



Extensive Use of Habitat-Damaging Fishing Gears Inside Habitat-Protecting Marine Protected Areas

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Marine protected areas (MPAs) are critical for halting marine biodiversity loss and safeguarding ecosystems. However, efforts to designate additional areas as MPAs have generally taken precedence over ensuring that designated sites are effectively protected. Serious concerns exist about marine “paper parks” in Europe, particularly in relation to the threat of fishing. We focussed on 1,945 MPAs in EU and UK waters that are designated to protect habitats, and assessed the extent of fishing inside them with gears that are known to directly threaten those same habitats. Such “high-risk” fishing was widespread, occurring within 510 MPAs that represented 86% of the area assessed, and was more prevalent in larger, offshore sites. More intense high-risk fishing inside reef and sandbank MPAs was associated with the poorer conservation status of those habitats in countries’ waters. Our findings indicate that without systematic restrictions on damaging fishing gears, MPAs are unlikely to help reverse the ongoing declines of European marine habitats.

Keywords: destructive fishing, fisheries management, fishing impacts, marine habitats, marine protected areas, paper parks, whole-site approach

INTRODUCTION

In the face of severe human pressure on the marine environment, marine protected areas (MPAs) are a critical tool for safeguarding biodiversity and maintaining and recovering ecosystems. During the past decade, efforts to expand MPA networks have been partly driven by global targets, particularly the aim of conserving at least 10% of coastal and marine areas by 2020, as agreed under the United Nations Convention on Biological Diversity (CBD) and Sustainable Development Goal 14 (Convention on Biological Diversity [CBD], 2013; United Nations, 2015). The need to protect significantly more marine area (O’Leary et al., 2016) has gained political recognition in the lead-up to the adoption of a post-2020 global biodiversity framework, with nearly 70 countries making commitments to protect at least 30% of the ocean by 2030 (High Ambition Coalition for Nature and People, 2021).

These targets are important for setting the course for action, yet have inadvertently led to a “race to designate” in which a critical aspect of the CBD and Sustainable Development Goal 14 targets has been ignored: neither target is about designation only, but instead call for MPAs that deliver effective conservation (Convention on Biological Diversity [CBD], 2013; United Nations, 2015). In the process towards achieving spatial protection, designation is merely one step (Sala et al., 2018). Without effective management, designated MPAs remain “paper parks” that provide little to no real protection, while creating a false impression of success.

The gap between designated and effective MPAs is increasingly apparent in Europe. In 2018, the European Union (which then included the United Kingdom) announced that it had met its international commitments ahead of the 2020 deadline, by designating 10.8% of its marine area as MPAs (European Commission [EC], 2018). Recent studies, however, have highlighted serious management failings associated with European MPAs (WWF, 2019; Claudet et al., 2020; Perry et al., 2020). Particular concerns have been raised about the impacts of fishing (European Environment Agency [EEA], 2019a), one of the most widespread threats reported within MPAs in Europe (Mazaris et al., 2019). For example, commercial trawling has been documented in 59% of Atlantic and Baltic Sea MPAs (Dureuil et al., 2018). Overall, European MPAs have failed to provide real protection (European Court of Auditors, 2020), and most protected marine habitats and species are of poor or unknown conservation status (European Environment Agency [EEA], 2020).

Most MPAs in the EU and UK are designated for individual features (i.e., species and/or habitats), which has given rise to a management approach that aims to avoid direct impacts only on those designated features, rather than a “whole-site” approach that considers the ecological integrity of MPAs (Rees et al., 2013; Solandt et al., 2020). To evaluate the effectiveness of European MPAs, it is important to understand whether they provide even this minimal level of feature-based protection. Here, we address this question by focusing on one of the most significant threats to marine ecosystems in Europe: fishing with habitat-damaging gears (European Environment Agency [EEA], 2019a). The impacts of such gears on benthic ecosystems have been widely documented, and include direct physical damage to the seabed and biogenic structures, reductions in biomass and species richness, and broadscale changes in ecosystem structure and function (Hall, 1999; Collie et al., 2000; Hall-Spencer and Moore, 2000; Jennings et al., 2001; Hall-Spencer et al., 2002; Sampaio et al., 2012; Eigaard et al., 2015; Eggleton et al., 2018). Studies within European MPAs have further highlighted specific examples of fisheries damage to vulnerable habitats (see **Table 1**), and also demonstrated their recovery following the cessation of damaging fishing activities (e.g., Guillén et al., 1994; Sheehan et al., 2013).

Specifically, we assess the extent, inside 1945 EU and UK MPAs that are designated for habitat protection, of “high-risk” fishing activities: fishing with gear types that are known to pose a direct threat to those specific habitats. We examine whether the intensity of high-risk fishing differs according to MPA distance from the coast or the habitats for which sites are designated. We also explore whether more intense high-risk fishing is associated with poorer conservation status of protected habitats in European waters.

MATERIALS AND METHODS

Selection of Sites

We focused on the largest network of European MPAs (the Natura 2000 network), which accounts for nearly 70% of the

protected marine area in the EU and the United Kingdom. Specifically, we selected those Natura 2000 MPAs that are designated (solely or partially) for the protection of marine habitats, under the EU Habitats Directive (Council Directive 92/43/EEC). Considering only these MPAs allowed for clearer comparisons across habitat types and sites, because they have been designated under a consistent legal framework.

We first identified MPAs within the Natura 2000 network, applying the method used by the European Environment Agency (European Environment Agency [EEA], 2015). As there is no official list of Natura 2000 MPAs, this method draws on complementary data sources that describe the network: tabular data detailing the characteristics of all Natura 2000 sites (both terrestrial and marine), and spatial data depicting their boundaries (European Environment Agency [EEA], 2019b). Using data reported to the European Commission by Member States at the end of 2018, we identified 2,090 sites within the tabular data that were designated under the Habitats Directive and included marine habitats as designated features (unlike the EEA, we included sites with coastal lagoons, on the basis of the species and habitats that they support). From the spatial data, we identified 3,967 sites with area lying seaward of the coastline (European Environment Agency [EEA], 2018). Finally, we combined the tabular and spatial data, and selected sites which could be identified as MPAs according to both datasets. The resulting 1,945 MPAs were located across the waters of all 23 countries (22 EU Member States and the United Kingdom) within the Natura 2000 MPA network. They comprised both types of sites designated under the Habitats Directive: Sites of Community Importance and Special Areas of Conservation. Countries are legally required to avoid the deterioration of designated habitats within these sites.

All spatial data analyses were performed using ArcGIS Pro 2.6.0 (Environmental Systems Research Institute, 2020).

High-Risk Fishing Activities

To quantify and assess fishing activities, we used data from Global Fishing Watch¹ (GFW), a free online tool that uses public broadcast data from an automatic identification system (AIS), collected by satellite and terrestrial receivers, to show the movement of fishing vessels over time. GFW applies a convolutional neural network algorithm to this global feed of AIS data to differentiate apparent fishing activity from non-fishing (i.e., transiting) activity, based on parameters such as speed, direction, and rate of turn (Kroodsma et al., 2018).

We obtained GFW data describing fishing activities in EU waters (including the United Kingdom) between January and December 2018. These data comprised 67,981,179 points corresponding to vessel locations during apparent fishing activities. We confirmed active vessels from the EU by matching International Radio Call Signs and Community Fishing Fleet Register numbers to the EU Fleet Register (European Commission [EC], n.d.-a). We cross-checked data from GFW with fishing gear information from the EU Fleet Register, and classified vessels according to their primary gear types. These

¹www.globalfishingwatch.org

TABLE 1 | Examples of documented cases of fisheries damage to vulnerable seabed habitats inside European marine protected areas (MPAs).

Country	MPA	Habitat	Fishing gear type(s)	Damage	References
Denmark	Logstør Bredning, Vejlerne og Bulbjerg	Reefs	Dredge	Macrofaunal depletion in mussel beds	Bromhall et al., 2022
Italy	Portofino	Reefs	Handline Longline Trammel net	Dead and damaged gorgonian colonies	Betti et al., 2020
Netherlands	Klaverbank	Reefs	Dredge Bottom trawl	Bottom disturbance, damage to epifauna	Jager et al., 2018
Portugal	Parque Marinho Professor Luiz Saldanha	<i>Zostera</i> meadows	Dredge Bottom trawl	Decline and disappearance of seagrass meadows	Cunha et al., 2013
Spain	Reserva Marina Isla de Tabarca	<i>Posidonia</i> meadows	Bottom trawl	Decline and disappearance of seagrass meadows	Guillén et al., 1994
United Kingdom	Strangford Lough	Reefs	Dredge Bottom trawl	Decline in horse mussel reefs and associated taxa	Strain et al., 2012

data provided a conservative estimate of fishing effort, as they only included those vessels that transmitted AIS signals. EU law requires AIS for vessels over 15 m length (Council Regulation (EC) No 1224/2009), meaning that AIS data are not complete for vessels below that length, which represent a large proportion of the fleet in certain regions (such as the Baltic and Mediterranean Seas), particularly in coastal areas.

We then applied a matrix of potential vulnerability of Natura 2000 habitats to different fishing methods (The N2K Group – European Economic Interest Group, 2014) to the GFW data. Using GIS, we identified “high-risk” fishing activities within each MPA: those interactions between the nine marine habitat types that are designated features of sites (Boreal Baltic narrow inlets, coastal lagoons, estuaries, large shallow inlets/bays, mudflats and sandflats, *Posidonia* beds, reefs, sandbanks, and submarine structures made by leaking gases) and gear types to which those habitats are highly vulnerable (**Supplementary Table 1**). We calculated the total number of hours apparently spent by vessels engaged in high-risk fishing during 2018, to estimate annual high-risk fishing effort per habitat type and per MPA. We then standardised these estimates to allow comparisons among MPAs; we divided annual high-risk fishing effort by MPA area, to yield annual intensities of high-risk fishing (h/km²).

Status of Protected Habitats

We compiled data about the conservation status of marine habitats listed in the Habitats Directive, as submitted to the European Commission by EU Member States and the United Kingdom (European Environment Information and Observation Network, 2020). These data covered the most recent reporting period (from 2013 to 2018), for the nine habitat types for which high-risk fishing was identified. Within these assessments, the conservation status of each habitat type was categorised as “favourable,” “unfavourable-inadequate,” or “unfavourable-bad,” for each marine region (i.e., Atlantic, Baltic, Black Sea, Macaronesia, and Mediterranean) within the entire territory of each country. For most countries, the assessments covered the entirety of national waters; in seven countries with waters in multiple marine regions (Denmark, France, Germany,

Portugal, Spain, Sweden, and the United Kingdom), separate assessments were available for each region. For clarity, we refer to each spatial reporting unit as an “assessment area.”

Statistical Analyses

We used *t*-tests to explore variation in MPAs with and without high-risk fishing; specifically, we compared log-transformed areas and $\log(x + 1)$ -transformed distances from the coast between these two groups of sites. We then used chi-square goodness-of-fit tests to compare the observed number and proportion of MPAs designated for each habitat type that were subject to high-risk fishing to the expected number (calculated from the overall proportion of sites designated for each habitat type) and the expected proportion (calculated assuming no differences among designated habitat types in the proportion of sites affected) of MPAs, respectively.

We explored the broader impacts of high-risk fishing on protected habitats by assessing, for each habitat type, whether intensities of high-risk fishing inside MPAs differed among assessment areas categorised as “favourable,” “unfavourable-inadequate,” or “unfavourable-bad.” We tested for these differences among conservation status categories with one-way ANOVA on the $\log(x + 1)$ -transformed intensity of fishing inside MPAs, averaged at the scale of assessment areas, followed by Tukey HSD *post-hoc* tests.

All statistical analyses were carried out using the programme SPSS (IBM Corp, 2020).

RESULTS

During 2018, a total of 1,011,473.1 h of high-risk fishing occurred inside Natura 2000 MPAs that are designated for marine habitat protection (**Table 2**). These fishing activities took place in the waters of all 23 countries within the Natura 2000 MPA network (**Figure 1**). Of the MPAs assessed, 510 (26%) were subject to high-risk fishing. These sites represented 86% of the 384,000 km² of total area designated for habitat protection.

MPAs with high-risk fishing were significantly larger [mean area ($\pm 95\%$ CIs) = 87.46 km² (73.64–103.87 km²)] than those without high-risk fishing [mean area ($\pm 95\%$ CIs) = 1.89 km²

TABLE 2 | Summary, by country, of Natura 2000 marine protected areas (MPAs) designated for habitat protection under the EU Habitats Directive, and annual high-risk fishing activity inside those MPAs during 2018.

Country	MPAs designated for habitat protection	Area of MPAs designated for habitat protection (km ²)	Total annual high-risk fishing effort inside MPAs (h)	Average annual high-risk fishing intensity inside MPAs (h/km ²)	Vessels using high-risk gear inside MPAs
Belgium	4	1,127.2	31,760.0	15.164	99
Bulgaria	18	2,488.5	1,628.1	0.157	16
Croatia	215	2,614.4	1,744.5	0.156	35
Cyprus	7	124.6	26.6	0.181	3
Denmark	92	16,380.4	105,958.3	1.779	498
Estonia	42	3,858.0	198.6	0.022	6
Finland	121	7,599.1	309.8	0.022	5
France	162	97,518.9	361,731.3	1.506	1,033
Germany	72	20,940.6	104,709.6	0.995	448
Greece	68	13,569.7	6,185.6	0.141	71
Ireland	96	9,028.3	4,896.3	0.539	124
Italy	336	5,733.0	4,528.5	0.547	322
Latvia	11	2,071.7	286.8	0.052	3
Lithuania	5	928.5	1,219.8	1.024	16
Malta	15	2,281.2	617.5	0.283	58
Netherlands	11	11,953.1	244,592.9	20.140	420
Poland	15	4,339.7	1,065.9	0.044	47
Portugal	13	23,601.0	972.8	0.072	36
Romania	9	5,912.2	47.6	0.002	2
Slovenia	8	4.3	1.9	0.637	1
Spain	210	54,680.3	64,848.3	0.575	459
Sweden	300	19,903.7	36,168.7	0.268	255
United Kingdom	115	66,945.1	37,973.3	0.835	586
Total	1,945	373,603.4	1,011,473.1	0.700	3,490

For each country, average high-risk fishing intensity inside MPAs is calculated as the average of high-risk fishing intensities (fishing effort/area) for all MPAs (Supplementary Figure 2).

(1.65–2.17 km²) (independent *t*-test: $t_{1182.91} = -34.32$, $P < 0.001$; Supplementary Figure 1). Eighty-two percent of MPAs without high-risk fishing were smaller than 20 km², which is the minimum size that is typically recommended in Europe for MPA effectiveness (Wolters et al., 2015). Sites with high-risk fishing were also located further from shore [mean distance ($\pm 95\%$ CIs) = 7.97 km (5.35–11.65 km)] than those without high-risk fishing [mean distance ($\pm 95\%$ CIs) = 0.46 km (0.34–0.59 km)] (independent *t*-test: $t_{573.32} = -10.04$, $P < 0.001$; Supplementary Figure 1).

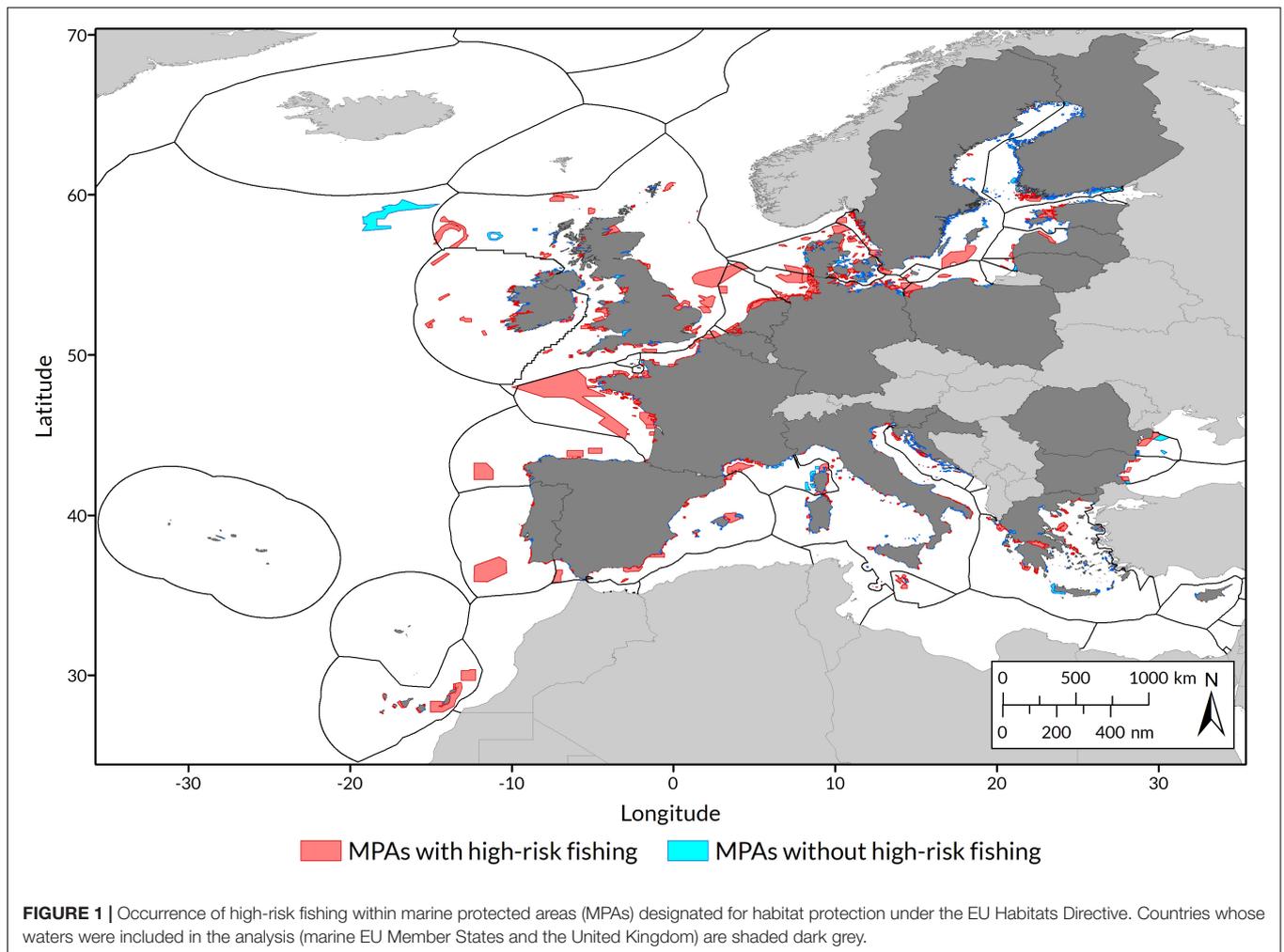
The threat of high-risk fishing inside MPAs was not equal across protected habitat types, in terms of the number of MPAs affected ($\chi^2 = 357.60$, $df = 8$, $P < 0.001$; Figure 2). High-risk fishing was most prevalent in MPAs designated for reefs ($n = 417$), sandbanks ($n = 256$), and *Posidonia* beds ($n = 134$). Proportionately, high-risk fishing was most common in sites designated to protect submarine structures made by leaking gases, occurring inside 70% of those MPAs ($n = 19$) that are intended to protect this fragile habitat type ($\chi^2 = 128.65$, $df = 8$, $P < 0.001$).

Differences in high-risk fishing intensity relative to conservation status could be assessed for eight of the nine habitat types associated with high-risk fishing; Boreal Baltic narrow inlets were excluded due to small sample size. For reefs

and sandbanks, intensities of high-risk fishing within MPAs were higher in assessment areas with poorer conservation status (reefs: $F_{2, 24} = 4.0$, $P = 0.03$; sandbanks: $F_{2, 19} = 5.6$, $P = 0.012$). For both habitat types, high-risk fishing intensity inside MPAs was significantly higher in assessment areas categorised as “unfavourable-bad” than in those categorised as “favourable” (Figure 3). For the remaining six habitat types, high-risk fishing intensity did not differ significantly according to conservation status (Supplementary Table 2).

DISCUSSION

Extensive areas of the European seabed are exposed to damaging fishing gears (European Environment Agency [EEA], 2019a), and even within MPAs, fishing represents the main pressure on seabed habitats (Aronsson et al., 2015). Our analysis revealed that the use of habitat-damaging fishing gears is pervasive across EU and UK MPAs that are intended to protect marine habitats. We identified 510 MPAs (representing 86% of the area of sites assessed) that were designated for the protection of habitats yet permitted fishing activities that pose a recognised threat to those very habitats. Such high-risk fishing was more common in larger, offshore sites, as well as within MPAs designated



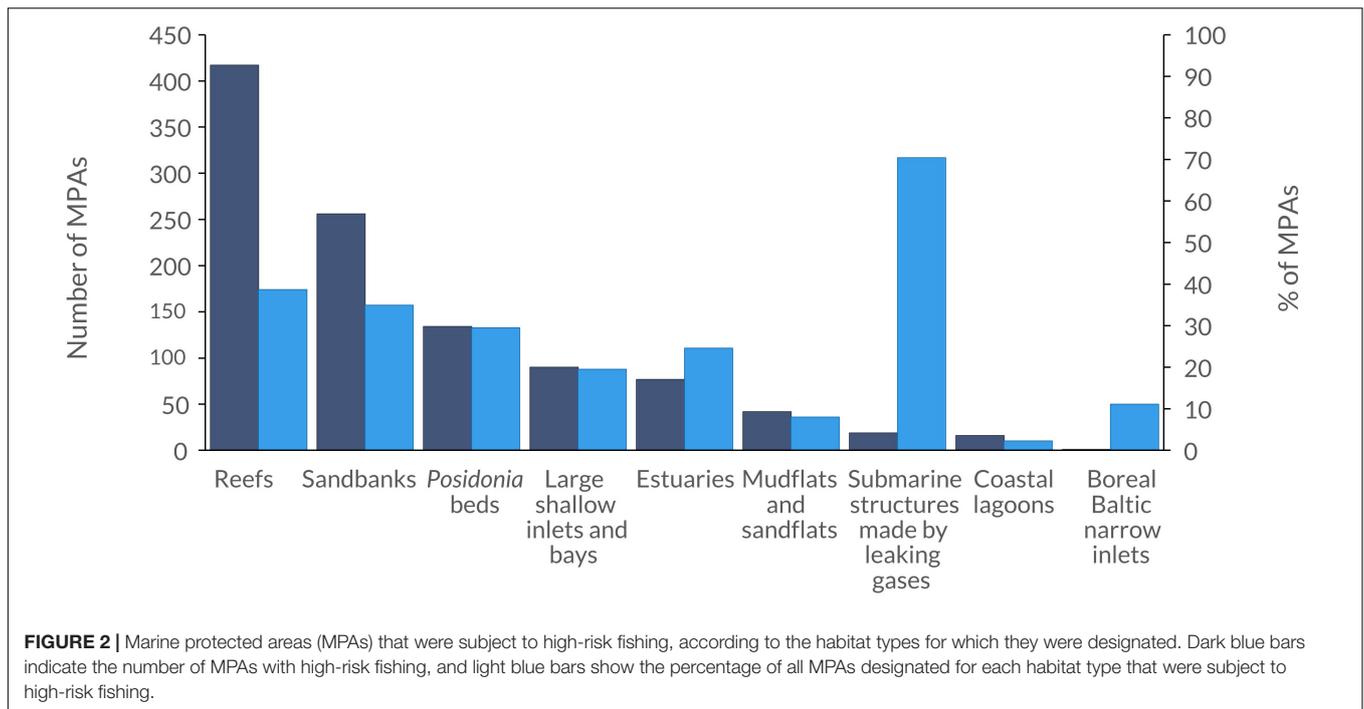
for the protection of reefs, sandbanks, and *Posidonia* beds. For reefs and sandbanks, more intense high-risk fishing inside MPAs was associated with poorer conservation status within countries' waters.

These results indicate that without a radical shift in approach to fisheries management, MPAs are unlikely to help reverse the ongoing decline of marine habitats (European Environment Agency [EEA], 2020). We documented high-risk fishing inside habitat-protecting MPAs of all 23 countries within the Natura 2000 MPA network, which suggests that weaknesses in fisheries management are systemic and thus require a regional-scale response. Our findings add to previous concerns raised that some of the most damaging fishing gears (i.e., bottom trawls) are used more intensively inside some European MPAs than in unprotected waters (Dureuil et al., 2018).

The prevalence of high-risk fishing in larger, offshore MPAs partly reflects the nature of the fisheries management framework for MPAs under the EU Common Fisheries Policy (Regulation (EU) No 1380/2013). EU Member States may unilaterally establish fisheries management measures within some of their MPAs, such as sites that are inshore (i.e., located within the 12 nautical mile zone) or those not fished by other Member

States. However, measures for offshore sites that are subject to multiple fishing interests must be proposed through a "joint recommendation" from the countries concerned. To date, countries have shown limited engagement in this process. Since 2015, only six joint recommendations have been adopted, covering 19 MPAs in two countries, out of 118 offshore MPAs that have been designated under the Habitats Directive (European Commission [EC], n.d.-b). The process has been further criticised for its ineffectiveness, as damaging activities continue during protracted negotiations that often result in weaker restrictions than those that were initially proposed (European Court of Auditors, 2020).

Elevated pressure on offshore MPAs was also apparent in the greater incidence of high-risk fishing on all three designated habitat types found in offshore waters: reefs, sandbanks, and submarine structures formed by leaking gases. For both reefs and sandbanks, more intense high-risk fishing inside MPAs was associated more broadly with poorer conservation status in EU and UK waters. This could reflect the fact that habitat status may be more directly linked to levels of fishing pressure in offshore waters, where other threats are less pronounced than in coastal areas (European Environment Agency [EEA], 2019a;

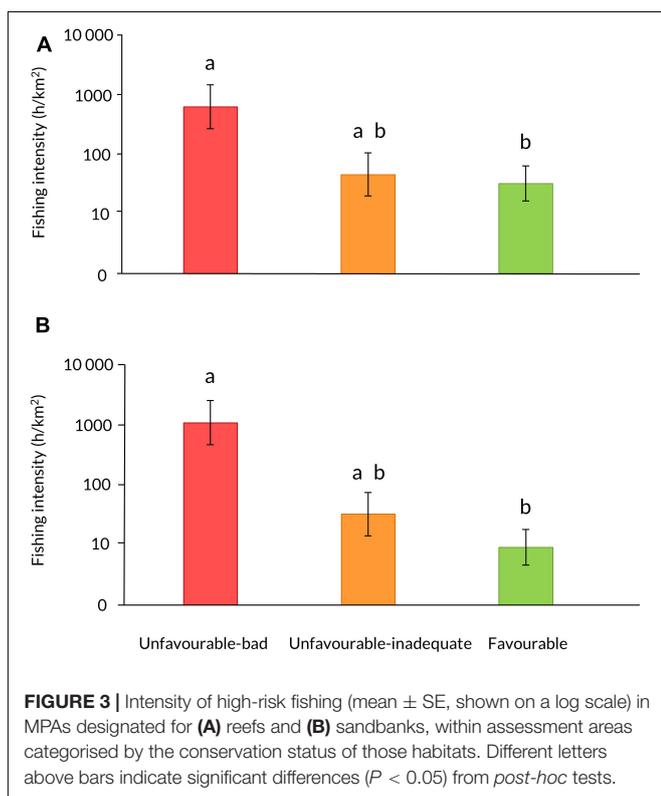


Korpinen et al., 2019). It may also relate to sites being designated because they represent the most extensive or best conserved examples of features (European Commission [EC], 2007). If habitats inside such MPAs experience damaging fishing, it is

unsurprising that the impacts are visible in terms of overall conservation status, particularly if fishing intensity inside MPAs is also indicative of fishing pressure in unprotected areas.

The greater observed incidence of high-risk fishing in larger, offshore sites may also partly relate to limitations in the fishing effort data used. Because AIS is only legally required for EU fishing vessels over 15 m length, AIS data provide a better indication of the fishing activity of larger vessels. Such vessels can fish further offshore, where larger MPAs also tend to be located (Figure 1). Despite this limitation, our main finding remains unchanged: habitat-damaging fishing gears are widely used across the largest network of European MPAs that are meant to protect benthic habitats. Unfortunately, comprehensive spatial data describing the fishing effort of small-scale vessels are not available at the scale of our analyses. These gaps in coverage of fishing effort data for smaller vessels mean that we are likely to have underestimated the real extent of high-risk fishing inside MPAs, particularly for coastal areas and the habitats associated with them, such as coastal lagoons, estuaries, and *Posidonia* beds.

It is worth noting that we considered high-risk fishing activities inside MPAs that are designated to protect specific habitats, but that this does not imply that high-risk fishing gears are necessarily being used directly over those habitats. Fishing activities may be concentrated in particular areas or habitats inside MPAs, and some sites may be managed through zonation-based approaches that restrict the use of certain gears where specific features are known to occur. However, it was not possible to examine fishing-habitat interactions at a finer resolution (i.e., within individual sites), because detailed habitat maps are lacking, incomplete, or not publicly available for many Natura 2000 MPAs (EMODnet, 2021). Nevertheless, our findings indicate that the use of high-risk fishing gears is likely



to directly contravene the conservation aims of MPAs, either because fisheries management measures are absent, or because such measures restrict fishing only in the precise locations where designated features have been mapped and therefore provide no protection to designated features that have not been sufficiently documented, or to other features within sites. The latter is an inherent weakness of feature-based MPA management, which ignores the ecological integrity of sites (Rees et al., 2013). This approach is also detrimental to any restoration possibilities of sites, another objective of the Natura 2000 network, as continuous high-risk fishing may prevent the regeneration of protected habitats beyond their existing distributions. In addition, allowing certain types of high-risk fishing (e.g., bottom trawling) around mapped features may also limit their potential restoration and expansion, because of the associated resuspension and displacement of sediments, organic materials, and contaminants over large distances underwater (Daly et al., 2018; Linders et al., 2018). More broadly, such disturbance of seafloor sediments—which represent a critical store of organic carbon—also raises concerns about the impacts on the global carbon sink (Cavan and Hill, 2022) and the reduced capacity of weakly protected MPAs to help mitigate climate change (Atwood et al., 2020).

Our findings provide compelling evidence that European MPAs are failing to curb the use of damaging fishing gears on protected habitats. As such, they also strongly indicate that countries are failing to meet their legal obligations to avoid habitat deterioration within sites. The EU and the UK have recognised the vital role of MPAs in halting marine biodiversity loss, committing to 30% marine protection by 2030, including the designation of strictly protected areas (Department for Environment, Food and Rural Affairs et al., 2018; European Commission [EC], 2020). However, the expansion of MPA networks must be matched with equally ambitious policies to strengthen management, to ensure that both existing and new MPAs provide actual protection.

In relation to fisheries, we argue that redressing MPA management failings requires a drastically scaled-up approach. First, countries should adopt a “whole-site” approach to MPA management, to better conserve and recover designated features while safeguarding ecosystem processes and functions (Solandt et al., 2020; Pikesley et al., 2021). This would involve establishing broader restrictions on fishing activities that contravene MPA conservation aims, rather than limitations only precisely where designated features have been identified. Second, a systematic “whole-network” approach is also required, to go beyond inconsistent site-specific measures, and recognise that damaging gears are fundamentally incompatible with MPA objectives. Detailed assessments of the highest-risk interactions between specific gears and conservation features

(e.g., Marine Management Organisation, 2014; The N2K Group – European Economic Interest Group, 2014) provide a clear basis for adopting such network-wide restrictions (Clark et al., 2017), which would allow the much swifter introduction of fisheries management measures than current site-by-site approaches, ensure consistency across sites, and facilitate monitoring and enforcement. The alternative—continuing with minimal, patchy management of damaging fishing inside MPAs—risks leaving Europe as a global leader in the creation of marine paper parks.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analysed in this study. The Natura 2000 data and shapefiles used in this study are freely available from the European Environment Agency (<https://www.eea.europa.eu/data-and-maps/data/natura-11>). Full data on fishing activities are available by request from Global Fishing Watch (<https://globalfishingwatch.org>).

AUTHOR CONTRIBUTIONS

AP conceived and designed the study and performed the statistical analyses. AP, JB, and SG were involved in compiling and processing the data. JB performed the spatial data analyses. AP wrote the manuscript with contributions from JB, SG, and NF. All authors have read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2022.811926/full#supplementary-material>

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