Black petrel distribution and range-wide overlap with pelagic longline fisheries

Javier Quiñones[1], Fiorella Vilela[1,2], Edward Barriga[1], Josymar Magallanes[1], Jamie Darby[3,4], Johannes H. Fischer[5], Graeme A. Taylor[5], Elizabeth Bell[6], Maria R. Düssler[5,7], Olivia C. Rowley[5], Igor Debski[5]

[1] Instituto del Mar del Perú, Callao, Perú.
[2] Universidade Federal do Rio Grande do Sul – UFRGS, Porto Alegre, Brasil.
[3] School of Biological Sciences, University of Auckland, New Zealand.
[4] School of Biological, Earth and Environmental Sciences, University College Cork, Cork, Ireland
[5] Aquatic Unit, Department of Conservation, Wellington, New Zealand.
[6] Wildlife Management International Ltd., Blenheim, New Zealand.
[7] Victoria University of Wellington, Wellington, New Zealand.

Abstract

The Black Petrel is a Vulnerable seabird, particularly susceptible to fisheries bycatch, including in pelagic longline fisheries, at least partially due to their deep-diving capabilities. Whilst the Black Petrel is a New Zealand breeding endemic, it ranges widely across the Pacific, spending its non-breeding period in the Peru EEZ and wider IATTC area. Using an extensive year-round tracking dataset of adults, we found a distinct spatiotemporal pattern in Black Petrel distribution, which almost exclusively occur in the IATTC Convention Area during the non-breeding period (June-September; although immature birds are known to occur year-round in this area). To assess the risk of bycatch in pelagic longline fisheries across the Black Petrel range, we overlayed the spatiotemporal bird data with a range of spatiotemporal pelagic longline fishing effort data across the New Zealand EEZ, Peru EEZ, and the Convention Areas of WCPFC and IATTC. We found widespread overlap of Black Petrels and pelagic longline fishing effort across their range, including considerable overlap in the IATTC area, predominantly in areas beyond the Peru EEZ as well as in a distinct hotspot off the coast of Mesoamerica. A substantial proportion of this overlap occurred in areas where no seabird bycatch mitigation use is required under IATTC Resolution C-11-02. To adequately protect the Vulnerable Black Petrel from pelagic longline fishing bycatch, it is vital to ensure that bycatch mitigation methods are used where birds and fishing effort co-occur, and that the applied mitigation methods are effective at preventing these birds from accessing baited hooks despite their deep-diving capabilities.

Introduction

Black Petrels (Tākoketai, *Procellaria parkinsoni*) are a Vulnerable species (IUCN 2024), with a comparatively small population of ~5,500 breeding pairs distributed across two islands in northern New Zealand (Bell et al. 2016a, Bell et al. 2022). Black Petrels are identified as one of the most at-risk seabirds to commercial fisheries bycatch in New Zealand (Edwards et al. 2023). Black Petrels are bycaught in a range of fishing gears in New Zealand, with substantial numbers caught annually in domestic pelagic longline fisheries (Edwards et al. 2023). However, previous tracking work of Black Petrels showed that, even while central-place constrained during the breeding period, Black Petrels travel well outside New Zealand's Exclusive Economic Zone (EEZ) (e.g., Bell et al. 2020). Outside of the breeding period, this highly mobile seabird extends its range across the Pacific (Fischer et al. 2023), spending juvenile, immature (Imber et al. 2003), and non-breeding periods feeding in the waters of the Equatorial South America (Reyes et al. 2017, 2024) and the Northern Humboldt Current area in northern Peru (Quiñones et al. 2021).

Black Petrels are particularly susceptible to bycatch in pelagic longline fisheries due to their deep-diving capabilities (Düssler 2025). Specifically, Black Petrels are the deepest and longest diving *Procellaria* petrel, frequently diving beyond 20 m depths and reaching depths of up to 38.5 m. In addition, Black Petrels are capable of diving faster (0.8 m/s) than most sink rates of hooks (usually <0.5 m/s). Finally, Black Petrels are also capable of diving at night. Due to these diving abilities, Black Petrels can retrieve baited hooks back to the surface, placing other seabirds with lesser diving capabilities (e.g., albatrosses) at additional risk (Jiminez et al. 2012). Consequently, Black Petrels, and therefore other seabirds, are susceptible to bycatch in pelagic longlines when common bycatch mitigation methods (bird scaring lines, line weighting, and night setting) are used in isolation (Düssler 2025).

Comparing the spatial distribution of the deep-diving Black Petrels and fisheries is essential to understand high-risk areas for bycatch, and to assess whether effective bycatch mitigation methods (i.e., combining methods to overcome the short-comings of individual methods) are in place where required (Debski et al. 2016). Such work has been conducted for Black Petrels within the New Zealand EEZ (Bell et al. 2013) and within the Convention Area of the Western and Central Pacific Fisheries Committee (WCPFC; Darby et al. 2024). Yet, insights into Black Petrel fisheries bycatch risk beyond the Western and Central Pacific are missing. Consequently, to fully understand bycatch risk of Black Petrels, it is necessary to consider fisheries overlap across the full range of this species.

Here, we combine fine-scale tracking data from breeding Black Petrels (GPS) with coarse-scale tracking data (geolocator) covering the full annual cycle, standardising locations from each source and creating a distribution estimate for each calendar month. We overlay these monthly distribution data with spatiotemporal pelagic longline fishing effort data from a number of sources to quantify range-wide fisheries overlap, reporting these across New Zealand and Peru EEZs, and other areas under the jurisdiction of relevant Regional Fisheries Management Organisations (RFMOs) for this species, the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Finally, we evaluate the identified spatiotemporal overlap in the light of the current area within the IATTC Convention Area within which bycatch mitigation methods are required as stipulated by IATTC Resolution C-11-02.

Methods & Results

Black Petrel distribution

The processed tracking data used in this study is shown in Figure 1. Details on the data processing can be found in Appendix 1. The more limited sample of high-resolution data from GPS tags (Figure 1B) corresponded closely to the breeding tracks obtained through the larger sample of geolocator tags (Figure 1A), providing confidence in the quality of processed geolocator tags obtained to adequate describe the year-round range. The annual range of Black Petrels extended from Eastern Australia in the west to South America, in the north up to the gulf of Panama and coastal areas of Nicaragua, and in the south in offshore waters of the Peruvian – Chilean elbow (Figures 1 and 2). Breeding Black Petrels also ranged considerable distances on foraging trips, often travelling well over 1000 km from the colony. Hotspots of occurrence were evident around the Peruvian coastal upwelling system, mainly between the boundary with Ecuador until 10°S, and areas west of the Galapagos Islands during the non-breeding season, from June through to September (Figure 2). Around the colony, densities were highest from January through to May, i.e. during the breeding season and while the birds are central-place constrained.

The proportion of bird occurrence by jurisdiction (Figure 3) illustrated the annual change from near total occurrence within the New Zealand EEZ and WCPFC Convention Area during the breeding period (November-April) to near total occurrence in the Peru EEZ and IATTC Convention Area during the non-breeding period (June-September). However, it is important to note that we only used tracking data on breeding adult birds in this study and the distribution of immature (and potentially other non-breeding birds) may vary markedly. For example, at-sea surveys in the Peru EEZ have revealed Black Petrel occurrence during the breeding season (Fischer et al. 2023), which likely pertained to juvenile and immature birds.

Pelagic longline fishing effort

To assess range-wide fisheries overlap with Black Petrel distribution, data were compiled from three primary sources: (i) New Zealand domestic fisheries data, (ii) Peruvian domestic fisheries data, and (iii) global Automatic Identification System (AIS) data. Domestic fisheries data were provided by the respective countries and encompassed fishing activity within each country's Exclusive Economic Zone (EEZ). Both the New Zealand and Peruvian datasets represented surface longline fisheries. Domestic fishing effort was quantified at a spatial resolution of 1° × 1°, using temporally averaged data. For New Zealand, data from the years 2017, 2018, and 2019 were used, for Peru, data from 2018, 2019, and 2021 were included. Effort was expressed as the average number of hooks deployed per day per degree square and was disaggregated by month to capture seasonal variation in fishing activity. Within the WCPFC and IATTC Convention Areas (exclusive of the New Zealand and Peru EEZs), fishing effort was derived from global AIS data curated by Global Fishing Watch using > 70,000 industrial fishing vessels from 2012 to present day (Kroodsma et al. 2018). These data were processed following the methodology outlined in Darby et al. (2024), resulting in estimates of fishing days per month per degree square.

To enable integration of domestic and AIS-derived datasets into a unified global fishing effort raster, high seas fishing effort (in fishing days) was converted to an equivalent measure of hooks deployed. This was achieved by multiplying the number of fishing days by 3,300 - the average number of hooks set per longline fishing event, - and dividing by the number of days in each respective month. The resulting metric, average number of hooks per day per degree, was consistent with the format of the domestic datasets and allowed for spatial and temporal merging.

Fisheries overlap

To quantify spatial and temporal overlap between Black Petrel distribution and fishing activity, monthly overlap rasters were generated by multiplying the species distribution raster by the corresponding fishing effort raster for each calendar month. The resulting values—expressed as the product of bird-days and fishing effort (hooks/day/degree)—provided a relative index of overlap in estimated hooks per bird per day per degree. This metric served as a proxy for potential interaction risk and was used in subsequent analyses to assess the spatial and seasonal intensity of fisheries exposure across the species' range.

Overlap between Black Petrels and pelagic longline fishing effort was extensive both spatially (i.e., throughout most of the species' range) and temporally (i.e., throughout the annual cycle; Figure 4). Fine-scale spatiotemporal patterns of overlap largely reflected Black Petrel occurrence rather than pelagic longline fishing effort, with overlap being centred in the New Zealand EEZ and the WCPFC Convention Area during the breeding period (December-April), while being centred within the IATTC Convention Area during the non-breeding period (June-October). May and November showed transitional overlap areas between these two key regions. Notably, within the Eastern Pacific, a major overlap hotspot was identified off the coast of Costa Rica and Nicaragua, east of Central America, indicating an elevated risk of fisheries interaction in this region (Figure 5).

The total annual overlap between pelagic longline fisheries and Black Petrels within the IATTC region is shown in Figure 6, together with the spatial extent of seabird bycatch mitigation use required under IATTC Resolution C-11-02. There is substantial overlap between Black Petrels and pelagic longline fishing effort in the Eastern part of the IATTC area where currently no seabird bycatch mitigation is required.

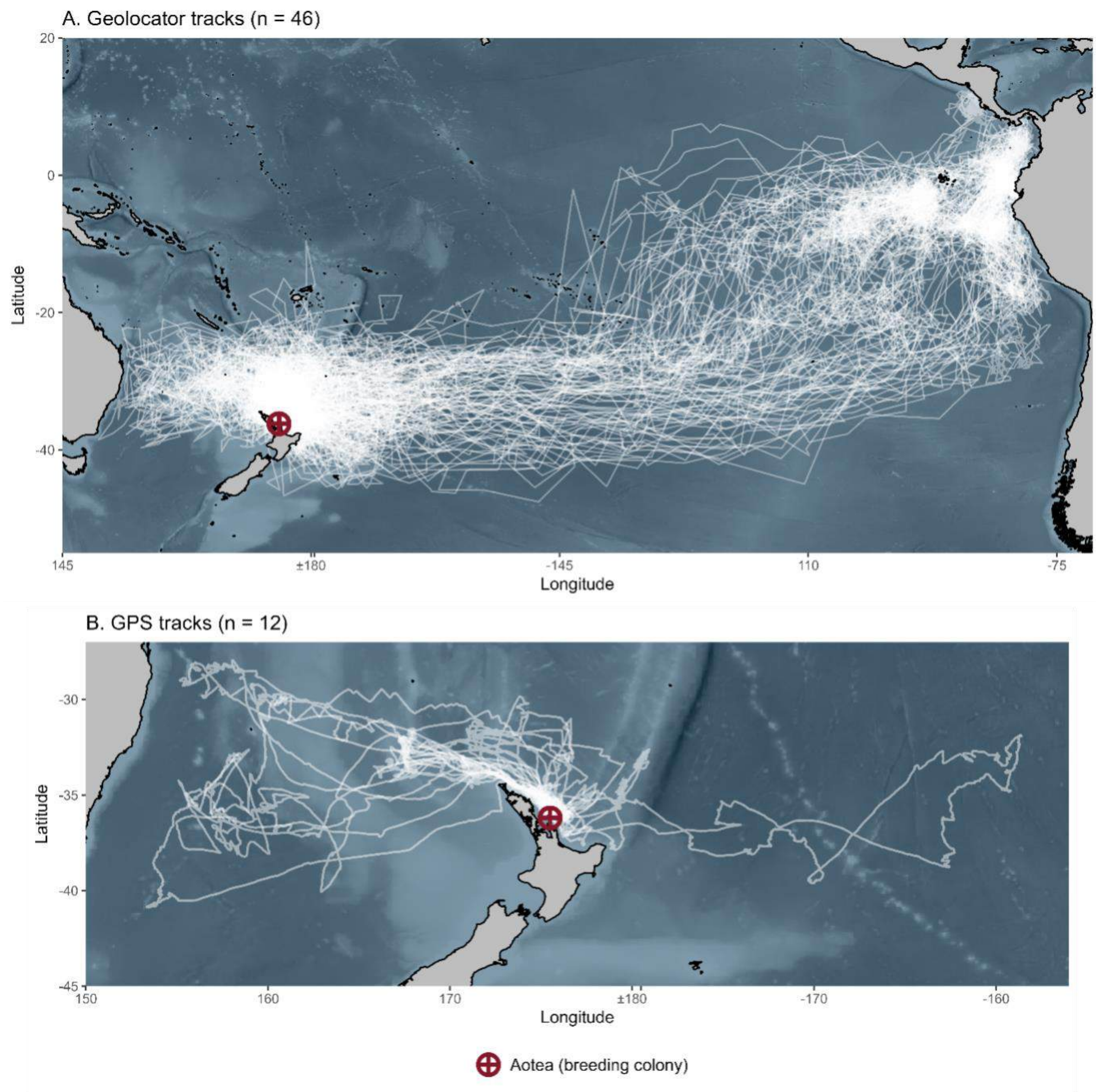

Figure 1. Tracks from Black Petrels equipped with geolocators (A) and GPS devices (B).

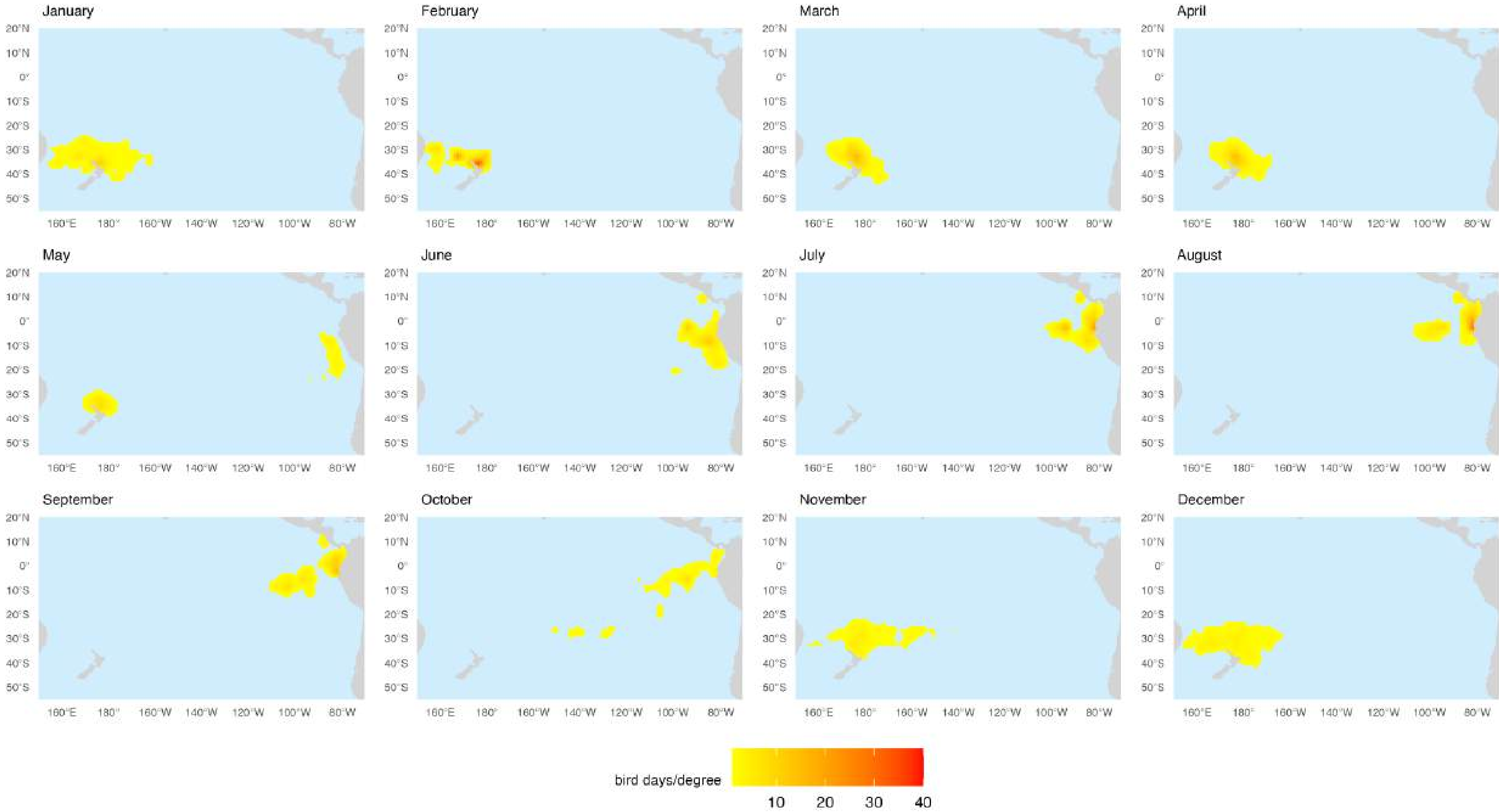

Figure 2. breeding

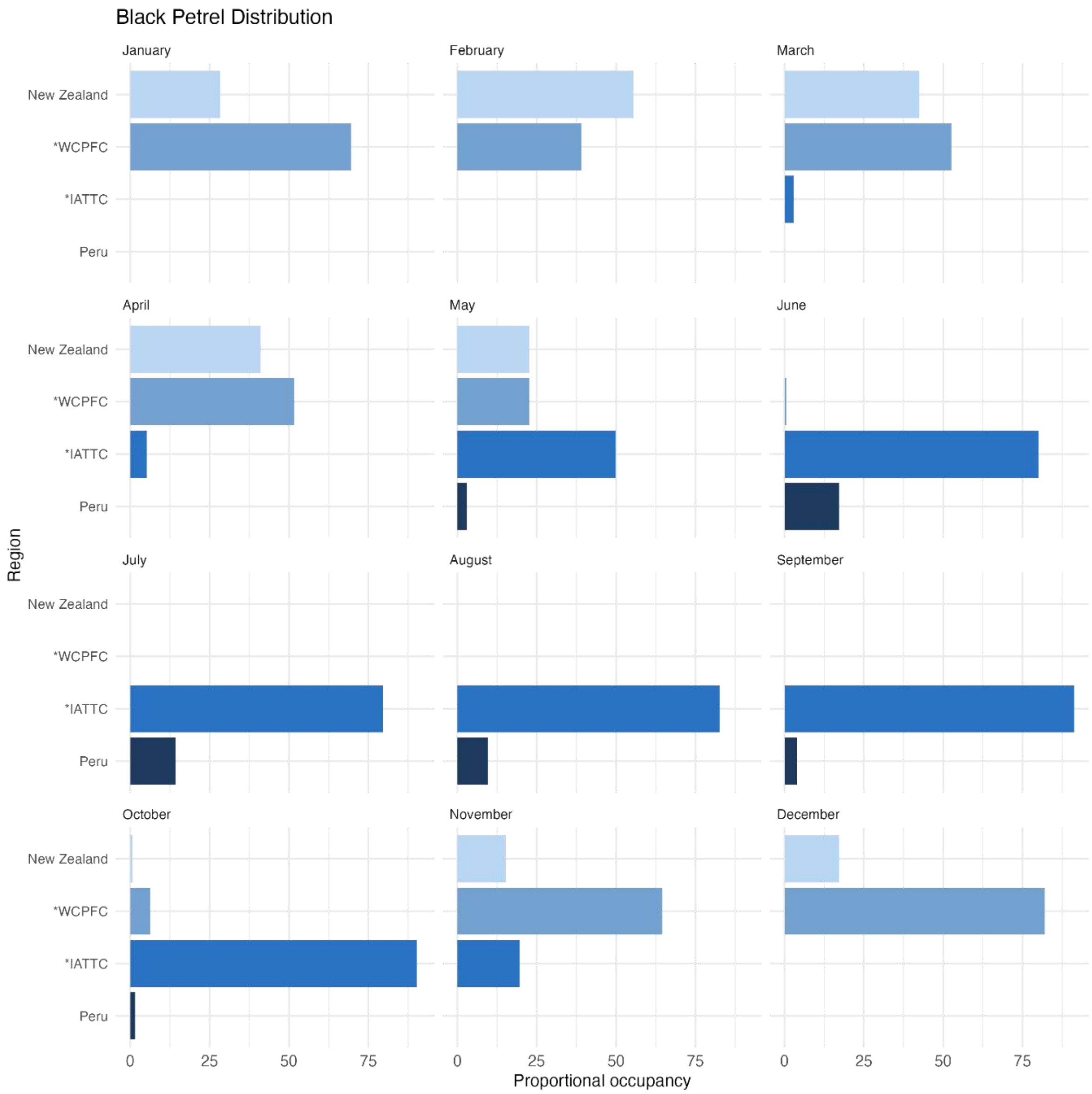

Figure 3. Monthly Black Petrel distributions by region. Bars titled New Zealand and Peru represent Black Petrel occupancy in the respective EEZs. *WCPFC represents fisheries management region exclusive of New Zealand EEZ and IATTC overlap. *IATTC represents fisheries management region exclusive of Peru EEZ.

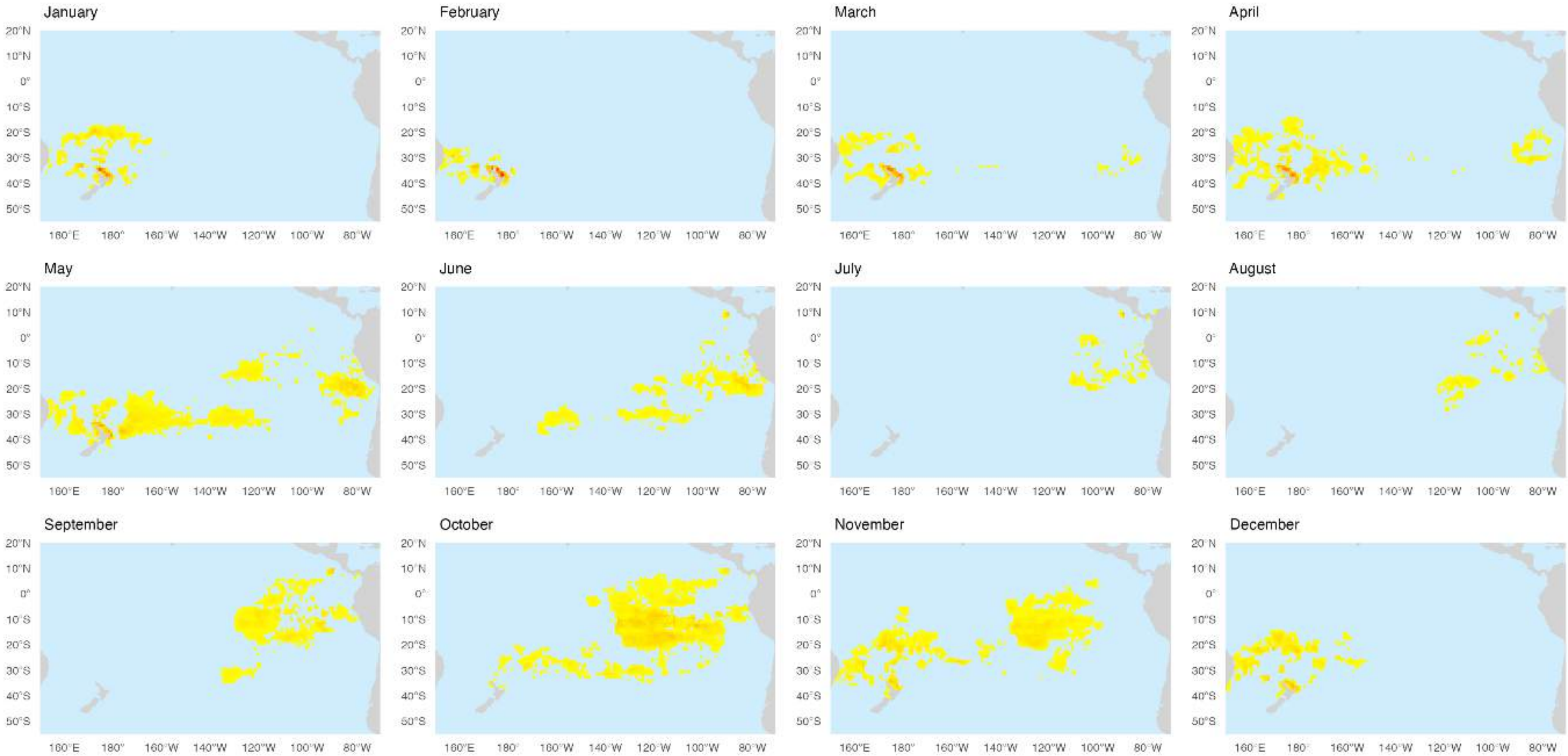

Figure 4. Range-wide overlap between Black Petrel and pelagic longline fisheries. Heatmaps illustrate the degree of relative overlap, with colours transitioning from yellow to red, where red indicates the highest levels of bird-vessel interaction.

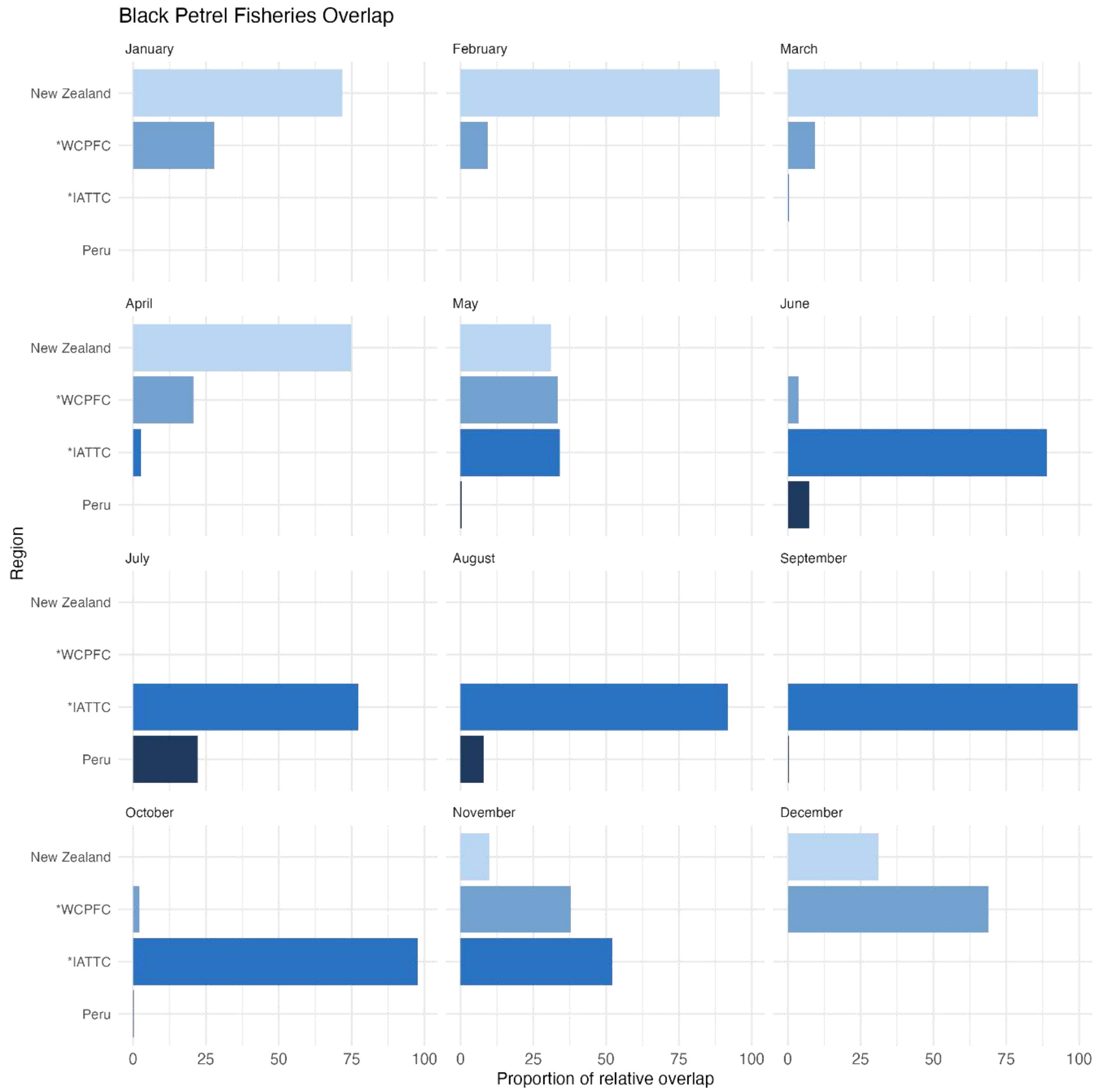

Figure 5 Monthly overlap between Black Petrel and fisheries by management region. Bars labelled 'New Zealand' and 'Peru' represent Black Petrel occupancy within the respective EEZs. WCPFC (Western and Central Pacific Fisheries Commission) represents the fisheries management region excluding the New Zealand EEZ and IATTC overlap. IATTC (Inter-American Tropical Tuna Commission) represents the fisheries management region excluding the Peru EEZ.

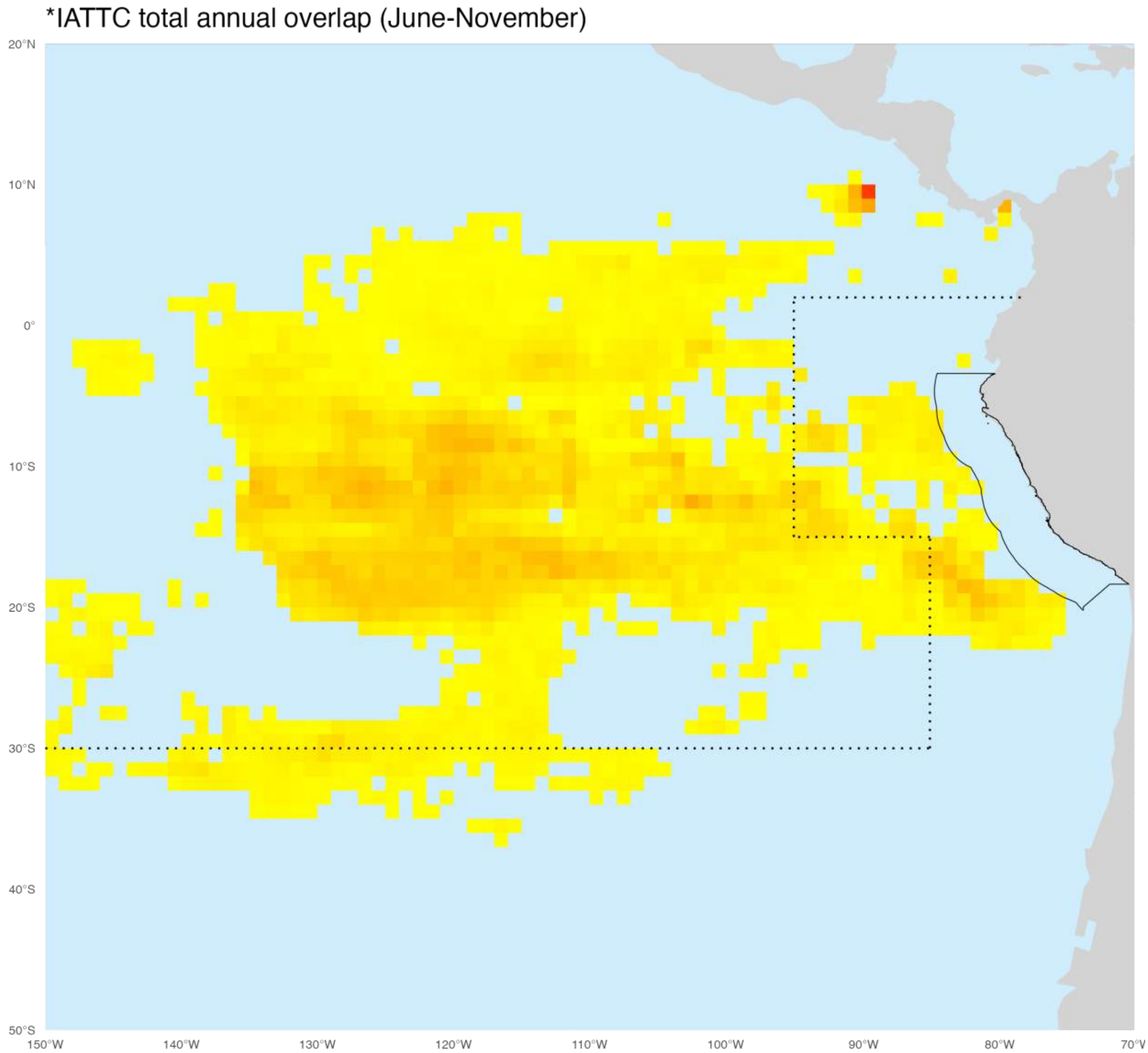

Figure 6 Total overlap between pelagic longline fisheries and Black Petrels within the IATTC region, excluding the Peru EEZ (see Figure 4). The data represents the period from June to November. Heatmaps display a gradient from yellow to red, with red indicating the highest levels of bird-vessel overlap. The dotted border delineates the spatial extent of seabird bycatch mitigation use required under IATTC Resolution C-11-02. All data are square root transformed for visualisation purposes.

Conclusions

Black Petrels are particularly susceptible to bycatch in pelagic longline fisheries and are recognised as a species of conservation concern. By analysing the spatial overlap between birds and pelagic longline fishing effort, we developed a comprehensive assessment of the relative bycatch risk to Black Petrels across their entire annual range. For breeding adult birds, by far the greatest overlap with pelagic longline fisheries during the non-breeding season is within the IATTC Convention Area, outside of the Peru EEZ and in a small but distinct hotspot off the coast of Costa Rica and Nicaragua. Considerable proportions of the overlap occur in areas where no seabird bycatch mitigation use is required by IATTC under Resolution C-11-02. While our findings indicate that the spatial overlap within the IATTC Convention Area is largely confined to the non-breeding period, it is known that juveniles and immature Black Petrels – as well as potentially other non-breeding individuals (Bell et al. 2024) - occur in the Eastern Pacific at different times of the year. However, the movement patterns of these age classes remain insufficiently tracked, highlighting a key gap in our understanding of their exposure to bycatch risk.

Amongst those albatross and petrel species listed under Appendix I the Agreement on the Conservation of Albatrosses and Petrels, Black Petrels have greatest diving capabilities. Consequently, highly effective seabird bycatch mitigation approaches (i.e., combining various bycatch mitigation methods) are required to prevent these deep- and fast-diving birds from 1) accessing baited pelagic longline hooks (Düssler 2025) and 2) retrieving hooks and returning them to the surface and placing other species, such as albatrosses (Jimenez et al. 2012) at further risk. To provide adequate protection for the Vulnerable Black Petrel and other seabirds from pelagic longline fishing bycatch it is vital to ensure that bycatch mitigation is used across the range of the species, and the mitigation measures are sufficient to protect these birds from accessing baited hooks in their diving range.

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Appendix 1: Methods

Data collection and location processing

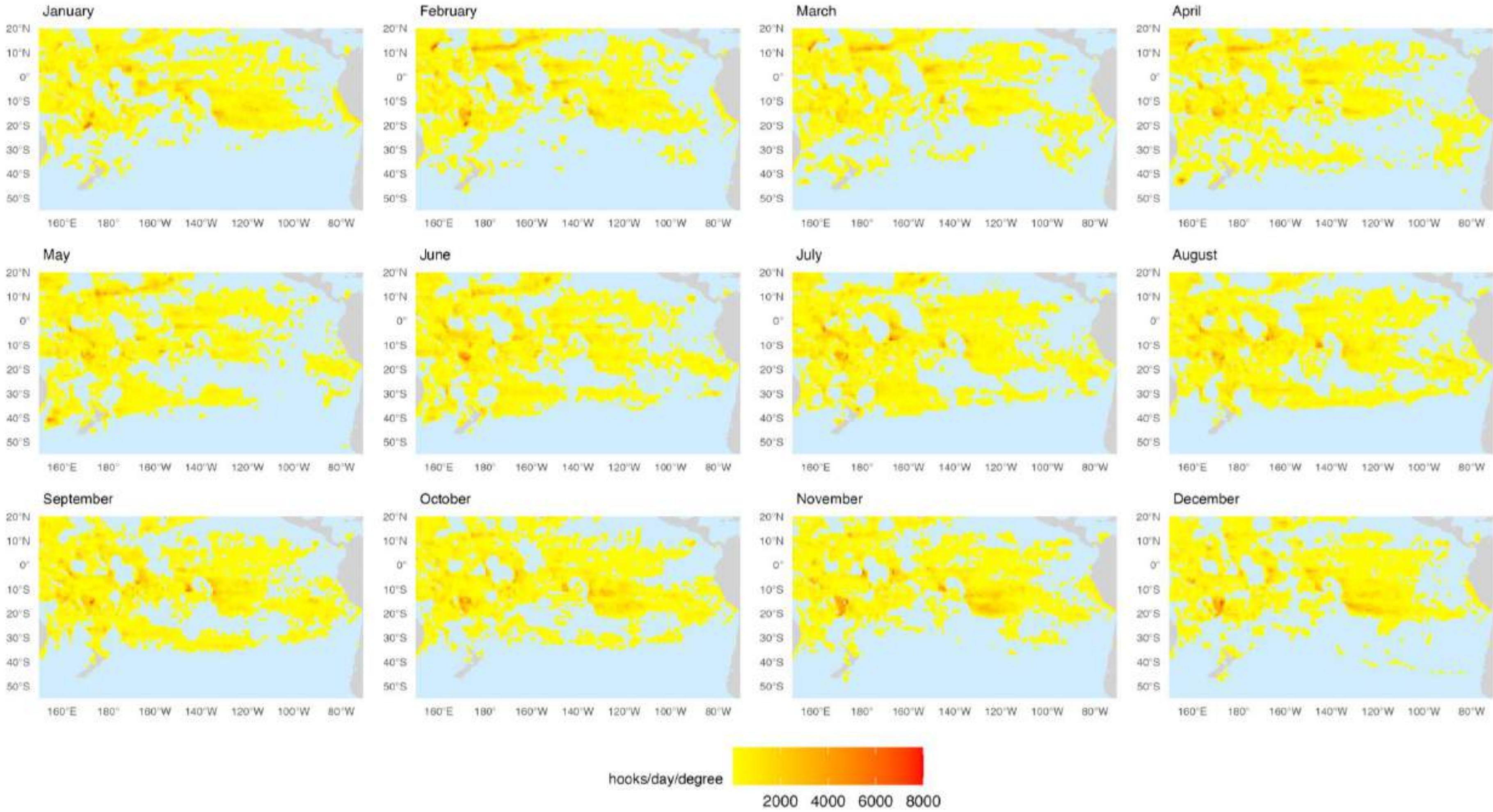
Year-round distribution layers for Black Petrels were developed using tracking data from 46 geolocators (GLS; Migrate Technology Ltd.) and 6 GPS loggers (PathTrack NanoFix). The geolocator data spanned the years 2018–2019, while the GPS data provided supplementary high-resolution location information collected between 2023 and 2024. Geolocator locations were processed in R (version 4.4.0) using the probGLS package (Merkel et al., 2016). All positional data were weighted according to tag type to reflect differences in spatial accuracy and sampling frequency and were standardised on a monthly basis to produce consistent temporal coverage across the annual cycle. For a comprehensive description of the data collection protocols and processing methodology, refer to Darby et al. (2024).

Fisheries overlap

To assess range-wide fisheries overlap with Black Petrel distribution, data were compiled from three primary sources: (i) New Zealand domestic fisheries data, (ii) Peruvian domestic fisheries data, and (iii) global Automatic Identification System (AIS) data. Domestic fisheries data were provided by the respective countries and encompassed fishing activity within each country's Exclusive Economic Zone (EEZ). Both the New Zealand and Peruvian datasets represented surface longline fisheries.

Domestic fishing effort was quantified at a spatial resolution of 1° × 1°, using temporally averaged data. For New Zealand, data from the years 2017, 2018, and 2019 were used, for Peru, data from 2018, 2019, and 2021 were included. Effort was expressed as the average number of hooks deployed per day per degree square and was disaggregated by month to capture seasonal variation in fishing activity.

For areas beyond national jurisdiction (hereafter referred to as the high seas), fishing effort was derived from global AIS data curated by Global Fishing Watch. These data were processed following the methodology outlined in Darby et al. (2024), resulting in estimates of fishing days per month per degree square. To enable integration of domestic and AIS-derived datasets into a unified global fishing effort raster, high seas fishing effort (in fishing days) was converted to an equivalent measure of hooks deployed. This was achieved by multiplying the number of fishing days by 3,300—the average number of hooks set per longline fishing event (Kroodsma et al. 2018)—and dividing by the number of days in each respective month. The resulting metric, average number of hooks per day per degree, was consistent with the format of the domestic datasets and allowed for spatial and temporal merging (Figure A).



Global fishing effort. Heatmaps illustrate the degree of fishing activity, with colours transitioning from yellow to red, where red indicates the highest levels fisheries activity. All data is square root transformed for visualisation.

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