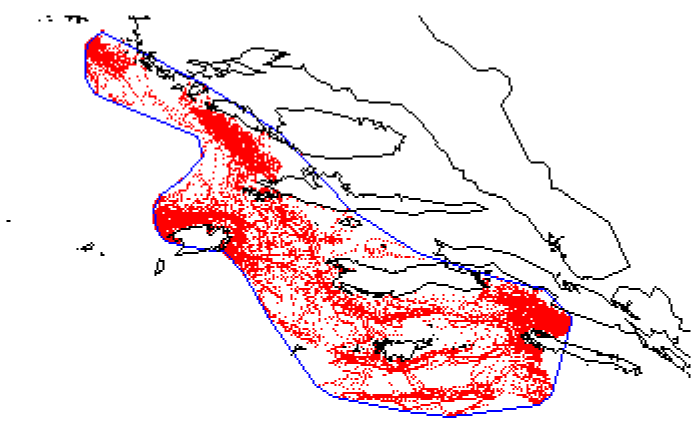


Figure 2: VMS longlines, speed filter between 1 and 10 knots

AIS (Automatic Identification System)

The AIS-based dataset was accessed through the GFW API by using the gfwr package.

This AIS dataset includes fishing gear type and the apparent fishing effort in hours per grid cell. For more information on the methodology used by GFW to transform raw AIS data into the fishing effort dataset, please see: https://globalfishingwatch.org/dataset-and-code-fishing-effort/

AIS data has a known bias for larger vessels. Cumulative effort by fishing gear shows trawlers as the most represented in the dataset, followed by 'other purse-seines', but also including other gear types with a higher potential seabird bycatch risk, such as drifting and set longlines as well as set gillnets:

geartype	effort_hrs
trawlers	1.855673e+06
other_purse_seines	5.403368e+05
fishing	3.634301e+04
drifting_longlines	3.541763e+04
set_longlines	2.638757e+04
tuna_purse_seines	2.340727e+04
set_gillnets	2.157518e+04
fixed_gear	1.048694e+04
pole_and_line	4.358924e+03
pots_and_traps	7.202127e+02
NULL (=UNKNOWN)	4.939928e+02
purse_seines	3.043678e+02
dredge_fishing	9.129000e+01
trollers	2.340278e+00

Filtering for set and drifting longlines and grouping by vessel flag reveals that for Croatian vessels the GFW dataset has very little data for set longlines and no data for drifting longlines:

flag	geartype	effort_hrs
ITA	drifting_longlines	34574.4847
CYP	drifting_longlines	843.1492
ITA	set_longlines	25171.2769
HRV	set_longlines	1216.2886

By year and month, the distribution of fishing effort in the dataset was the following (Figure 3):

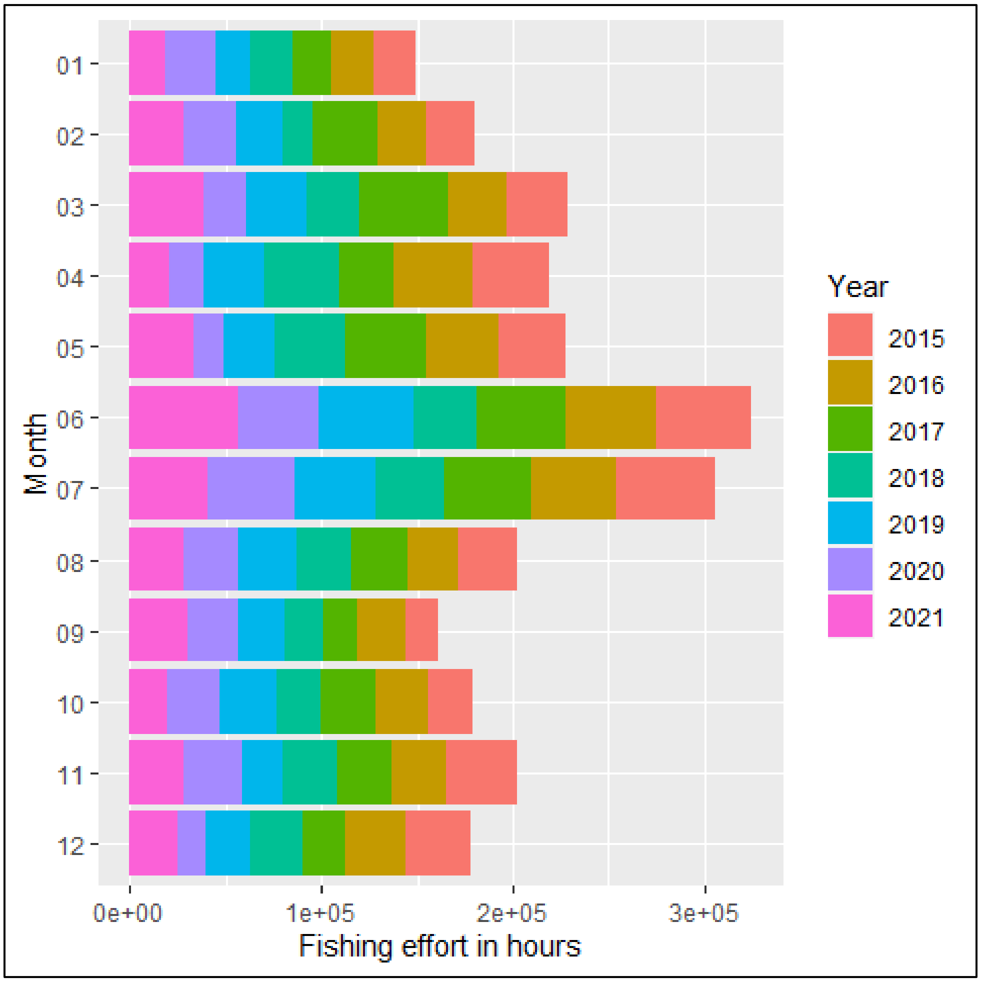


Figure 3: Cumulative fishing effort in hours by month/year

The years 2015-2021 were included in the analysis, and the estimated cumulative fishing effort was similar for all years:

year	effort_hrs
2015	396046.0
2016	387977.4
2017	388305.9
2018	338966.0
2019	350949.4
2020	325870.2
2021	367483.1

The cumulative fishing effort was calculated for each grid cell. For plotting purposes, the top 0.5% of values were restricted (or 'clamped') to eliminate outlier cells (Figure 4):

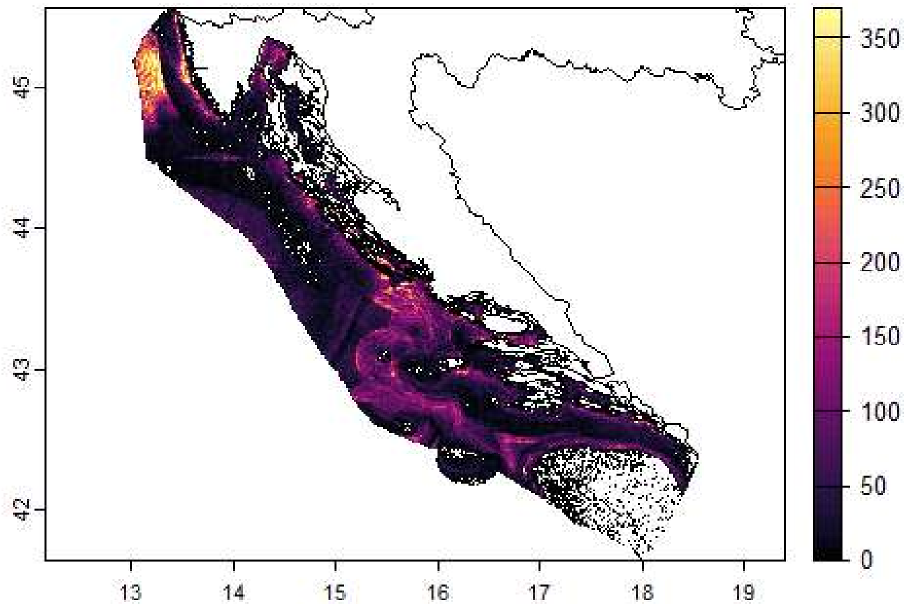


Figure 4: Fishing effort across the study area

The same was done for longline fishing effort, but the results are almost exclusively outside Croatian territorial waters (Figure 5), which seems to further confirm that Croatian vessels are excluded from the sample.

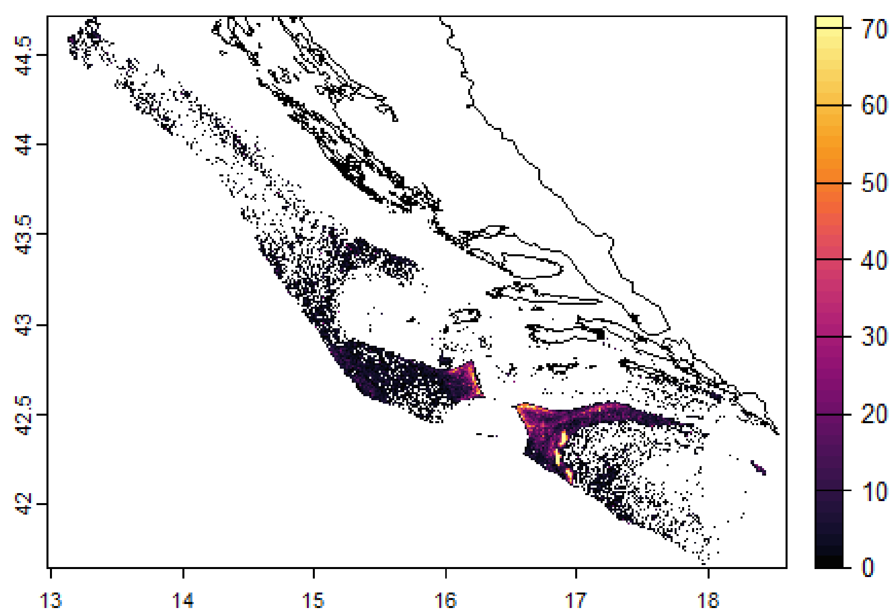
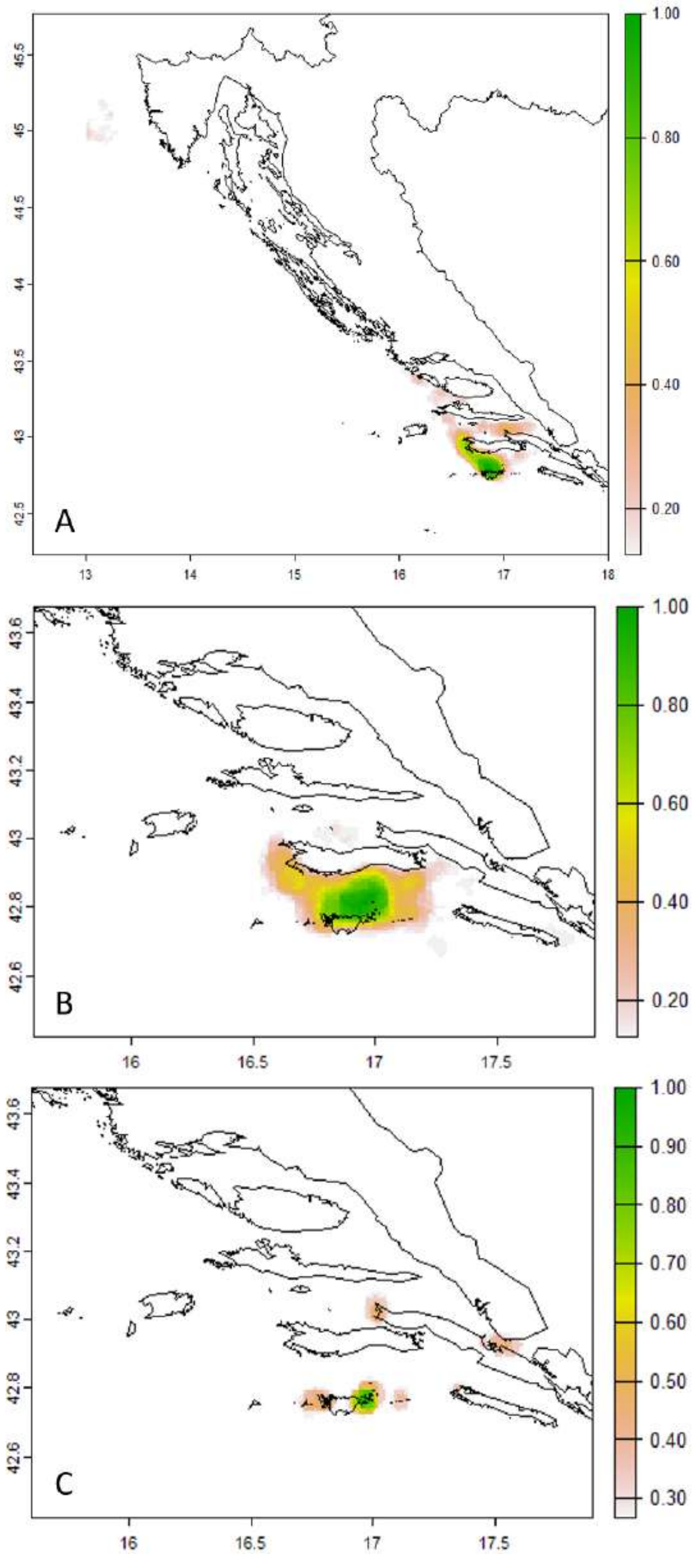


Figure 5: Longline fishing effort across the study area

Seabird distribution



Movement data was collected with GPS tracking devices mounted on seabirds from several colonies around the island of Lastovo during the breeding seasons in 2019, 2020 and 2021 (for more details see Zec et al., 2023). A total of 40 Yelkouan shearwaters, 40 Scopoli's shearwaters and 25 Audouin's gull were tagged with GPS devices. This data was analyzed according to the BirdLife track2KBA methodology (BirdLife International, 2010) to identify core areas for each of these species based on individual birds' overlapping utilization distributions (UD). Only representative core areas, as defined by the track2KBA methodology, were considered for this analysis. These areas represent areas used regularly by a significant number of birds from the tagged colonies (Figure 6). For a detailed description of the methodology see https://github.com/BirdLifeInternational/track2kba.

An output of this analysis is the estimated number of mature individuals regularly present in a certain area. The inputs were resampled to the same raster as the GFW fishing data for further analysis.

Figure 6: Relative bird density for Yelkouan shearwater (A), Scopoli's shearwater (B) and Audouin's gull (C)

Marine Important Bird & Biodiversity Areas (mIBAs)

The above-mentioned analysis of seabird distributions and representative core areas also resulted in the designation of several marine IBAs (Important Bird and Biodiversity Areas) following the BirdLife IBA criteria. These areas include 5 newly designated sites (Hvar Channel, Korčula Channel, Lastovo Channel, East Mljet Channel and Northern Adriatic) and the extension of 2 existing IBAs (Lastovo Archipelago and Offshore Islands) (Figures 7 & 8), all of which have been proposed to be converted into Special Protected Area (SPAs) and to be included in the Natura 2000 network of Croatia (Zec et al. 2023).

In this study seabird bycatch risk was calculated for each of these sites separately, as well as for these sites combined ('inside mIBAs'), and the rest of the Croatian Adriatic ('outside mIBAs'). A number of calculations were used, including the mean and median values for grid cells, as well as the sum of fishing effort divided by the total area inside vs outside of mIBAs. The mean fishing effort is the mean of the fishing effort values that are inside/outside of mIBA calculated on the fishing effort raster (sum of values of raster cells divided by number of raster cells). The average was calculated as the sum of values of the same raster cells divided by the surface area of the inside/outside mIBAs.

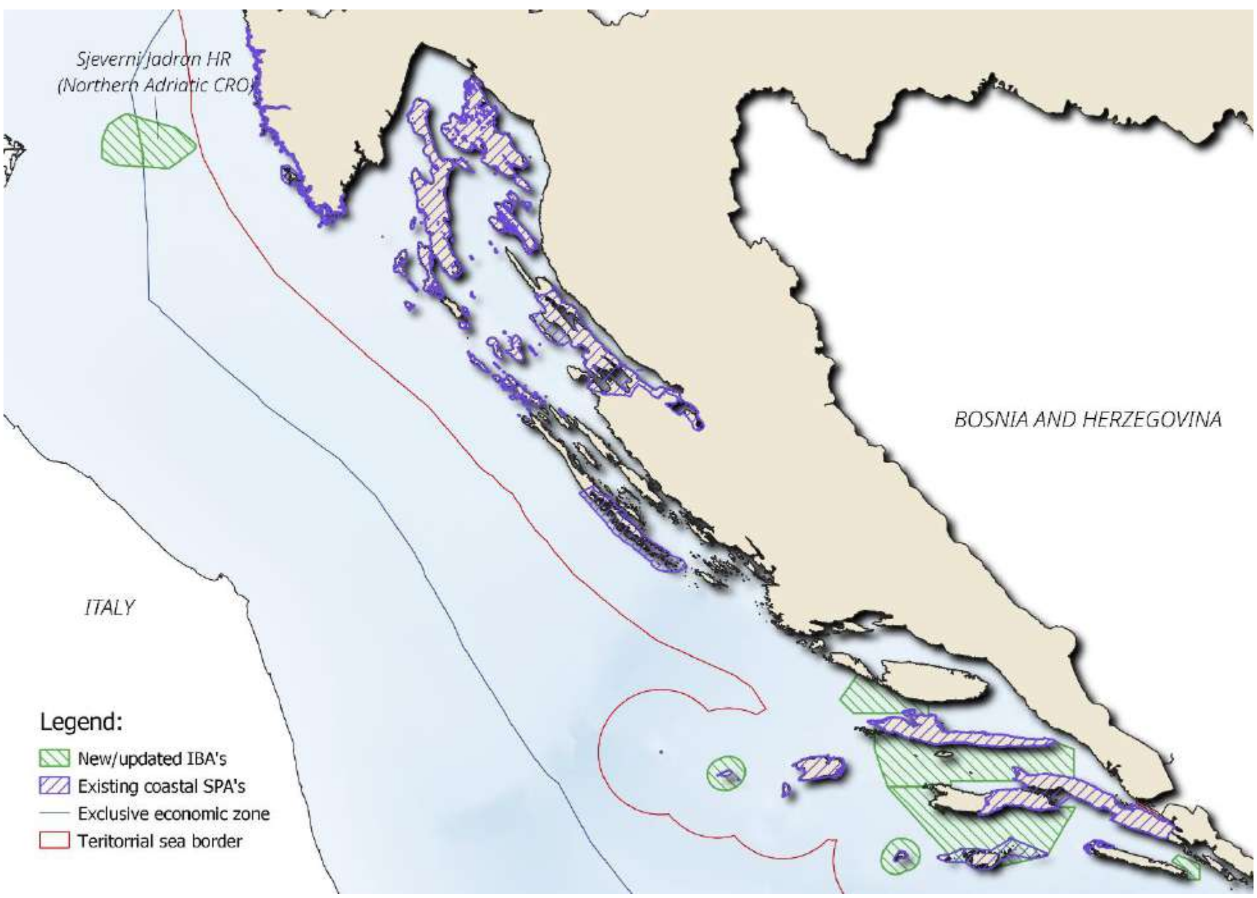


Figure 7: Newly designated marine IBAs in the Croatian Adriatic (green) as a result of LIFE Artina

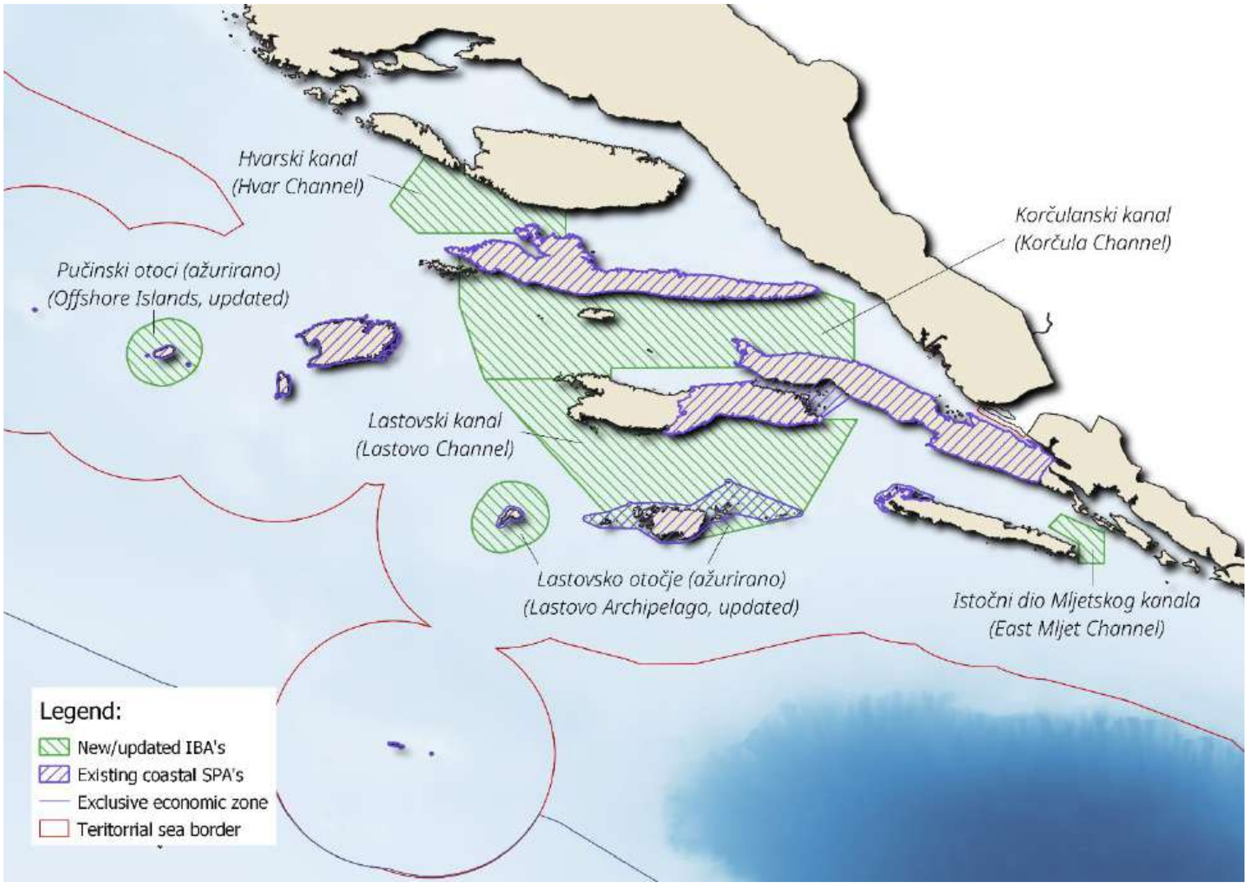


Figure 8: Newly designated marine IBAs in the Croatian Adriatic (green) as a result of LIFE Artina. This image is a zoomed in version of Figure 7.

Output data

VMS vs AIS comparison

Because the GFW AIS-based fishing effort dataset doesn't seem to include drifting longline effort for any Croatian-flag vessels (Figure 5), and the VMS dataset covers only a small part of the Croatian Adriatic, their direct comparison is challenging. We attempted to overlap this data and check to what extent they are similar, primarily to verify whether the AIS dataset, which covers the whole Croatian Adriatic, can reasonably be assumed to represent the fishing effort by drifting longlines. For this purpose, a comparison was performed in the following way:

- The AIS data was masked to the area with rasterized VMS data
- The values representing effort in both rasters (estimated hours in AIS, number of overlapping vessel location points in VMS) were normalized to the range 0-1
- For pairwise combinations of different AIS dataset gear types and the VMS raster, RMSE (root mean square error) was calculated as a measure of difference between the rasters

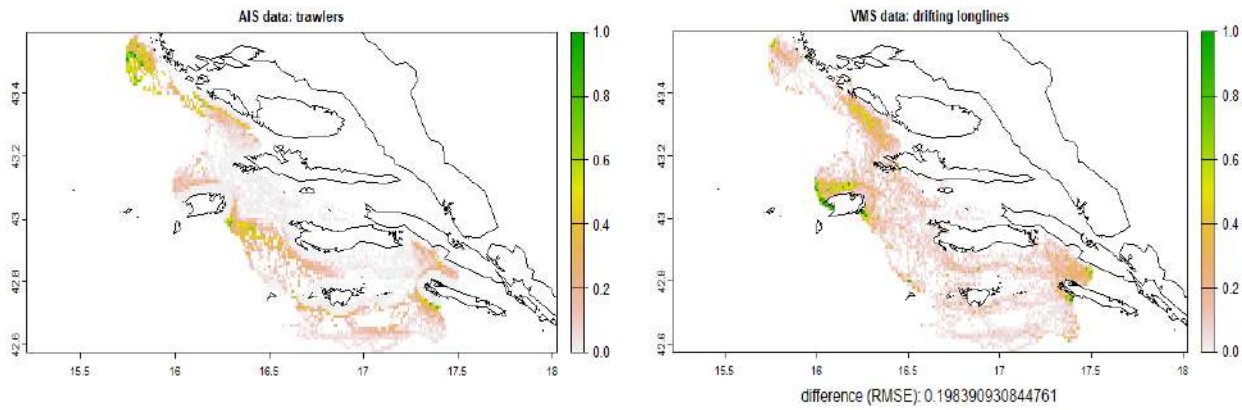


Figure 9: Comparison between AIS 'trawlers' category and VMS drifting longlines raster

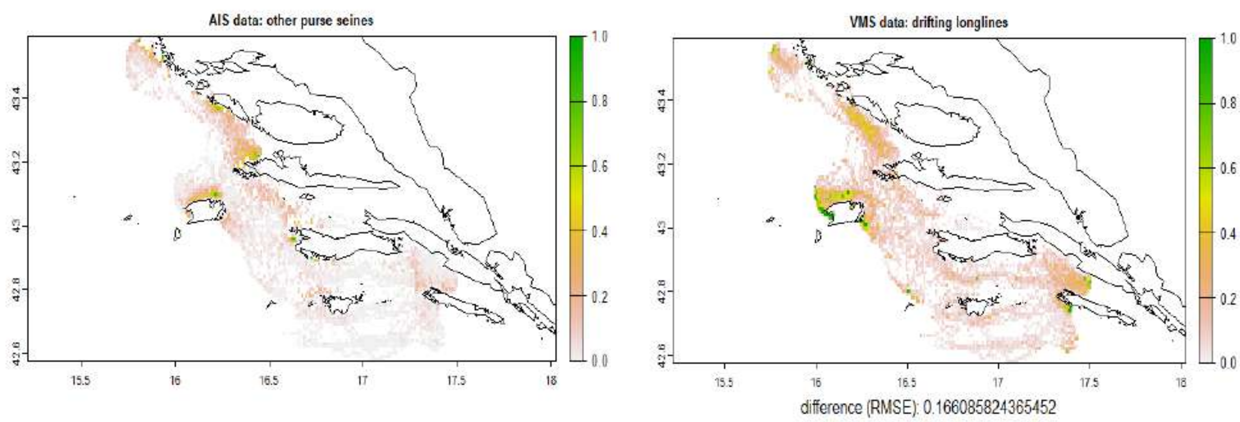


Figure 10: Comparison between AIS 'other purse seines' category and VMS drifting longlines raster

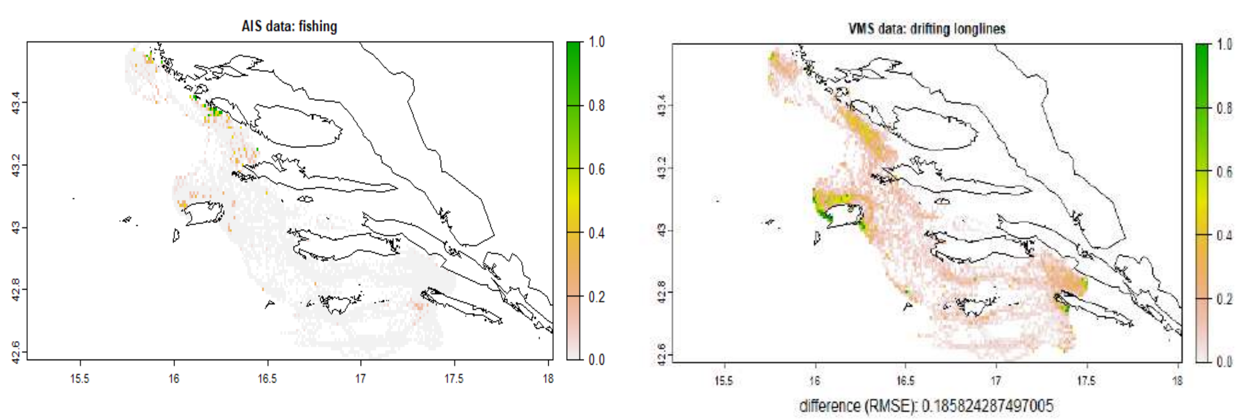


Figure 11: Comparison between AIS 'fishing' category and VMS drifting longlines raster

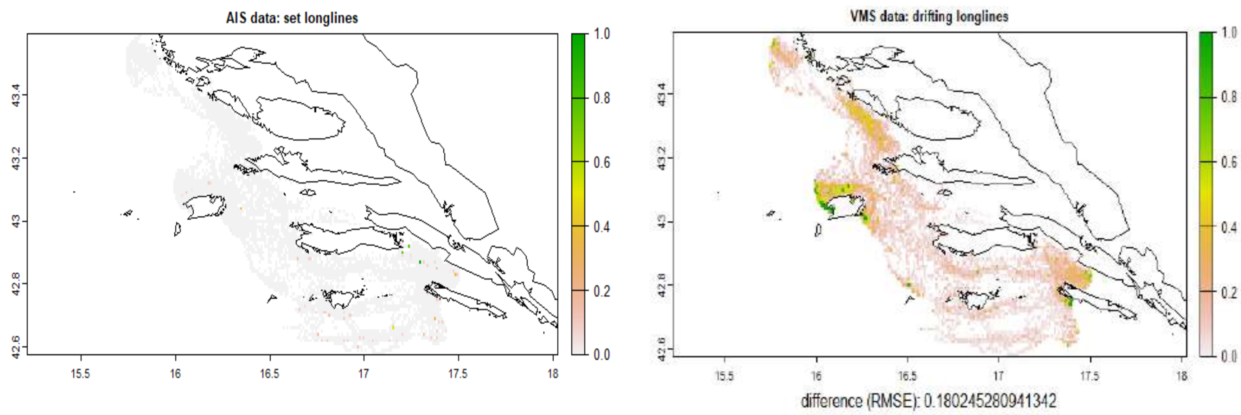


Figure 12: Comparison between AIS' set longlines' category and VMS drifting longlines raster

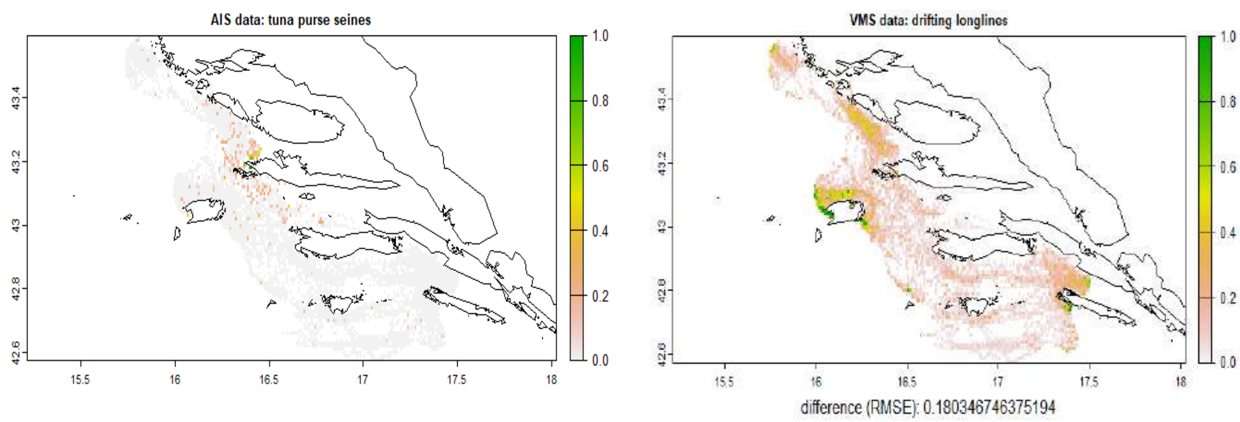


Figure 13: Comparison between AIS' tuna purse seines' category and VMS drifting longlines raster

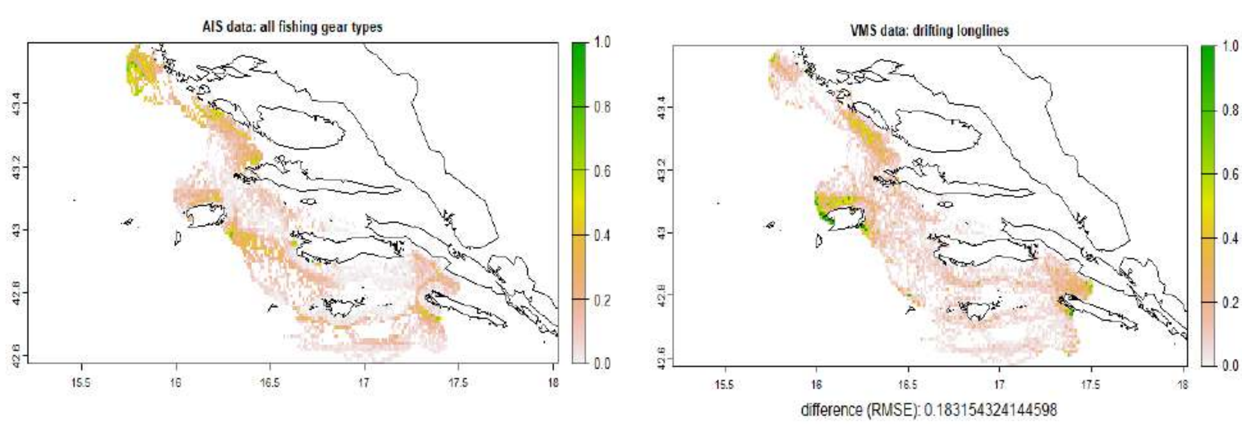


Figure 14: Comparison between AIS total fishing effort category and VMS drifting longlines raster

Based on this analysis, the most similar fishing gear type in the AIS dataset seems to be "other purse seines" (Figure 10, RMSE: 0.166), whereas the worst overlap is with "trawlers" (Figure 9, RMSE: 0.198). Other categories have RMSE values in between these two, but are categories with limited data available in general (fishing (Figure 11, RMSE: 0.185), set longlines (Figure 12, RMSE: 0.180) and tuna purse seines (Figure 13, RMSE: 0.180)). Finally, the normalized sum of all fishing gear types has an RMSE value of 0.183 (Figure 14), and reflects the notice that the overall fishing patterns in this area seem to be broadly similar across the entire range of different fishing gear types.

Risk maps

In order to combine the data into a map of elevated seabird bycatch risk, a product of the fishing effort and bird density rasters was calculated for each bird species. This effectively means that only the representative core areas will be assigned a risk value, with the relative bird density acting as a weighting factor – e.g. for a grid cell with a bird density of 0.5, the fishing effort would need to be twice as large to have the same risk value as a grid cell with a bird density of 1 (the highest value). The resulting rasters were down-sampled with bilinear interpolation to create more manageable areas and to smooth out the outlier grid cells (Figure 15).

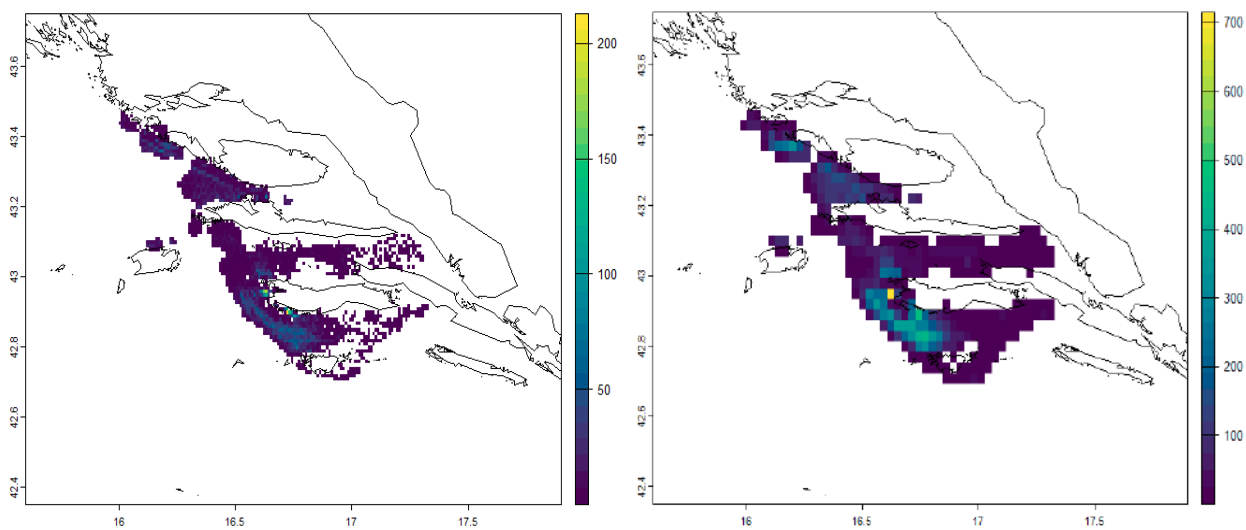


Figure 15: Example of down sampling to create more manageable areas and smoothen out the outer grid cells: 1/100 (left) vs 1/30 (right) degree resolution.

Results

Fishing effort inside and outside mIBAs

The fishing effort (based on the AIS data) across the Adriatic is shown in figure 16. Overall, the mean and average by area values seem to suggest that fishing effort is higher inside mIBAs than outside them.

	Incl. trawling		Excl. trawling	
measure	inside mIBA	outside mIBA	inside mIBA	outside mIBA
mean fishing effort by grid cell	**57.89256**	48.63380	**19.913044**	17.257806
median fishing effort by grid cell	18.52847	**27.98139**	**7.758472**	5.735138
average fishing effort per km^2	**49.75779**	44.60423	**13.407151**	11.521646

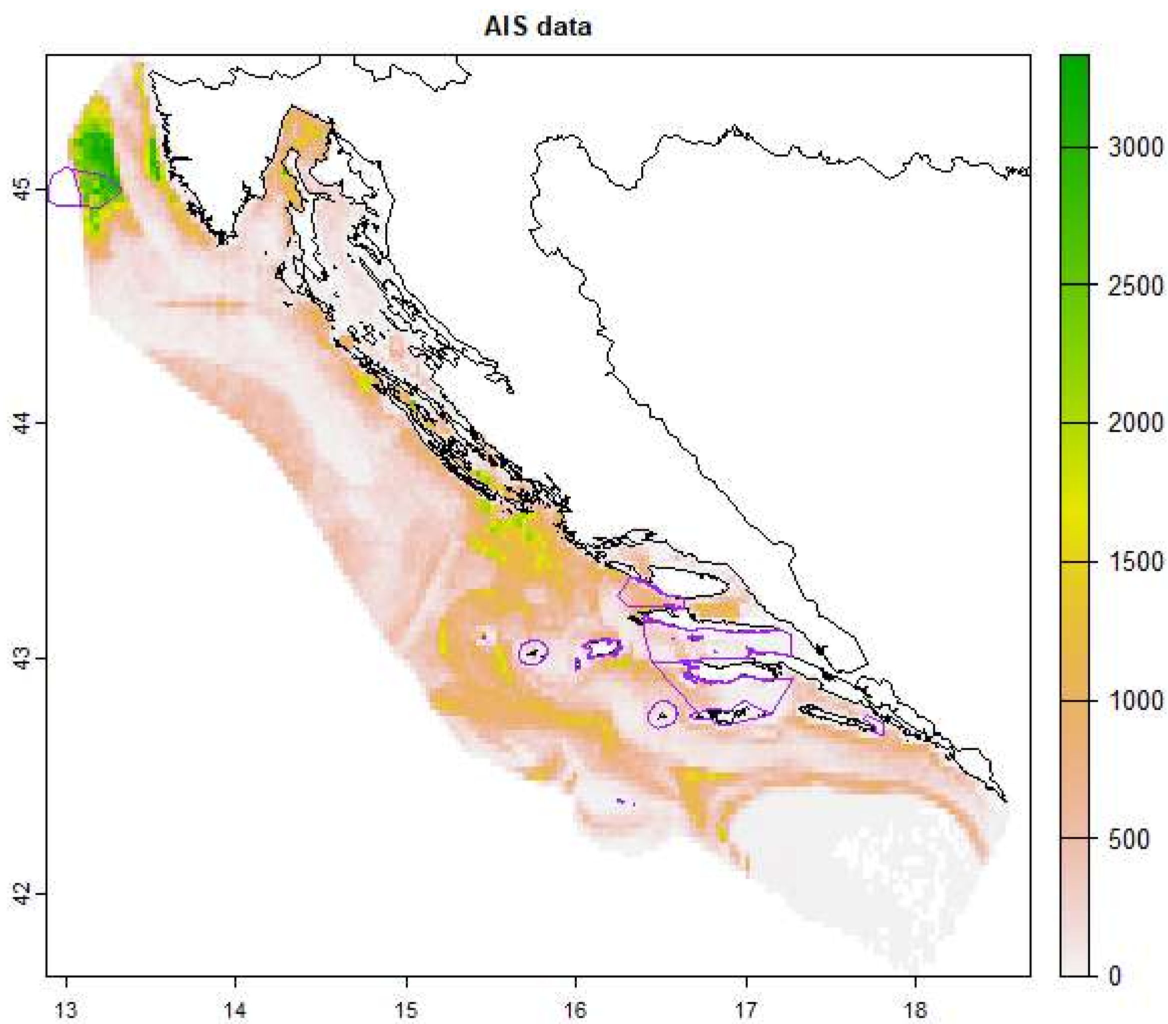


Figure 16: Estimated total fishing effort in the Adriatic based on the AIS data (1/30 degree resolution) with marine IBAs delineated in purple

When comparing the same measure of estimated fishing effort among the different mIBAs, Sjeverni Jadran seems to have considerably higher efforts than other mIBAs. However, when not taking into account trawling as a fishing method, the IBA with the highest fishing effort is Hvarski kanal, followed by Lastovski and Korčulanski kanal, while Sjeverni Jadran ends up at the bottom of the table.

mIBA name	Average effort per km^2 Incl. trawling	Average effort per km^2 Excl. trawling
Sjeverni Jadran HR	310.604213	2.784988
Hvarski kanal	72.041798	51.300784
Lastovski kanal	25.460646	10.337947
Korčulanski kanal	14.141411	11.350492
Pučinski otoci	12.232708	5.099200
Istočni dio Mljetskog kanal	7.603519	4.074679
Lastovsko otočje	6.040487	3.007170
Outside mIBAs	45.295850	11.521646

Bycatch risk

Yelkouan shearwater - The Northern Adriatic seems to be an important foraging site for Yelkouan shearwaters (Figure 6), with a high pressure from fishing (Figure 16), resulting in an elevated bycatch risk map as show in figure 17. This part of the Adriatic is very shallow (up to ~40 m depth) and trawling is the main fishing method here. Trawling poses unclear (and likely low) bycatch risk to Yelkouan shearwaters. While trawlers are reported to pose a threat to long-winged seabirds of the order of *Procellariiformes* (incl. albatrosses and shearwaters) in terms of collision risk with the warp and netsonde cables of these vessels (Løkkeberg 2011), such cables are not used by the smaller trawling vessels in the Adriatic (pers. comm Institut za Oceanografiju i Ribartsvo).

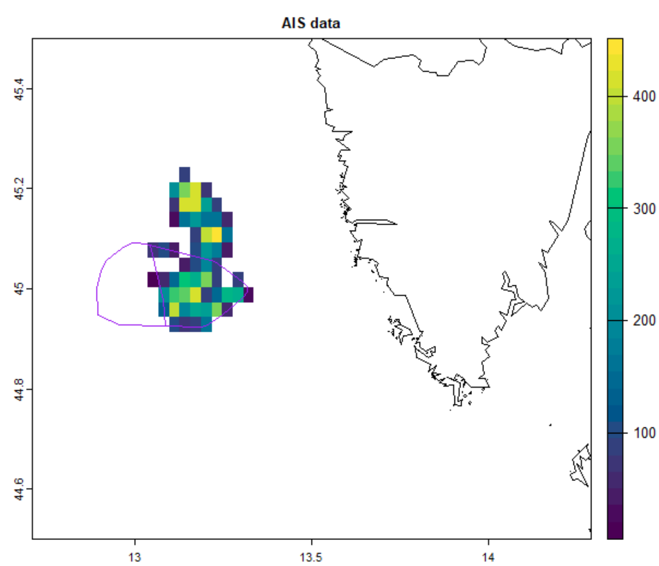


Figure 17: Elevated bycatch risk map for Yelkouan shearwater in the northern Adriatic, based on the AIS dataset (1/30 degree resolution).

In the Southern Adriatic, the bycatch risk for Yelkouan Shearwater based on the AIS dataset seems to be higher in the western part of the Lastovo channel, along the western tip of the island of Korčula, the western part of the Hvar channel and along the southern coast of the island of Šolta (Figure 18a). When applying the VMS data, it roughly highlights the same overall areas for elevated bycatch risk, but in the Lastovo channel the highest risk seems to have moved more towards the middle of the IBA (Figure 18b). Also, it should be noted that no VMS data was not made available for the eastern half of the Korčula channel (Figure 14).

The relatively high bycatch risk for Yelkouan shearwaters in the (west of the) Lastovo Channel IBA is also explained by the fact that the birds are tagged from islands around Lastovo, thus resulting in many movements to and from their colonies. Therefore, some of the bird densities might not be foraging birds, but rather rafting, or simply birds arriving to and departing from the colony. This aspect has not been considered for this explorative analysis.

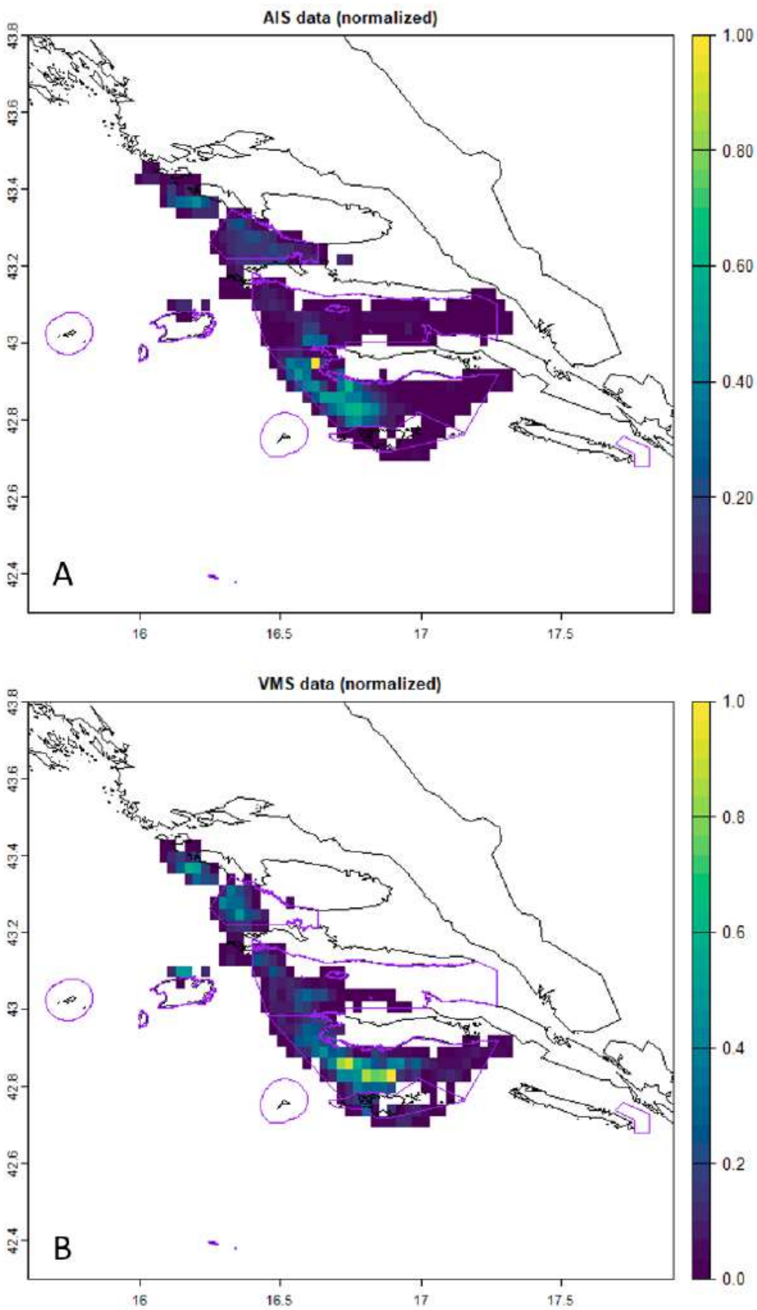


Figure 18: Elevated bycatch risk map for Yelkouan shearwater in the southern Adriatic, based on the AIS (A) and VMS (B) datasets (1/30 degree resolution).

Scopoli's shearwater – Whereas Yelkouan shearwaters seem to forage mostly around Lastovo and in areas to the north(west) from the archipelago, Scopoli's shearwater movements are more around Lastovo and towards the southeast (e.g. Mljet). Using the AIS dataset the highest bycatch risk for Scopoli's shearwaters seems to be to the northwest of Lastovo and along the western tip of Korčula (Figure 19a). Using VMS data, however, shows a more even distribution of elevated bycatch risk across the entire Lastovo channel, with the highest risk again more centrally located in the IBA (Figure 19b). It should also be noted that the VMS dataset does not cover one of the other important foraging sites for the species, namely the East Mljet Channel IBA (Figure 14).

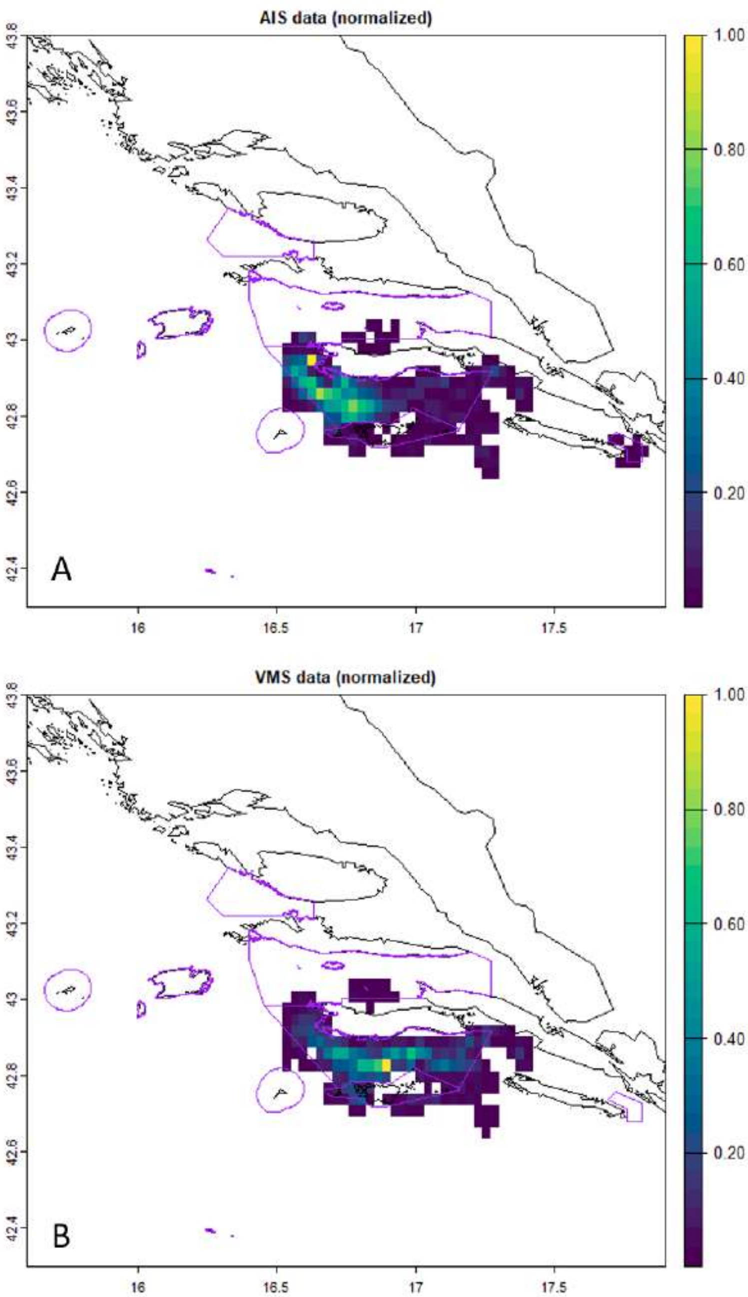


Figure 19: Elevated bycatch risk map for Scopoli's shearwater in the southern Adriatic, based on the AIS (A) and VMS (B) datasets (1/30 degree resolution).

Audouin's gull – Contrary to the two species of shearwater, Audouin's gull is not as pelagic in its habits, but rather stays closer to the coastline and their breeding colonies. Their core areas are more restricted (Figure 6), and as a result their bycatch risk results show similarly restricted areas. Both the AIS and VMS datasets highlight bycatch risk around Lastovo (with a focus on the west in the AIS dataset, and a focus on the southeast in the VMS dataset) and to the west of Mljet (Figure 20a & b). The AIS data also shows an elevated bycatch risk for Audouin's gull at the western tip of the Pelješac peninsula, but this area is not covered by the VMS dataset (Figure 14).

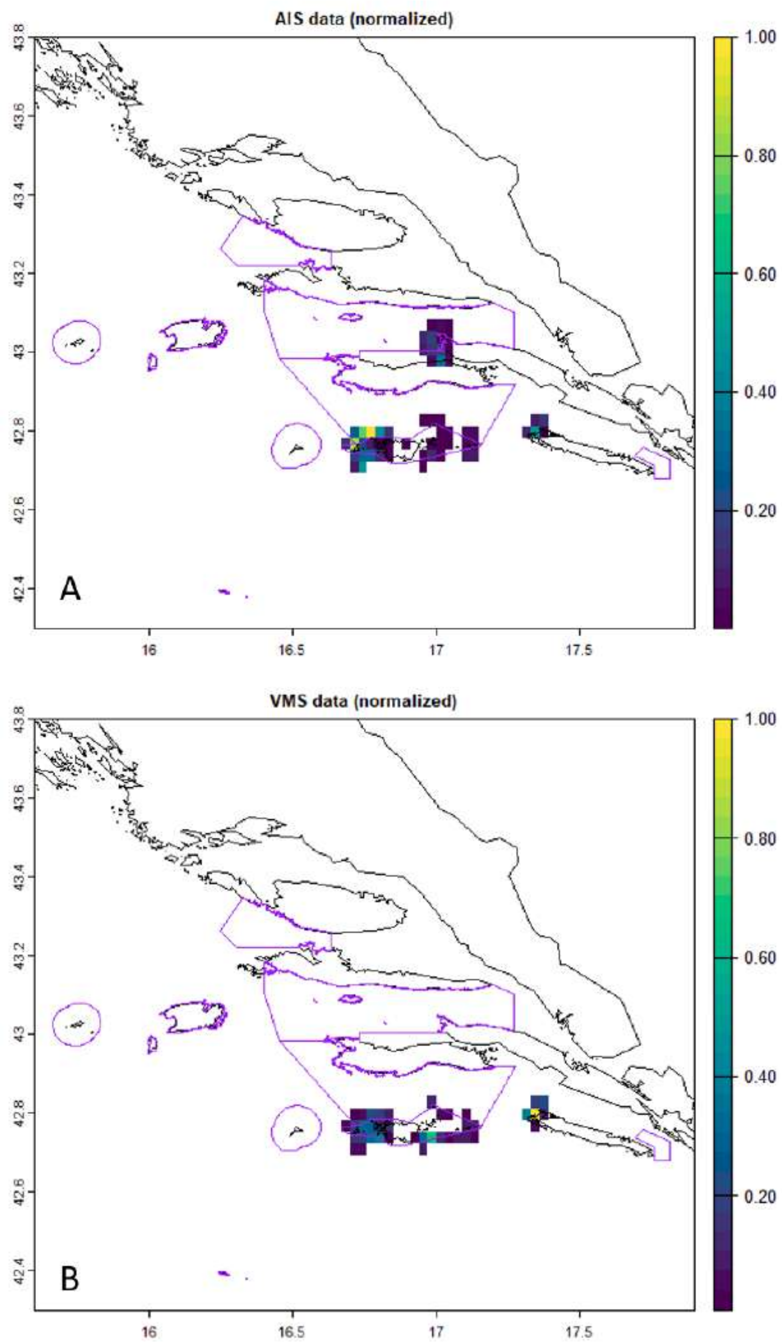


Figure 20: Elevated bycatch risk map for Audouin's gull in the southern Adriatic, based on the AIS (A) and VMS (B) datasets (1/30 degree resolution).

Assumptions and limitations

It is important to realize that this approach includes some limitations which are important to keep in mind when interpreting the results. As mentioned earlier in the report, both the AIS and available VMS data have their limitations. AIS data is usually biased to larger vessels (only vessels above 15m are obliged to have AIS) whereas the vast majority of the Adriatic fleet consists of smaller, artisanal vessels. Then again, the provided VMS data, besides being geographically limited, only includes the drifting longline data of a few years (for a max of 15 vessels, of which 8 are working only in external waters – pers. comm. IZOR). While comprehensive VMS data could be more representative for the fishing situation in the Adriatic, the system is not enforced, it can be turned off easily, and it may reflect the wrong fishing method (as small vessel fisheries often have a mix of fishing methods on board, not necessarily only the one they are registered for – pers. comm IZOR)**.**

For now, inside the area where data was available for all fishing gear types (VMS for longline data and AIS for everything else), the patterns in fishing effort seem to be broadly similar, which suggests that AIS fishing effort data can generally be thought of as a reasonable measure of overall fishing effort, even given its inherent limitations.

Apart from the fisheries data, a few notes should be made regarding the seabird density data as well. Firstly, seabird movement data was collected only from seabird colonies around Lastovo. While in general these colonies are representative for the respective Croatian populations of each of the three seabird species, shearwater movement data is missing from some of the largest colonies out there, namely Sušac, Svetac and Palagruža. This probably also explains why no elevated seabird bycatch risk is observed around those islands in this analysis. When shearwaters from these colonies would be tagged, it would increase the number of bird tracks visiting and leaving the colonies (as seen in the current dataset as well), and thus increase the bird density in these areas. A second point, related to this, is that currently the bird density data does not try to distinguish the behavior of the birds in a given place. One could argue that bycatch risk is higher in places with active foraging or rafting behavior, rather than in places where birds just travel. The movement data would need to be analyzed more in detail to see if this can be further refined. Finally, no distinction was made based on the conservation status of the species (e.g. the global IUCN red list status of "VU-Vulnerable" for Yelkouan shearwater and Audouin's gull, and "LC-Least Concern" for Scopoli's shearwater). An arbitrary choice of weighing factor could be made to reflect this difference in the final risk map.

As the elevated seabird bycatch risk is calculated including both the fishing effort and the seabird density data, it is obvious that changing either can impact the calculations. Nevertheless, given the available data, this report provides the best approximation of elevated bycatch risk in the Adriatic for Yelkouan and Scopoli's shearwater and Audouin's gull.

Conclusions

1. Fishing effort from the GFW AIS-based dataset follows the same broad activity patterns as VMS data for drifting longlines. In the absence of more comprehensive VMS data for an array of fishing activities, the AIS-based fishing effort is a reasonable approximation of total fishing effort.
2. Overall, the fishing effort within marine IBAs seems to be on average higher than outside them (i.e. in non-mIBA areas of the Croatian Adriatic) when taking total area into account.
3. For the channel IBAs of Lastovo, Korčula and Hvar, the western parts of the IBAs seem to be under more pressure from fishing activity than the eastern parts.
4. A considerable spatial overlap exists between high fishing effort areas as defined by AIS data and areas actively used by seabirds during breeding season, and a risk of seabird bycatch in these areas cannot be ruled out. Further refinements should be based on a more detailed understanding of the risk that different fishing gear types pose to seabirds, try to distinguish different bird behaviors, possibly account for bird conservation status and preferably include both AIS and more comprehensive VMS data.

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