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

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► To cite this version:

Alison A. Kock, Pieter Koen, Felipe Ladino, Fernanda O. Lana, James S. E. Lea, et al.. Reply to: Caution over the use of ecological big data for conservation. *Nature*, 2021, 595 (7866), pp.E20–E28. 10.1038/s41586-021-03464-9 . hal-03415669

HAL Id: hal-03415669

<https://hal.umontpellier.fr/hal-03415669v1>

Submitted on 26 Oct 2023

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

<https://doi.org/10.1038/s41586-021-03464-9>

Received: 14 February 2021

Accepted: 16 March 2021

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

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Our global analysis¹ 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 Braccini² 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 propose², 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 study¹. We acknowledged

in our previously published paper¹ 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 Braccini², the central results and conclusions of our paper¹ do not change.

In our use of a third-party dataset such as GFW³, we stated clearly¹ 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 Zealand¹). The characterization of GFW vessels (gear) is undertaken using two convolutional neural networks that were trained³ on 45,441 marine vessels (fishing and non-fishing) that identified six

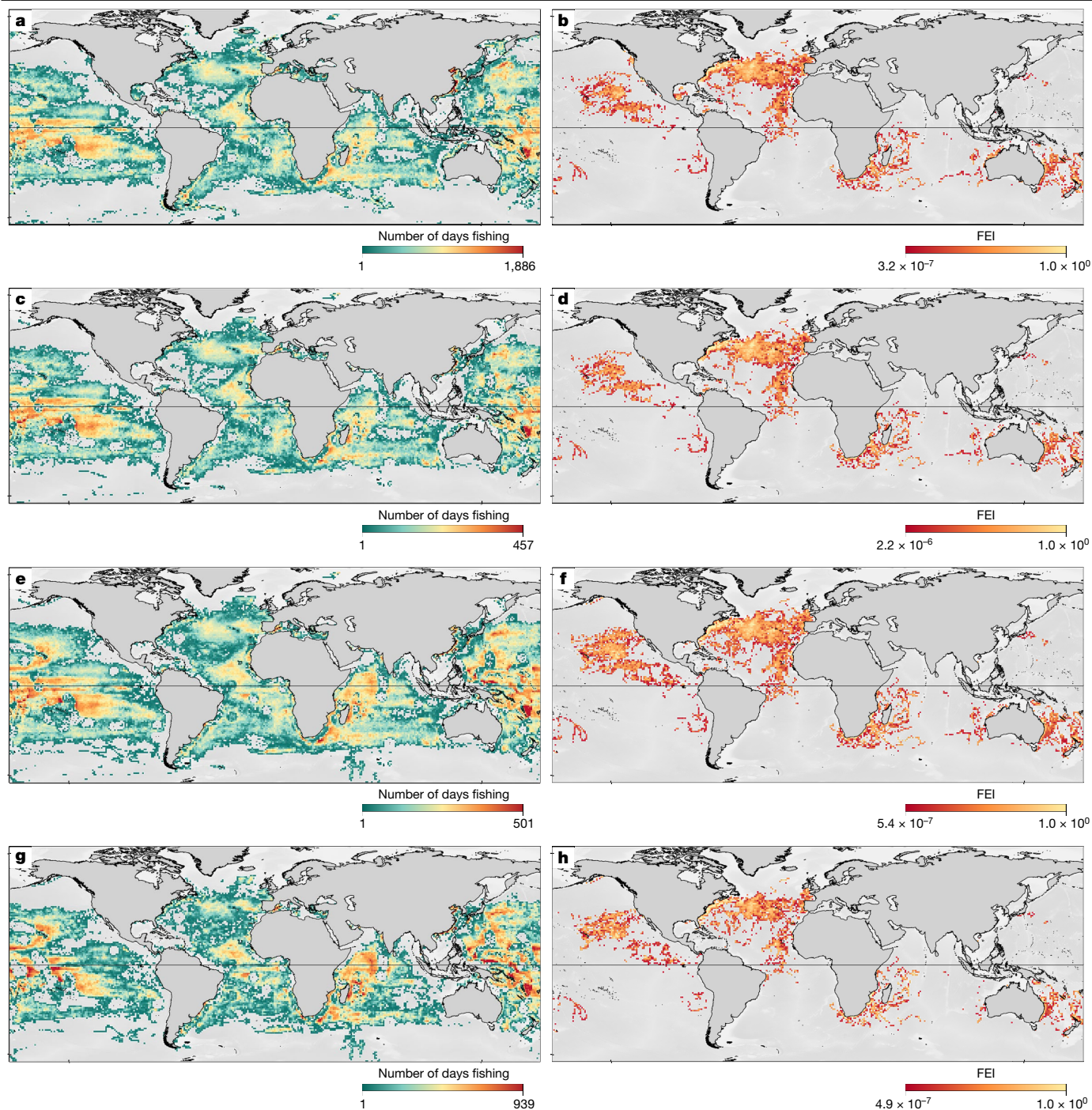


Fig. 1 | Comparing AIS longline fishing datasets. **a–h**, Comparison of GFW data of AIS longline fishing effort (**a, c, e, g**; fishing days, where 1 day = 24 h fishing effort) and spatial overlap intensity (FEI) with pelagic sharks (**b, d, f, h**) for three GFW datasets of longline fishing effort 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 paper¹. 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 country⁴. 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 paper¹ 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

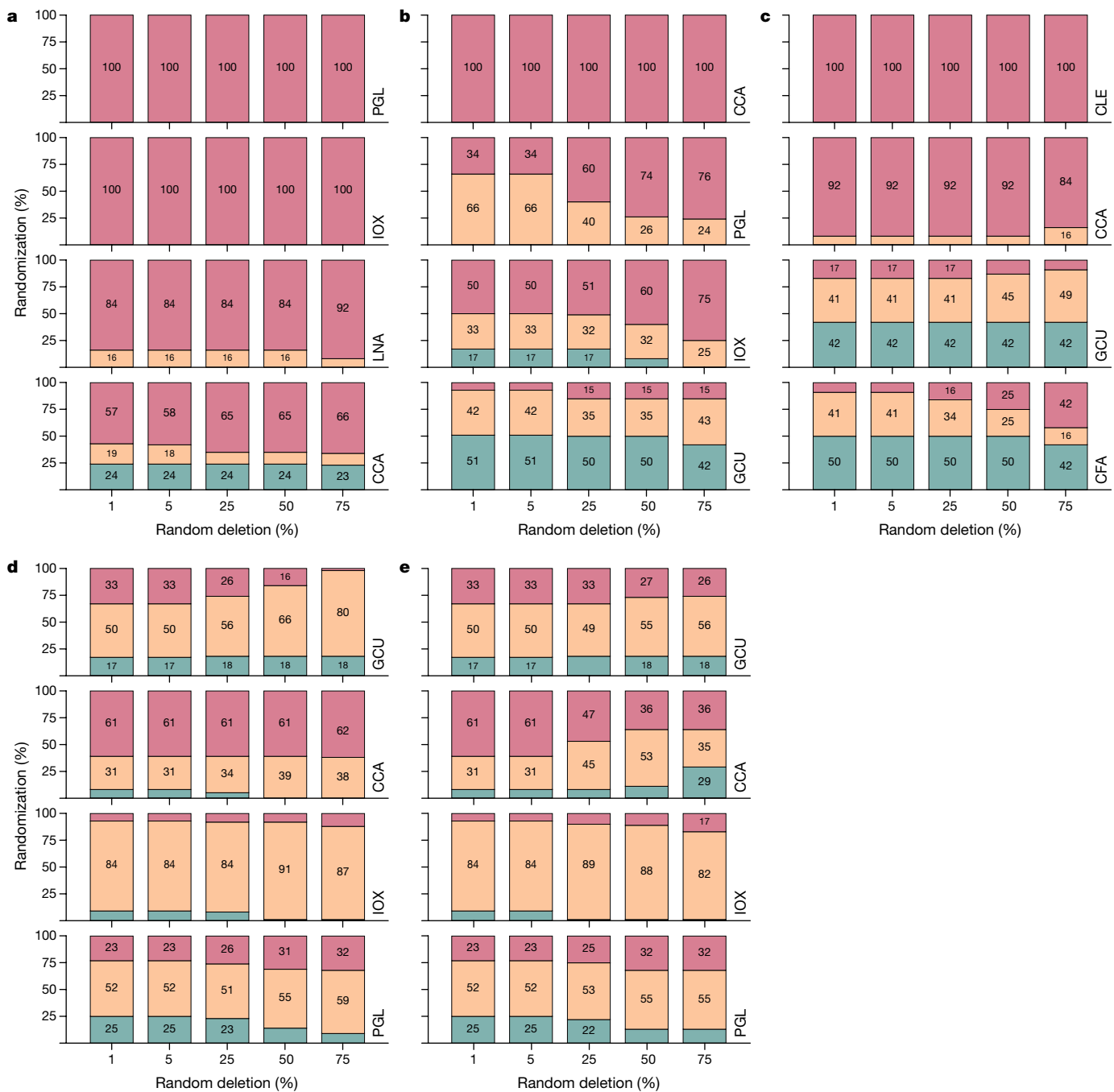


Fig. 2 | Example effects of random deletions of fishing effort data on exposure risk patterns. a–e, The percentage of randomized deletions from 100 repeats that resulted in a species exposure risk estimate occurring within the high (red), moderate (yellow) or low (green) risk category at each level of 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 raised² is whether the reclassification of the gear types of 47 vessels directly affects the calculations of fishing exposure and our conclusions. In our paper¹, 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

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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 paper¹ 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 Braccini² 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 classifications³. Clearly, our results are not as sensitive to minor changes in sub-region vessel reclassifications as suggested by Harry and Braccini².

Harry and Braccini² 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 paper¹ (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 Braccini² 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 NWS². Longline and gillnet fishing not only occurred historically in the NWS and offshore to the boundary of Australia’s EEZ⁵, 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 paper¹. Illegal, unreported and unregulated fishers are known to target sharks—including tiger sharks⁹—for fins, an ongoing threat that has been a major problem in Australia’s NWS⁷, which overlaps with the tiger shark hotspot⁸. Therefore, it cannot be discounted that the shark hotspot overlaps with non-AIS monitored fishing activity, especially as more than 0.5 million km² of the NWS remains open to commercial shark fishing¹⁰. 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 NWS¹³. In our view, Harry and Braccini² 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 paper¹ 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 review¹⁴ 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 paper¹ 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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Acknowledgements Funding support was provided by the Natural Environment Research Council (NERC) (NE/R00997/X/1), European Research Council (ERC-AdG-2019 883583 OCEAN DEOXYFISH) (D.W.S.), Fundação para a Ciência e a Tecnologia CEECIND/02857/2018 (N.Q.) and PTDC/BIA-COM/28855/2017 (M.V.). This research is part of the Global Shark Movement Project (<http://globalsharkmovement.org/>).

Author contributions N.Q. and D.W.S. planned the data analysis. N.Q. led the data analysis with contributions from M.V. and D.W.S. N.E.H. contributed analysis tools. D.W.S. led the manuscript writing with contributions from N.Q., N.E.H. and all authors. Seven of the original authors were not included in the Reply authorship; two authors retired from science and the remaining five, although supportive of our Reply, declined to join the authorship due to potential conflicts of interest with the authors of the Comment and/or their institutions.

Competing interests The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s41586-021-03464-9>.

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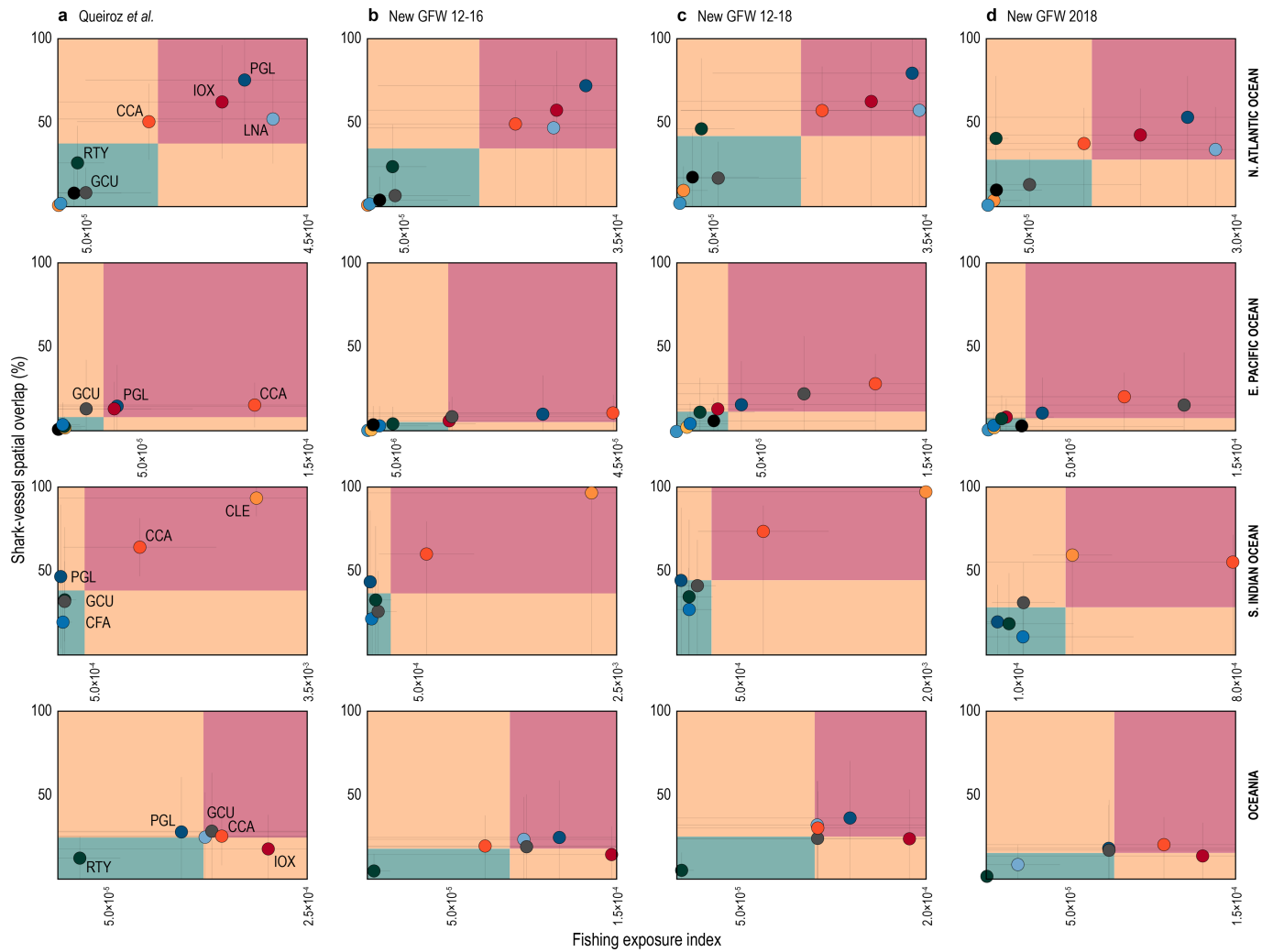
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Extended Data Fig. 1 | Comparing shark exposure risk between AIS longline fishing effort datasets. a–d, Estimated exposure risk of sharks to capture by GFW AIS longline fishing effort across ocean regions for Queiroz et al.¹ (a) compared with three 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 GFW 2012–2016. c, Data from GFW 2012–2018. d, Data from GFW 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

Matters arising

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

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

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

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

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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Data collection No data collection software was used.

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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>).

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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.
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