Reply to: Caution over the use of ecological big data for conservation

Alison A. Kock, Pieter Koen, Felipe Ladino, Fernanda O. Lana, James S. E. Lea, Fiona Llewellyn, Warrick S. Lyon, Anna Macdonnell, Bruno C. L. Macena, Heather Marshall, et al.

Matters arising

Reply to: Caution over the use of ecological big data for conservation

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Check for updates

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REPLYING TO A. V. Harry & J. M. Braccini *Nature* https://doi.org/10.1038/s41586-021-03463-w (2021)

Q1 Q2 Q3 Q4 Q5

Our global analysis[1] estimated the overlap and fishing exposure risk (FEI) using the space use of satellite-tracked sharks and longline fishing effort monitored by the automatic identification system (AIS). In the accompanying Comment, Harry and Braccini[2] draw attention to two localized shark–longline vessel overlap hotspots in Australian waters, stating that 47 fishing vessels were misclassified as longline and purse seine vessels in the Global Fishing Watch (GFW)[3] 2012–2016 AIS fishing effort data product that we used. This, they propose[2], results in misidentifications that highlight fishing exposure hotspots that are subject to an unexpected level of sensitivity in the analysis and they suggest that misidentifications could broadly affect the calculations of fishing exposure and the central conclusions of our study[1]. We acknowledged in our previously published paper[1] that gear reclassifications were likely to occur for a small percentage of the more than 70,000 vessels studied, however, here we demonstrate that even using much larger numbers of vessel reclassifications than those proposed by Harry and Braccini[2], the central results and conclusions of our paper[1] do not change.

In our use of a third-party dataset such as GFW[3], we stated clearly[1] that the dataset is undergoing continuous refinement to correct for acknowledged contamination of some gear types with others in some regions (for example, drifting longlines with bottom-set longlines off New Zealand[1]). The characterization of GFW vessels (gear) is undertaken using two convolutional neural networks that were trained[3] on 45,441 marine vessels (fishing and non-fishing) that identified six

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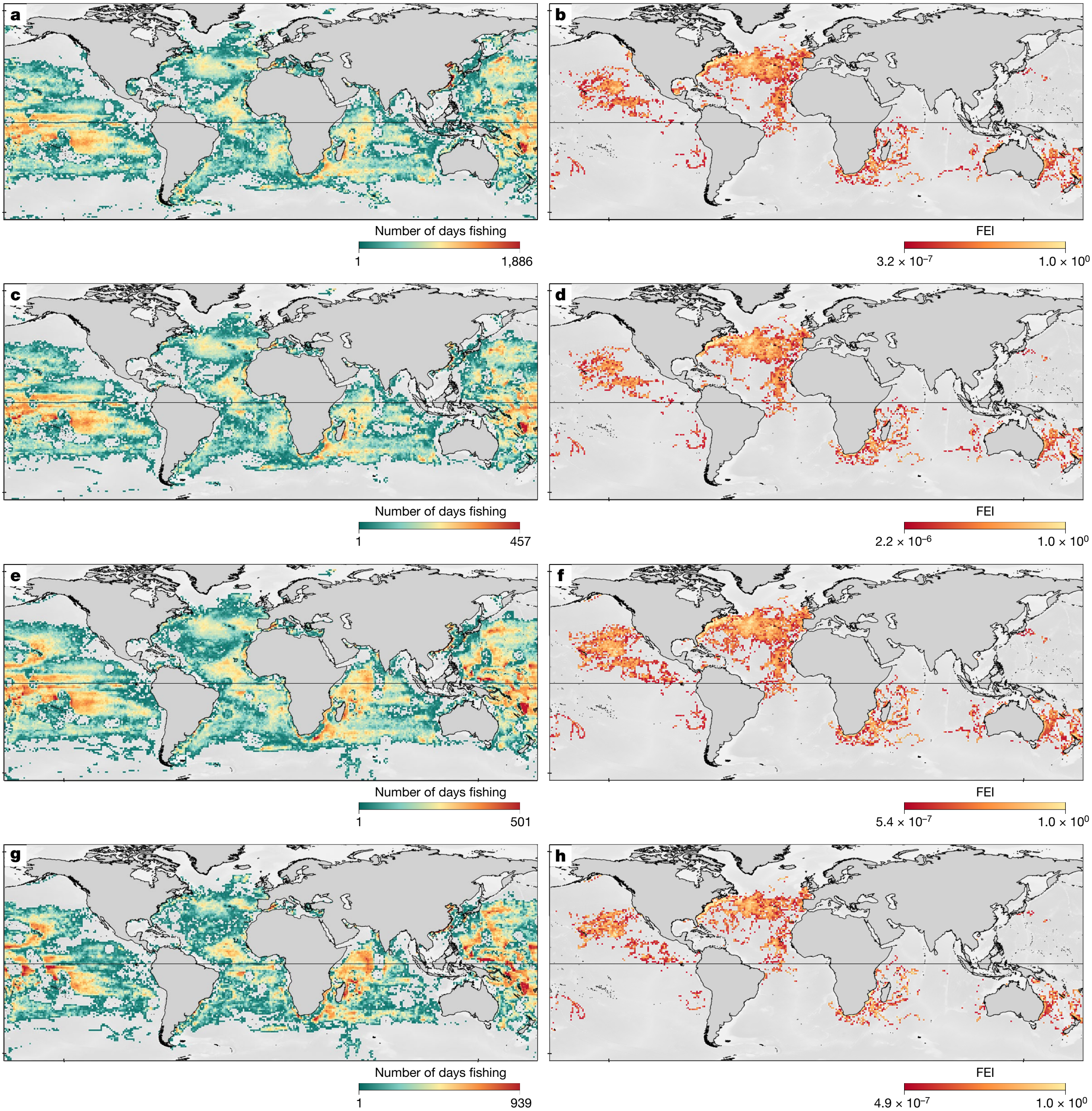

Fig. 1 | Comparing AIS longline fishing datasets. a–h, Comparison of GFW data of AIS longline fishing effort (**a**, **c**, **e**, **g**; fishing days, where 1 day = 24 h fishing effort) and spatial overlap intensity (FEI) with pelagic sharks (**b**, **d**, **f**, **h**) for three GFW datasets of longline fishing effort and Queiroz et al.[1]. The original 2012–2016 AIS longline fishing effort and FEI (**a**, **b**) was compared with the new data releases of GFW fishing effort for 2012–2016 (**c**, **d**), 2012–2018 (**e**, **f**) and 2018 only (**g**, **h**). These analyses show minor global differences across the datasets even in the light of improvements in gear characterization algorithms and further verification with additional fishing vessel metadata.

classes of fishing vessels and six classes of non-fishing vessels with 95% accuracy, as stated in our paper[1]. It is inevitable, therefore, that for some of the more than 70,000 AIS-monitored fishing vessels analysed, the gear was misclassified. Fortunately, a growing number of nations now maintain publicly accessible, online vessel registries to promote transparency and science within the fishing sector. For example, the European Union (EU) releases identifying information (including vessel name, identification numbers and fishing gear) for all fishing vessels registered to any EU country[4]. This eliminates the need to develop and refine models to estimate this information, as was the case for most of the vessels that we analysed. For countries that have not adopted this practice, including Australia, models provide necessary estimates in lieu of official information.

Since the publication of our paper[1] there have been further improvements, including the recent data of AIS longline fishing effort for 2018 with updated gear assignments based on convolutional neural networks and data for more vessels. Mapping the new data (Fig. 1) shows that, indeed, the fishing effort by 12 vessels in Australia's Northwest Shelf

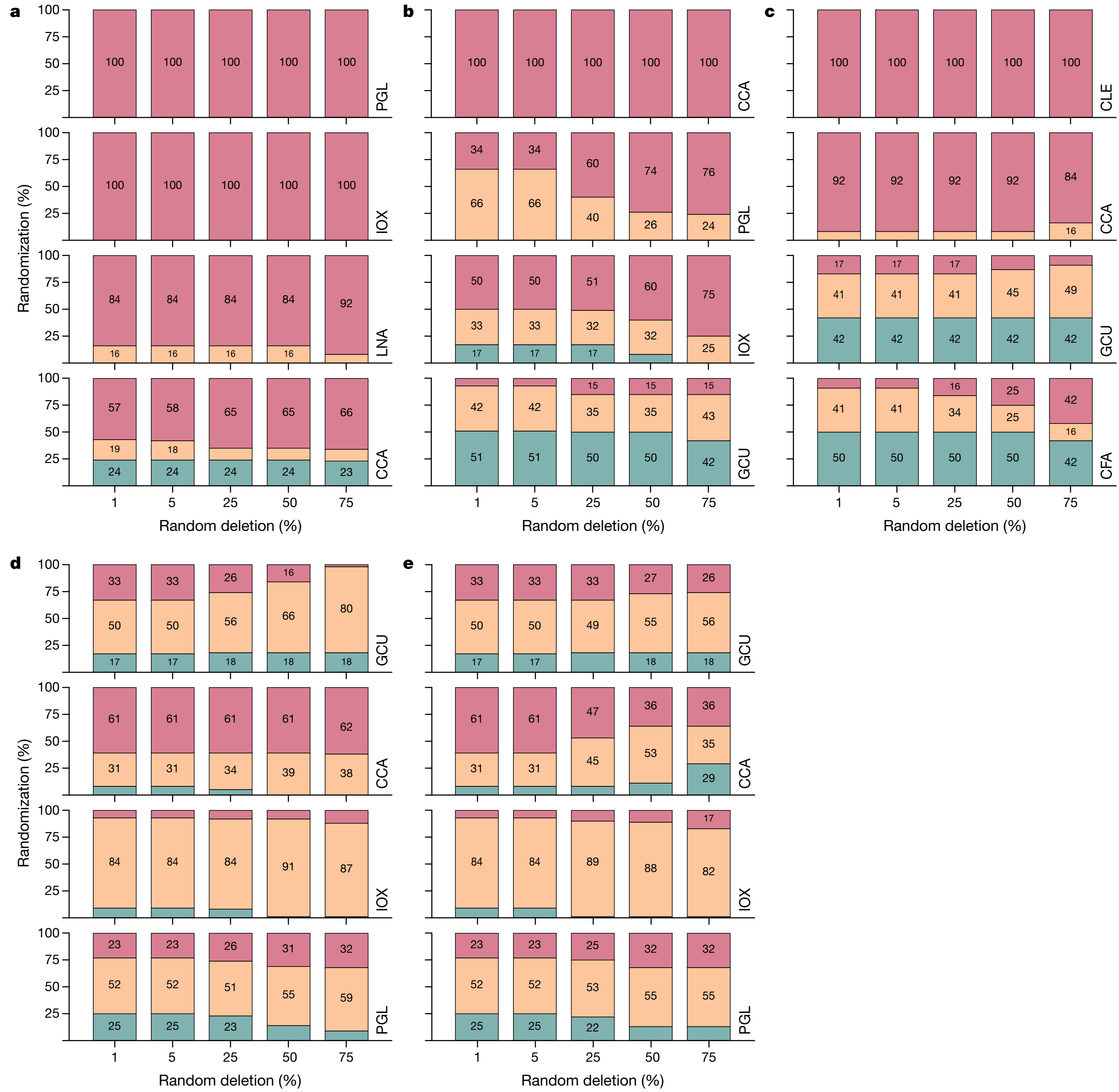

Fig. 2 | Example effects of random deletions of fishing effort data on exposure risk patterns. a–e, The percentage of randomized deletions from 100 repeats that resulted in a species exposure risk estimate occurring within the high (red), moderate (yellow) or low (green) risk category at each level of deletion (1%, 5%, 25%, 50% or 75%) of fishing effort grid cells per sub-region. **a**, North Atlantic. **b**, Eastern Pacific Ocean. **c**, Southwest Indian Ocean. **d**, Northwest Oceania. **e**, Eastern Oceania. The map that shows the locations of sub-regions is provided in Supplementary Fig. 1. CCA, white shark (*Carcharodon carcharias*); CFA, silky shark (*Carcharhinus falciformis*); CLE, bull shark (*Carcharhinus leucas*); GCU, tiger shark (*Galeocerdo cuvier*); IOX, shortfin mako shark (*Isurus oxyrinchus*); LNA, porbeagle shark (*Lamna nasus*); PGL, blue shark (*Prionace glauca*). Overall, only 6 out of 36 species–region combinations (16.7%) showed significant differences in the proportion of 100 randomizations per combination that each resulted in exposure risk falling within higher, moderate and lower risk categories when comparing 1% and 75% of random deletions of fishing effort data. Detailed summaries are provided in Supplementary Tables 1–7.

(NWS) is now removed, indicating that these few longline and purse seine vessels were not classified accurately in the GFW 2012–2016 data product. However, the GFW 2018 product does not show the reclassifications proposed off the southern Great Barrier Reef (GBR); therefore, further verifications are needed to correct those.

We agree that the space use hotspot for tiger shark (*Galeocerdo cuvier*) in Australia's NWS does not overlap with AIS-monitored longline fishing effort in that area based on the GFW 2012–2016 data product that we used. Therefore, an important question raised[2] is whether the reclassification of the gear types of 47 vessels directly affects the calculations of fishing exposure and our conclusions. In our paper[1], the area (at the 1° × 1° grid cell scale) covered by AIS longline fishing effort in Western Australia is 0.4% of the global coverage and the southern GBR area represents only 0.06%. Within the Oceania region used in our paper, Western Australia comprises 2.2% and GBR 0.35%. Therefore, the areas comprising reclassifications provide a minor contribution to the spatial overlap and FEI values that we calculated not only globally but also within the Oceania region.

To check our results within the global context, we compared the spatial overlap of sharks and longline fishing effort in our paper[1] with the new releases of GFW fishing effort data that have been made available since the publication of our paper (Fig. 1 and Extended Data Table 1). The new releases of GFW data take into account refinements in the algorithms used to classify vessel (gear) types and new knowledge from metadata on the gear of the vessels. We find that—globally—the GFW longline fishing patterns remain almost identical (Fig. 1). Spatial overlap and exposure patterns also remain very similar. For example, the mean monthly spatial overlap estimate for all oceans of 24% presented in our paper is within the range (19–29%) calculated using the new GFW data (Extended Data Table 1). In the Exclusive Economic Zone (EEZ) of Australia, the number of FEI grid cells actually increased from 151 to 155 between the original GFW data (2012–2016) and the updated 2012–2018 data, whereas in the EEZ of western Australia the number decreased from 50 to 37 grid cells between datasets. For Oceania (including Australian shelf waters), the spatial overlap of 24% in our paper is within the 17–25% range estimated with newer GFW data. We also find that the spatial overlap–FEI plots remain largely unchanged across the four GFW datasets (Extended Data Fig. 1). Therefore, the NWS vessel reclassifications are minor and affect a single hotspot for tiger sharks.

To address the potential issue raised by Harry and Braccini[2] that longline vessel reclassifications occur more broadly and may alter results in substantial ways, we randomly deleted 1% of grid cells that contained longline fishing effort per ocean region to simulate reclassification of longline vessels to other gears and this randomization was repeated 100 times. This is more extreme than simply removing a few individual vessels because each replicate removes 1% of grid cells, each comprising summed fishing effort from single or multiple vessels. Extended Data Table 2 shows that of the 30 species–region pairs available for analysis, we found that only 7% of species–region pairs changed from highest (red) to moderate (yellow) fishing exposure risk, whereas 3% changed from moderate to highest risk after the simulated 'reclassification'. We repeated this for 5% random deletions. Even at this much higher level of longline gear reclassification, we obtained the same results (Extended Data Table 3).

To examine what level of localized reclassification may lead to a breakdown of the fishing exposure risk patterns that we found, we randomly deleted 1%, 5%, 25%, 50% and 75% of fishing effort grid cells within five sub-regions (Supplementary Fig. 1) and recalculated spatial overlap and FEI for four key species per sub-region (Fig. 2 and Supplementary Methods). Results reveal no change in patterns of overlap and FEI for the four key species for the random deletion of up to 75% of data for regions in which shark spatial densities and fishing effort were both high and spatially extensive (for example, the North Atlantic (Fig. 2a)). Patterns change marginally above deletion of 25% of data for some species in other sub-regions in which fewer vessels and sharks were tracked (Fig. 2b, d). Seasonal patterns in exposure risk also remained largely unchanged albeit with larger differences at higher levels of fishing effort deletions (Supplementary Fig. 2). Levels of inaccuracy as high as we simulated in these tests are not evident in worldwide GFW vessel classifications[3]. Clearly, our results are not as sensitive to minor changes in sub-region vessel reclassifications as suggested by Harry and Braccini[2].

Harry and Braccini[2] emphasize that regional results should not be overlooked within a global-scale study. We agree, which is why we provided region-specific results for individual species that were discussed in detail in our paper[1] (see supplementary results and discussion 2.6 of ref. [1]), in which each regional analysis was informed by regional experts among the authorship, including for Western Australia. Although continued refinements to fishing gears ascribed to AIS-monitored vessels in the GFW dataset are useful, we disagree with Harry and Braccini[2] about the levels of fishing threatening large sharks in Australia's NWS where we identified the space use hotspot for tiger sharks. They incorrectly assert that longline fishing has not occurred for two decades in Australia's NWS[2]. Longline and gillnet fishing not only occurred historically in the NWS and offshore to the boundary of Australia's EEZ[5], but also continues to occur there through illegal, unreported and unregulated fishing[6–8] by vessels that are not equipped with or that do not use AIS, which we discussed in our paper[1]. Illegal, unreported and unregulated fishers are known to target sharks—including tiger sharks[9]—for fins, an ongoing threat that has been a major problem in Australia's NWS[7], which overlaps with the tiger shark hotspot[8]. Therefore, it cannot be discounted that the shark hotspot overlaps with non-AIS monitored fishing activity, especially as more than 0.5 million km^2 of the NWS remains open to commercial shark fishing[10]. Furthermore, the 55-year-long shark control program along 1,760 km of coastal northeastern Australia shows a long-term decline in the abundance of tiger sharks[11,12]; this is a region with movement and genetic connectivity with tiger sharks of the NWS[13]. In our view, Harry and Braccini[2] overlook existing threats to tiger sharks and other shark species from fishing in the NWS.

As a consequence, we disagree with the opinion that existing science-based management has been undermined by our results or conclusions. Rather, in our paper[1] we highlighted specifically the need to incorporate tracking and other spatial data into scientific assessments. However, this should not be misinterpreted as spatial data representing a regional management tool to replace assessments that rely on other types of data, such as time-series catch data. Indeed, a review[14] cited in our paper identifies examples in which marine animal tracking and space use data informed policy, and it is evident that these data were never used in isolation from existing management regimes or complementary scientific assessments. Our paper[1] emphasizes the need for a holistic approach to shark management that should also incorporate dynamic, spatial data.

Reporting summary

Further information on experimental design is available in the Nature Research Reporting Summary linked to this paper.

Data availability

Data used to prepare the maps (shark relative spatial density, longline-fishing effort and shark–longline-fishing overlap and FEI) are available on GitHub (https://github.com/GlobalSharkMovement/GlobalSpatialRisk).

Code availability

Code used to prepare the maps (shark relative spatial density, longline-fishing effort and shark–longline-fishing overlap and FEI) is available on GitHub (https://github.com/GlobalSharkMovement/GlobalSpatialRisk).

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Competing interests The authors declare no competing interests.

Additional information

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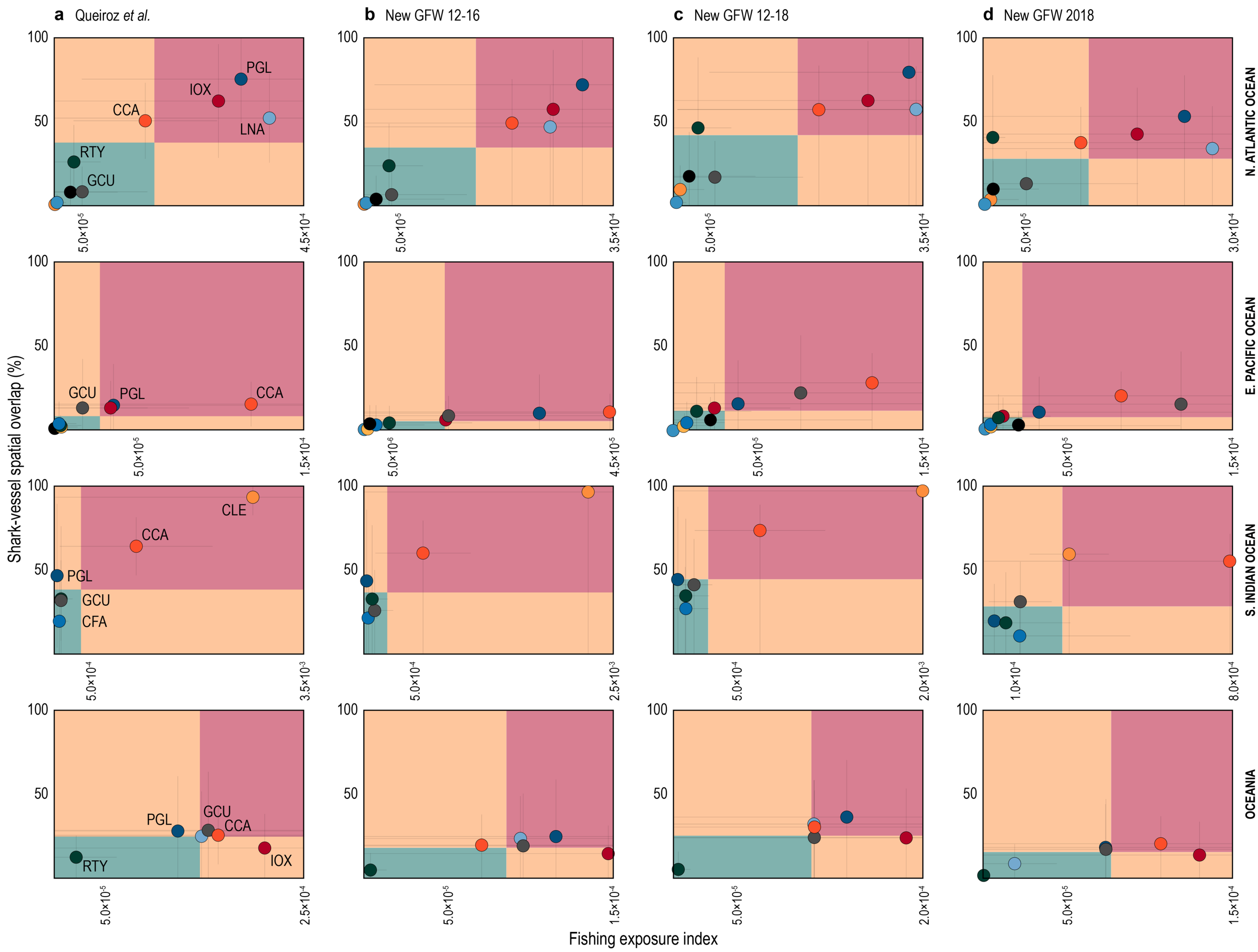

Extended Data Fig. 1 | Comparing shark exposure risk between AIS longline fishing effort datasets. a–d, Estimated exposure risk of sharks to capture by GFW AIS longline fishing effort across ocean regions for Queiroz et al.[1] (**a**) compared with three improved data releases since the paper was published (**b**–**d**). The plots show minor effects of any changes on estimates of shark exposure risk from AIS longline fishing effort and confirm the global results and conclusions of our paper. **a**, Data from Queiroz et al.[1]. **b**, Data from GWF 2012–2016. **c**, Data from GWF 2012–2018. **d**, Data from GWF 2018.

Extended Data Table 1 | Mean monthly spatial overlap estimates (%) of pelagic shark space use and AIS longline fishing effort for different AIS datasets

	N tags	Queiroz et al.		New GFW 2012-16		New GFW 2012-18		New GFW 2018	
		mean	S.D.	mean	S.D.	mean	S.D.	Mean	S.D.
Global	1611	24.37	33.08	21.98	32.20	28.93	34.44	18.98	25.79
N Atlantic	649	37.41	38.60	34.62	37.58	42.00	38.21	27.92	29.09
E Pacific	588	7.80	15.99	5.18	13.29	11.38	19.14	7.53	14.89
SW Indian	153	38.31	35.31	36.69	35.14	44.53	36.95	28.38	28.20
Oceania	151	24.42	27.21	18.13	25.18	25.32	29.04	15.61	23.21

Extended Data Table 2 | Effect of 1% random deletion of fishing effort grid cells within each region on risk exposure estimates

	N Atlantic		E Pacific		SW Indian		Oceania	
Main species	Before	After	Before	After	Before	After	Before	After
Prionace glauca								
Isurus oxyrinchus								
Lamna nasus								
Carcharodon carcharias								
Galeocerdo cuvier								
Sphyrna spp.								
Rhincodon typus								
Carcharinus longimanus								
Carcharhinus falciformis								
Carcharhinus leucas								
Lamna ditropis								

Q6

The results show minor effects of substantial removal of longline fishing effort. Before/after denotes before/after deletion. Red denotes the highest risk exposure category, green indicates the least risk. The 'after' colour represents the category with the highest percentage of occurrence after 100 randomizations. No change in colour between before/after indicates no change in spatial overlap and exposure risk of species from AIS longline fishing effort. White indicates that no tracking data are available to undertake analysis. There are no changes from high to low, or vice versa.

Extended Data Table 3 | Effect of 5% random deletion of fishing effort grid cells within each region on risk exposure estimates

	N Atlantic		E Pacific		SW Indian		Oceania	
Main species	Before	After	Before	After	Before	After	Before	After
Prionace glauca								
Isurus oxyrinchus								
Lamna nasus								
Carcharodon carcharias								
Galeocerdo cuvier								
Sphyrna spp.								
Rhincodon typus								
Carcharinus longimanus								
Carcharhinus falciformis								
Carcharhinus leucas								
Lamna ditropis								

The results show minor effects of substantial removal of longline fishing effort. Before/after denotes before/after deletion. Red denotes the highest risk exposure category, green indicates the least risk. The 'after' colour represents the category with the highest percentage of occurrence after 100 randomizations. No change in colour between before/after indicates no change in spatial overlap and exposure risk of species from AIS longline fishing effort. White indicates that no tracking data are available to undertake analysis. There are no changes from high to low, or vice versa.

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Journal: **Nature**
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nature research

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Reporting Summary

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For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

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☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	No data collection software was used.
Data analysis	All analyses described were undertaken in R.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

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Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

Data and source code used for preparing figure maps (shark relative spatial density, longline-fishing effort and shark–longline-fishing overlap and FEI) are available on GitHub (https://github.com/GlobalSharkMovement/GlobalSpatialRisk).

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	This study is a Reply to a Matters Arising comment on our original paper. To answer the points raised we re-plotted some of the original shark movements and fishing effort data in our paper which are fully described in figure and table legends and in the original paper. We also carried out new analyses using newer data releases of global longline fishing effort data that were freely available from Global Fishing Watch (www.globalfishingwatch.org).
Research sample	In this Reply, the additional data used were the Global fishing Watch updated data release for AIS-monitored longline fishing effort in 2012-2018.
Sampling strategy	Global longline fishing effort data were obtained for automatic identification system (AIS) monitored vessels >300 gross tons.
Data collection	Global longline fishing effort data for automatic identification system (AIS) monitored vessels >300 gross tons were made available by the Global Fishing Watch.
Timing and spatial scale	Global for 2012-2018.
Data exclusions	No relevant data were excluded.
Reproducibility	No experiments as such were conducted, rather our data are based on satellite tracked movements of individual pelagic sharks and fishing vessels.
Randomization	Randomization procedures were used when removing 1, 5, 25, 50 and 75% of the AIS data for breakpoint sensitivity analysis. Methods are fully described in the Reply and Supplementary Information files.
Blinding	Blinding is not relevant to this type of study because our original data were based on movements of wild animals and fishing vessels.

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

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n/a	Involved in the study	
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☒	☐	Palaeontology and archaeology
☒	☐	Animals and other organisms
☒	☐	Human research participants
☒	☐	Clinical data
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Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging