



Agreement on the Conservation
of Albatrosses and Petrels

**Joint Thirteenth Meeting of the Seabird Bycatch
Working Group and Ninth Meeting of the Population
and Conservation Status Working Group**

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**Range-wide black petrel distribution and
overlap with pelagic longline fisheries: Insights
from AIS and domestic vessel data**

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SUMMARY

The Black Petrel *Procellaria parkinsoni* is a Vulnerable New Zealand endemic seabird that exhibits high susceptibility to bycatch in pelagic longline fisheries. The species undertakes extensive trans-Pacific movements, exposing it to fisheries operating across multiple jurisdictions where bycatch mitigation requirements coverage vary substantially. To quantify spatiotemporal exposure to pelagic longline effort across the species' full range, we integrated fine and coarse-scale year-round tracking data from 58 breeding adults with multiple fishing-effort datasets (AIS-derived effort from Global Fishing Watch, eLogbook data from the New Zealand EEZ, and reported artisanal effort from the Peruvian EEZ). Tracking data revealed pronounced seasonal movements, with adults occurring almost exclusively within the eastern Pacific (e.g., in the IATTC Convention Area and the Peruvian EEZ) during the non-breeding period (June–September). During the breeding season, individuals foraged widely with the New Zealand EEZ and across the high seas within the WCPFC Convention Area. Spatial overlays demonstrated extensive overlap throughout the Pacific. High overlap occurred near New Zealand where and when birds are breeding, but substantial overlap was also detected in regions where seabird bycatch mitigation requirements are reduced or absent (North of 30°S in the high seas of the WCPFC Convention Area). Notably, a large area of diffuse overlap was identified in the high seas within the IATTC Convention Area as well as in the form of a distinct hotspot in the high seas off the coast of Costa Rica and Nicaragua. Overlap within the Peruvian EEZ was limited. Most of the overlap hotspots in the East Pacific are not subject to bycatch mitigation requirements. These results indicate that Black Petrels experience significant exposure to bycatch-prone fisheries across multiple jurisdictions throughout their annual cycle, often with limited management in place, underscoring the need for consistent, effective mitigation measures capable of preventing access to baited hooks.

RECOMMENDATIONS

We recommend that the Joint SBWG13/PaCSWG9:

1. *Acknowledge* the updated spatial information for Black Petrels, including off the west coast of Mesoamerica, and the considerable overlap of Black Petrels with pelagic longline fisheries in the East Pacific.
2. *Recommend* that AC15 note the importance of incorporating of domestic artisanal fishing effort into range-wide bycatch assessments and encourage Parties to take such an approach to inform actions to mitigate bycatch.
3. *Recommend* that AC15 note the value in coordinated engagement with the Inter-American Tropical Tuna Commission to improve bycatch mitigation requirements to ensure year-round protection for Black Petrels, and other ACAP species, and prioritise work to achieve relevant targeted outcomes in the RFMCO Strategy.
4. *Recommend* that AC15 consider how ACAP and Parties could engage with Mesoamerican jurisdictions to promote at-sea conservation of Black Petrels and other ACAP-listed species in their waters and potentially grow ACAP membership in this region.

Distribución de *Procellaria parkinsoni* en toda su área de distribución y superposición con las pesquerías de palangre pelágico: perspectivas de los datos de AIS y de las embarcaciones nacionales

RESUMEN

Procellaria parkinsoni es un ave marina endémica vulnerable de Nueva Zelanda que presenta una alta susceptibilidad a la captura secundaria en las pesquerías de palangre pelágico. Esta especie se desplaza largas distancias a través del Pacífico, lo que la expone a pesquerías que operan en múltiples jurisdicciones, en las cuales la cobertura de los requisitos de mitigación de captura secundaria varía sustancialmente. Para cuantificar la exposición espaciotemporal al esfuerzo de palangre pelágico en toda el área de distribución de la especie, integramos datos de rastreo a escala fina y gruesa de 58 ejemplares adultos reproductores durante todo el año con múltiples conjuntos de datos de esfuerzo pesquero (esfuerzo derivado del AIS de Global Fishing Watch, datos de la bitácora electrónica de la ZEE de Nueva Zelanda y esfuerzo artesanal informado de la ZEE del Perú). Los datos de rastreo revelaron movimientos estacionales pronunciados, con adultos presentes casi exclusivamente en el Pacífico oriental (por ejemplo, en el área de la Convención de la CIAT y en la ZEE del Perú) durante la época no reproductiva (de junio a septiembre). Durante la temporada de reproducción, los ejemplares buscan alimento principalmente en la ZEE de Nueva Zelanda y en alta mar, dentro del Área de la Convención de la WCPFC. Las superposiciones espaciales demostraron una amplia superposición en todo el Pacífico. Hubo

una alta superposición cerca de Nueva Zelanda, en el lugar y el momento de reproducción de las aves, pero también se detectó una superposición sustancial en regiones donde los requisitos de mitigación de captura secundaria de aves marinas son reducidos o nulos (al norte de 30° S en alta mar del Área de la Convención de la WCPFC). Notablemente, se identificó un área grande de superposición difusa en alta mar dentro del Área de la Convención de la CIAT, así como en forma de una zona crítica perceptible en alta mar frente a las costas de Costa Rica y Nicaragua. La superposición dentro de la ZEE del Perú fue limitada. La mayoría de las zonas críticas de superposición en el Pacífico oriental no están sujetas a requisitos de mitigación de capturas secundarias. Estos resultados indican que las especies de *Procellaria parkinsoni* experimentan una exposición significativa a las pesquerías propensas a capturas secundarias en múltiples jurisdicciones a lo largo de su ciclo anual, a menudo con una ordenación limitada, lo que pone de manifiesto la necesidad de medidas de mitigación coherentes y efectivas capaces de prevenir el acceso a los anzuelos cebados.

RECOMENDACIONES

Recomendamos que la reunión conjunta de GdTCS13 y GdTPEC9:

1. Reconozca la información espacial actualizada sobre *Procellaria parkinsoni*, incluida la costa oeste de Mesoamérica, y la considerable superposición de *Procellaria parkinsoni* con las pesquerías de palangre pelágico en el Pacífico oriental.
2. recomiende que la CA15 tome nota de la importancia de incorporar el esfuerzo pesquero artesanal nacional a las evaluaciones de capturas secundarias en toda su área y anime a las Partes a adoptar este enfoque como base para las acciones de mitigación de captura secundaria.
3. recomiende que la CA15 tome nota del valor de la interacción coordinada con la Comisión Interamericana del Atún Tropical para mejorar los requisitos de mitigación de captura secundaria a fin de garantizar la protección de las especies de *Procellaria parkinsoni* y otras especies del ACAP durante todo el año, y priorice el trabajo para lograr los resultados específicos pertinentes en la estrategia de interacción con las OROCP.
4. recomiende que la CA15 considere cómo el ACAP y las Partes podrían colaborar con las jurisdicciones mesoamericanas para promover la conservación en el mar de *Procellaria parkinsoni* y otras especies incluidas en la lista del ACAP en sus aguas y, potencialmente, sumar miembros al ACAP en esta región.

Distribution du pétrel noir à l'échelle de son aire de répartition et chevauchement avec les pêcheries à la palangre pélagique : Éclairages tirés des données AIS et des données de navires nationaux

RÉSUMÉ

Le pétrel noir (*Procellaria parkinsoni*) est un oiseau marin endémique de Nouvelle-Zélande classé « vulnérable », qui présente une forte susceptibilité aux captures accessoires dans les pêcheries à la palangre pélagique. L'espèce effectue d'importants déplacements transpacifiques, l'exposant à des pêcheries opérant dans plusieurs juridictions où la couverture des exigences en matière d'atténuation des captures accessoires varie considérablement. Pour quantifier l'exposition spatiotemporelle à l'effort de pêche à la palangre pélagique sur l'ensemble de l'aire de répartition de l'espèce, nous avons intégré des données de suivi à échelle fine et grossière couvrant toute l'année, provenant de 58 adultes reproducteurs, avec plusieurs ensembles de données sur l'effort de pêche (effort dérivé de l'AIS de Global Fishing Watch, données de journaux de pêche électroniques de la ZEE néo-zélandaise et effort artisanal déclaré de la ZEE péruvienne). Les données de suivi ont révélé des mouvements saisonniers marqués, les adultes se trouvant presque exclusivement dans le Pacifique oriental (par exemple, dans la zone de convention de l'IATTC et la ZEE péruvienne) pendant la période inter-nuptiale (juin–septembre). Pendant la saison de reproduction, les individus exploitaient largement les zones d'alimentation dans la ZEE néo-zélandaise et en haute mer au sein de la zone de convention de la WCPFC. Les superpositions spatiales ont montré un chevauchement étendu dans l'ensemble du Pacifique. Un chevauchement élevé a été observé près de la Nouvelle-Zélande pendant la période de reproduction, mais un chevauchement important a également été détecté dans des régions où les exigences en matière d'atténuation des captures accessoires d'oiseaux marins sont réduites ou inexistantes (au nord de 30° S en haute mer dans la zone de convention de la WCPFC). Une vaste zone de chevauchement diffus a notamment été identifiée en haute mer au sein de la zone de convention de l'IATTC, ainsi qu'un point chaud distinct en haute mer au large des côtes du Costa Rica et du Nicaragua. Le chevauchement au sein de la ZEE péruvienne était limité. La plupart des points chauds de chevauchement dans le Pacifique oriental ne sont pas soumis à des exigences en matière d'atténuation des captures accessoires. Ces résultats indiquent que les pétrels noirs sont fortement exposés aux pêcheries à risque de captures accessoires dans plusieurs juridictions tout au long de leur cycle annuel, souvent en l'absence de mesures de gestion suffisantes, ce qui souligne la nécessité de mesures d'atténuation cohérentes et efficaces permettant d'empêcher l'accès aux hameçons appâtés.

RECOMMANDATIONS

Nous recommandons que le SBWG13/PaCSWG9 conjoint :

1. Reconnaître les informations spatiales mises à jour concernant les pétrels noirs, y compris au large de la côte ouest de la Mésoamérique, ainsi que le chevauchement important des pétrels noirs avec les pêcheries à la palangre pélagique dans le Pacifique oriental.

2. Recommande que le CC15 prenne note de l'importance d'intégrer l'effort de pêche artisanale domestique dans les évaluations des captures accessoires à l'échelle de l'aire de répartition et encourage les Parties à adopter une telle approche pour orienter les actions visant à atténuer les captures accessoires.
3. Recommande que le CC15 prenne note de l'intérêt d'un engagement coordonné avec la Commission interaméricaine du thon tropical (IATTC) afin d'améliorer les exigences en matière d'atténuation des captures accessoires pour garantir une protection tout au long de l'année des pétrels noirs et d'autres espèces de l'ACAP, et de prioriser les travaux visant à atteindre des résultats ciblés pertinents dans la Stratégie RFMCO.
4. Recommande que le CC15 examine comment l'ACAP et les Parties pourraient s'engager auprès des juridictions mésoaméricaines afin de promouvoir la conservation en mer des pétrels noirs et d'autres espèces inscrites à l'ACAP dans leurs eaux, et potentiellement accroître l'adhésion à l'ACAP dans cette région.

1. Introduction

Black Petrels (Tākōketai, *Procellaria parkinsoni*) are a Vulnerable seabird species (IUCN 2024) with a small breeding population of ~5,500 pairs restricted to two island colonies in northern New Zealand (Bell et al. 2016a; Bell et al. 2022). They are identified as one of the most at-risk seabirds to commercial fisheries bycatch in New Zealand and are caught in multiple fishing gears, with substantial annual captures recorded in domestic pelagic longline fisheries (Edwards et al. 2023). Previous tracking studies have demonstrated that, even while central-place constrained during the breeding season, Black Petrels routinely forage well beyond New Zealand's Exclusive Economic Zone (EEZ) (Bell et al. 2020). Outside the breeding period, this highly mobile species ranges widely across the Pacific, with juveniles, immatures, and non-breeding adults occupying waters of the Equatorial South America region (Imber et al, 2003, Reyes et al. 2017, 2024) and the Northern Humboldt Current off Peru (Quiñones et al. 2020, Fischer et al. 2023).

Black Petrels are particularly susceptible to bycatch in pelagic longline fisheries due to their deep-diving capabilities (Düssler et al. 2026). 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 can dive 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 associated seabird species, remain vulnerable even when standard mitigation measures (e.g., bird-scaring lines, line weighting, night setting) are implemented in isolation (Düssler et al. 2026). If no mitigation measures are implemented, as can be the case for artisanal fisheries (e.g., those targeting mahi-mahi off the coast of South America), Black Petrels are at a very high risk of bycatch.

Understanding the spatial and temporal overlap between Black Petrels and pelagic longline fisheries is essential for identifying high-risk areas and evaluating whether current mitigation requirements are in place where required and adequate for species protection (Debski et al. 2016). While previous assessments have examined overlap within the New Zealand EEZ (Bell et al. 2013), range-wide analyses encompassing the full annual cycle and multiple management jurisdictions have not yet been conducted. Here, we integrate fine-scale GPS tracking of breeding adults with coarse-scale geolocator data spanning the full annual cycle to characterise Black Petrel distribution and generate standardised monthly range estimates. These distribution layers are then overlaid with spatiotemporal pelagic longline fishing-effort datasets, including AIS-derived effort from Global Fishing Watch and reported effort data across the Exclusive Economic Zones of New Zealand and Peru to quantify fisheries overlap across the species' entire range. This combined approach enables simultaneous assessment of species distribution dynamics and exposure to fishing effort. Finally, we interpret these results in the context of current bycatch mitigation requirements, including spatial provisions under the Inter-American Tropical Tuna Commission (IATTC) and the Western Central Pacific Fisheries Commission (WCPFC).

2. Methods

2.1 Data Collection

Geolocators (C330, Migrate Technology Ltd; 1 g) were fitted to 55 breeding Black Petrels on Aotea Great Barrier Island (36.21°S, 175.45°E) in March 2018, and 46 units were successfully recovered in January 2019. No adverse effects of carrying the devices were detected, and birds showed an average mass increase of 86 g between deployment and recapture. Further methodological details are provided in Bell et al. (2020). To enhance coarse-scale distribution estimates from geolocators, and to cover periods when geolocator data were missing (e.g., February) or influenced by behaviour (Halpin et al. 2021), GPS units were deployed on breeding adults between December 2023 and May 2024. GPS loggers recorded positions every 5 minutes for short deployments (n = 6, 2 - 22 days) and every 10 minutes for longer deployments (n = 6, 59 - 78 days). Devices used were iGotU GT120 (17 g) or customised PathTrack NanoFix (9 g), attached to mantle feathers with fabric (Tesa) tape. Combined device and attachment mass remained below 3% of each bird's body weight. All fieldwork was conducted with approval from Ngāti Rehue Ngātiwai ki Aotea and the New Zealand Department of Conservation.

2.2 Location data processing

Data processing and analysis were conducted in R version 4.4.0 (R Core Team 2024). Geolocator records were converted into twice-daily position estimates using the *probGLS* package, which applies a probabilistic framework incorporating saltwater immersion and sea-surface temperature to address known limitations in geolocator accuracy (Merkel et al. 2016). A land mask was included to prevent positions being assigned over terrestrial areas. Occasional erroneous tracks such as jumps to the equator or across land into the Caribbean were removed through additional spatial filtering. Location estimates derived from this approach are expected to have median errors of up to ~185 km during solstice and equinox periods, when uncertainty is greatest. GLS and GPS locations were then combined, with each point assigned a weight based on its temporal resolution, expressed as a fraction of a day (Table 1).

Table 1: Expected temporal resolution of each device, and the corresponding weight of each location contributing to distribution estimates.

Device	Resolution	Weight (days)
Geolocator	12 hours	0.5
GPS (short-term)	5 minutes	0.0035
GPS (long-term)	10 minutes	0.007

Monthly distribution layers were generated by mapping all locations onto a 1° × 1° grid using the *raster* package (Hijmans 2023), summing weighted locations within each cell to represent bird-days. To reduce positional noise inherent in geolocator data, rasters were first aggregated by a factor of three and then resampled back to a 1/12° grid using bilinear interpolation. A final land mask was applied using bathymetric data from the *marmap* package (Pante et al. 2023) to remove any remaining terrestrial values. Because tracking effort varied among months, for example due to additional GPS deployments in the austral summer or gaps created during processing, each monthly layer was standardised by its total weighted sum.

2.3 Pelagic longline fishing effort data compilation and standardisation

To quantify range-wide overlap between Black Petrel distribution and pelagic longline fisheries, we assembled fishing-effort information from three main sources: (i) New Zealand domestic eLogbook data, (ii) Peruvian domestic fisheries records, and (iii) global Automatic Identification System (AIS) data. Domestic datasets were supplied directly by national authorities and described fishing activity occurring within each country's Exclusive Economic Zone (EEZ). Both datasets represented pelagic longline operations targeting highly migratory species.

Domestic fishing effort was summarised on a $1^{\circ} \times 1^{\circ}$ spatial grid using temporally averaged effort values. For New Zealand, data from 2017–2019 were included, while the Peruvian dataset comprised effort from 2018, 2019, and 2021. Effort was standardised as the mean number of hooks deployed per day per degree square and was further partitioned by month to capture seasonal patterns in fishing intensity. In accordance with New Zealand fisheries data-confidentiality requirements, both the New Zealand and Peruvian datasets were screened prior to analysis and any $1^{\circ} \times 1^{\circ}$ grid cell in which fishing activity was associated with <3 vessels was redacted to protect vessel-level privacy. These confidentiality filters were applied before spatial standardisation and integration with AIS-derived effort, ensuring that all domestic fishing-effort layers complied with national reporting rules while maintaining consistency across the combined global dataset.

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 via the *gfw* R package (Sanchez-Tapia et al. 2025). Global Fishing Watch provides these data as both vessel hours and fishing hours at a 0.01° spatial and daily temporal resolution, split by gear type. For this study, average pelagic longline fishing days per month were calculated at a 1° squared resolution, using averaged data from 2017, 2018, and 2019 (centred around the geolocator tracking data), and across the full range of this species, 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 AIS 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.

2.4 Fisheries overlap

To evaluate spatial and temporal overlap between Black Petrel distribution and pelagic longline activity, we generated monthly overlap rasters by multiplying each species-distribution layer with the corresponding monthly fishing-effort layer. The resulting values, representing the product of bird-days and fishing effort (hooks per day per degree), provided a relative index of exposure, expressed as estimated hooks per bird per day per degree. This metric served as a proxy for potential interaction risk and was subsequently used to examine spatial patterns and seasonal variation in bycatch risk across the species' range.

3. Results

3.1 Black Petrel Distribution

The annual range of Black Petrels encompassed a broad expanse of the Pacific Basin, highlighting the species' extensive trans-oceanic movements. Across the full annual cycle, tracked birds ranged from Eastern Australia in the west to the continental margins of Central and South America in the east, reaching as far north as the Gulf of Panama and coastal Costa Rica and Nicaragua, and extending southward into offshore waters of the Peruvian–Chilean upwelling zone (Figures 1–2). During the breeding season, individuals undertook long-distance foraging trips from Aotea Great Barrier Island, frequently travelling more than 1,000 km from the colony (Figure 1B). Despite these wide-ranging movements, the highest densities during January–May were concentrated around the colony and in waters north of New Zealand, reflecting the spatial constraints imposed by incubation and chick-rearing.

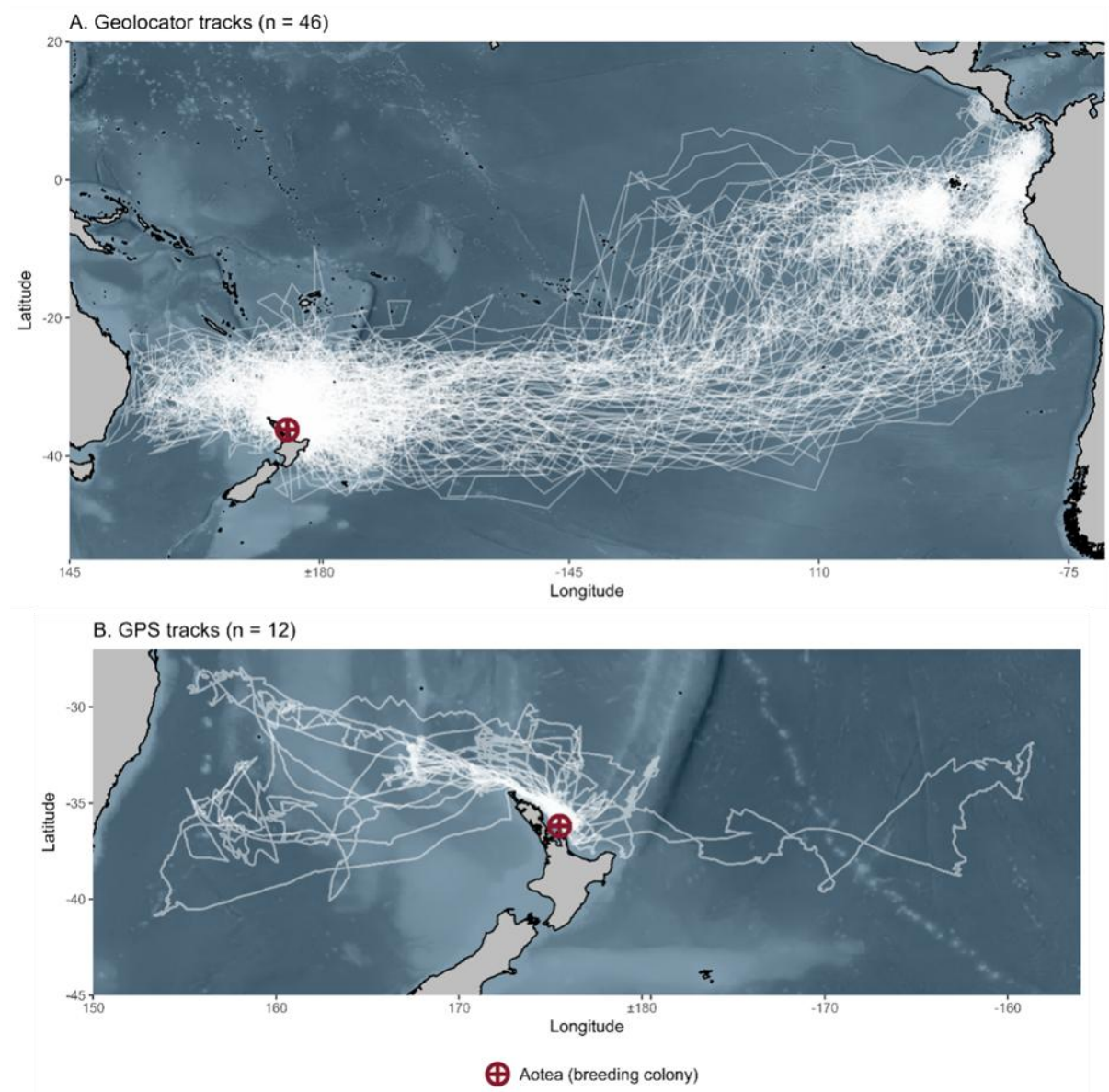


Figure 1: Tracks from Black Petrels equipped with geolocators (A) and GPS devices (B).

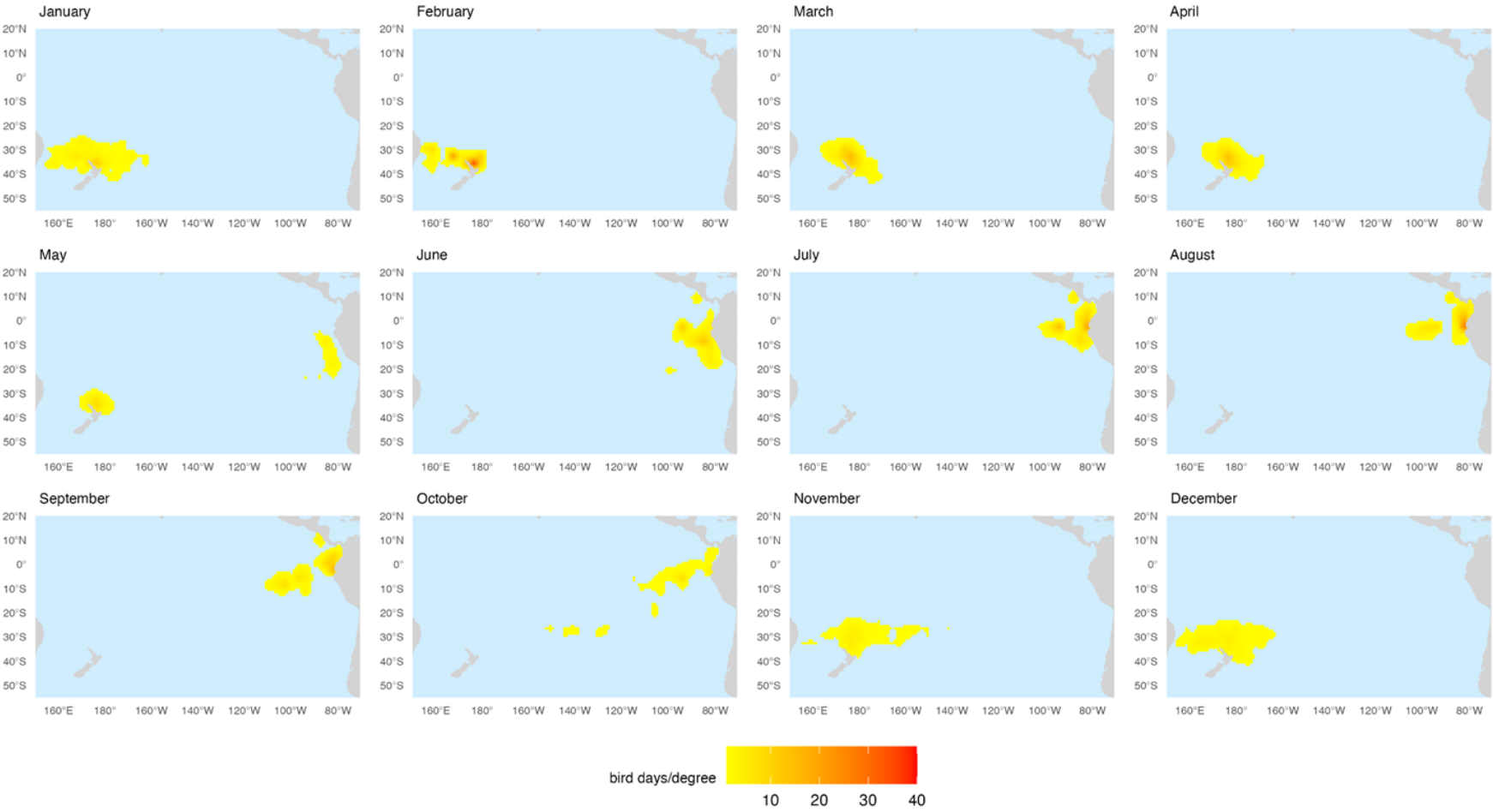


Figure 2: Monthly Black-Petrel distribution - geolocator and GPS data.

Outside the breeding period, distribution shifted markedly eastward. From June to September, birds aggregated in two prominent non-breeding hotspots: (i) the highly productive Peruvian coastal upwelling system—particularly between the Ecuador–Peru boundary within the ecotone transitional zone —and (ii) waters west of the Galapagos Islands (Figure 2). These areas are characterised by elevated primary productivity and predictable prey availability, and the strong seasonal shift in occupancy underscores the species’ reliance on eastern Pacific upwelling systems during the non-breeding months.

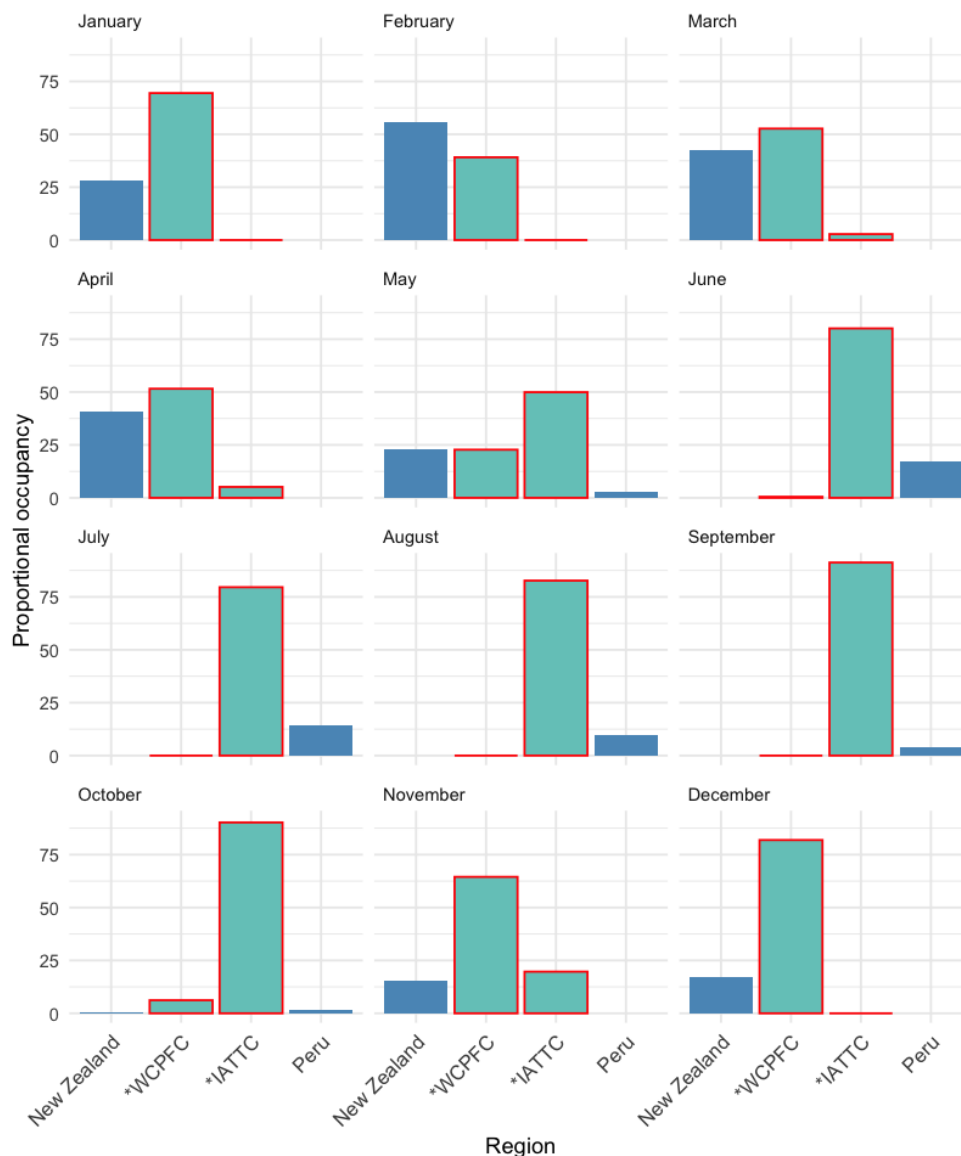


Figure 3: Monthly Black Petrel distributions by jurisdiction. Bars titled New Zealand and Peru represent Black Petrel occupancy in the respective EEZs. *WCPFC represents fisheries management region exclusive of New Zealand EEZ and IATTC overlap. *IATTC represents fisheries management region exclusive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

It is important to note that these results reflect the movements of breeding adults only. The distribution of immature and other non-breeding birds may differ substantially from that of adults. For example, at-sea surveys in the Peru EEZ have documented Black Petrels during the breeding season (Quiñones et al. 2020, Fischer et al. 2023), likely representing juvenile and immature individuals that do not return to the colony. Such age-specific differences in

distribution suggest that the species' true range may be even broader or more seasonally complex than indicated by adult-based tracking alone. Additional tracking of younger age classes would therefore improve understanding of population-level spatial ecology and refine assessments of exposure to fisheries across the full demographic spectrum.

3.2 Fisheries overlap

Black Petrels overlapped extensively with pelagic longline fisheries across much of their range and throughout the annual cycle (Figure 4 - 7). Spatial patterns of overlap closely mirrored seasonal shifts in Black Petrel distribution, with the highest overlap during the breeding period (December to April) occurring within the New Zealand EEZ and adjacent areas of the WCPFC Convention Area. High-density overlap was evident not only around the breeding colony but also across the high seas south of 30°S in the Tasman Sea and east of New Zealand (Figure 4). Additional areas of substantial overlap occurred between 30°S and 25°S in both the high seas and the Australian EEZ, as well as north of 25°S across multiple EEZs and high-seas regions where bycatch mitigation requirements are reduced or not mandatory (Figure 5 & 6).

Relative overlap - defined as overlap per unit of bird occurrence - was highest north of 25°S (Figure 6) within the West Pacific. Although birds spent comparatively little time in these lower latitudes (Figure 2), the intensity of fishing effort in these areas resulted in disproportionately high overlap values, suggesting elevated bycatch risk during the periods birds were present.

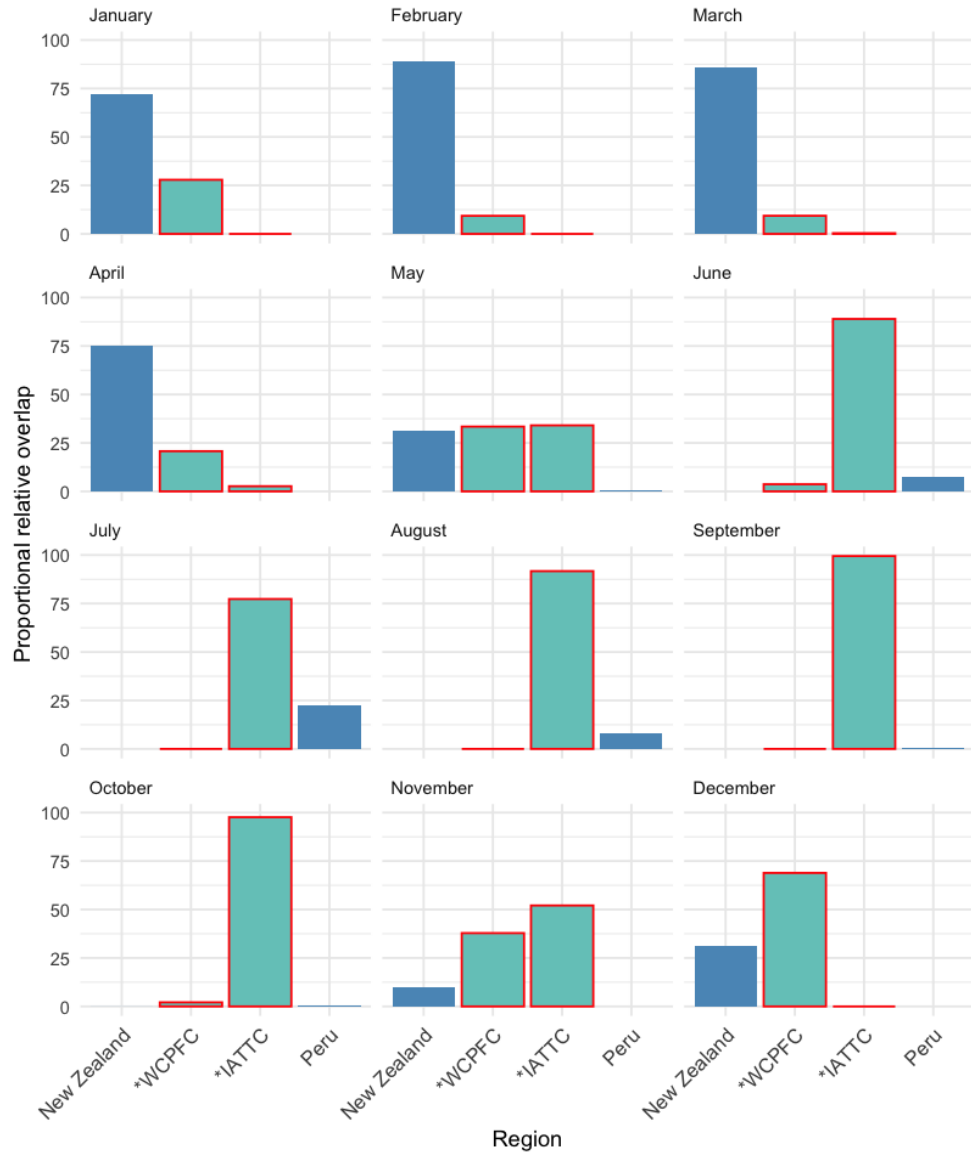


Figure 4: Monthly Black Petrel overlap by region. Bars titled New Zealand and Peru represent Black Petrel occupancy in the respective EEZs. *WCPFC represents fisheries management region exclusive of New Zealand EEZ and IATTC overlap. *IATTC represents fisheries management region exclusive of Peru EEZ.

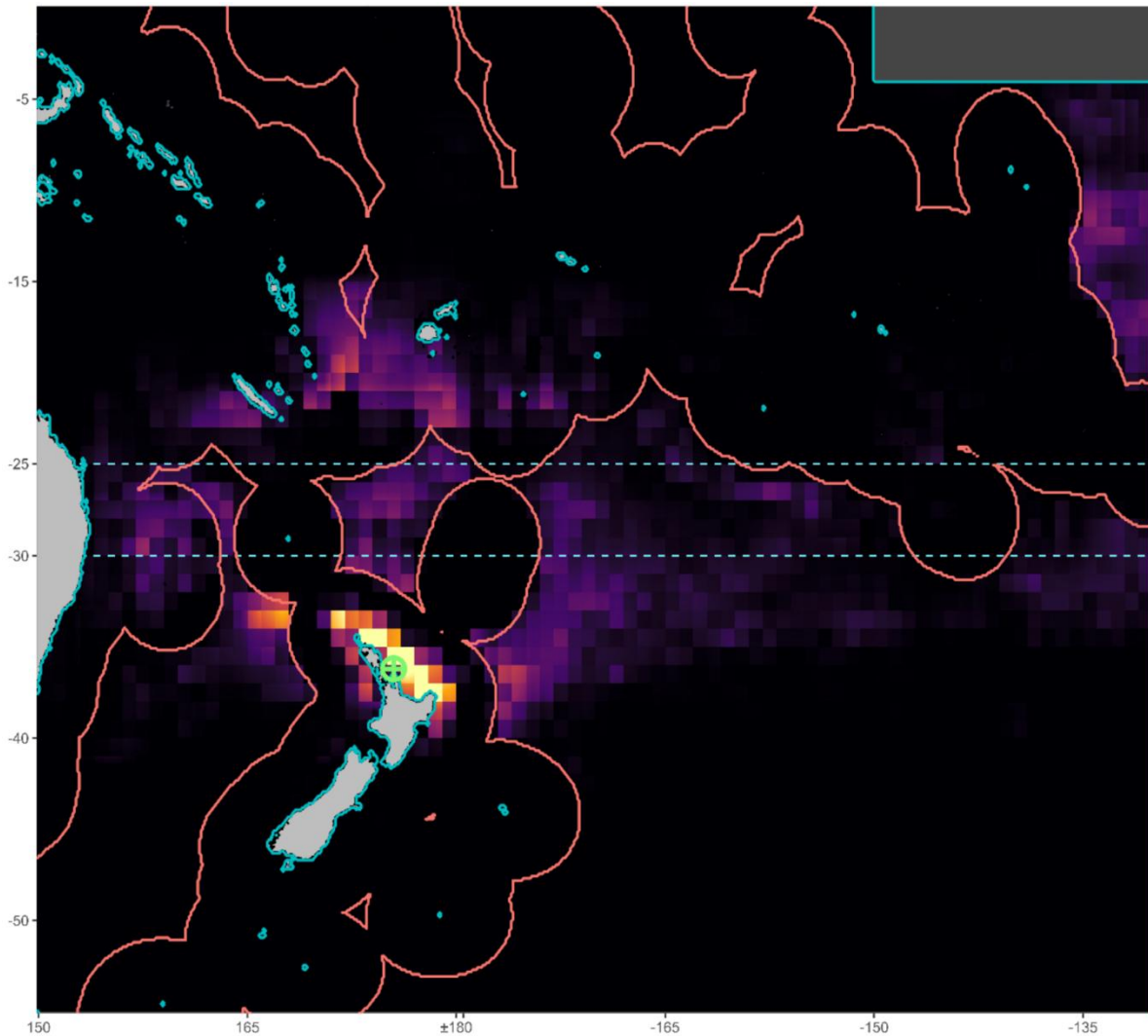


Figure 5: Black Petrel overlap with pelagic longline fishing effort in the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area. Intensity of colour is representative to degree of relative overlap.

During the non-breeding period (June–October), overlap shifted almost entirely into the eastern Pacific, aligning with the species' seasonal migration into the Peru EEZ and the IATTC Convention Area. A pronounced overlap hotspot was identified off the coasts of Costa Rica and Nicaragua, east of Central America (Figure 6 & 7), indicating a previously undocumented region of elevated potential interaction risk. In addition to this pronounced hotspot, a diffuse, large overlap pattern across much of the IATTC Convention Area became evident. Transitional months (May and November) showed intermediate overlap patterns spanning both western and eastern Pacific regions.

Within the IATTC Convention Area, total annual overlap between Black Petrels and pelagic longline fisheries (Figure 6) revealed substantial exposure in the eastern portion of the region where seabird bycatch mitigation is not currently required under IATTC Resolution C-11-02. This mismatch between areas of high overlap and areas where mitigation measures are mandated highlights a significant vulnerability for the species during the non-breeding season.

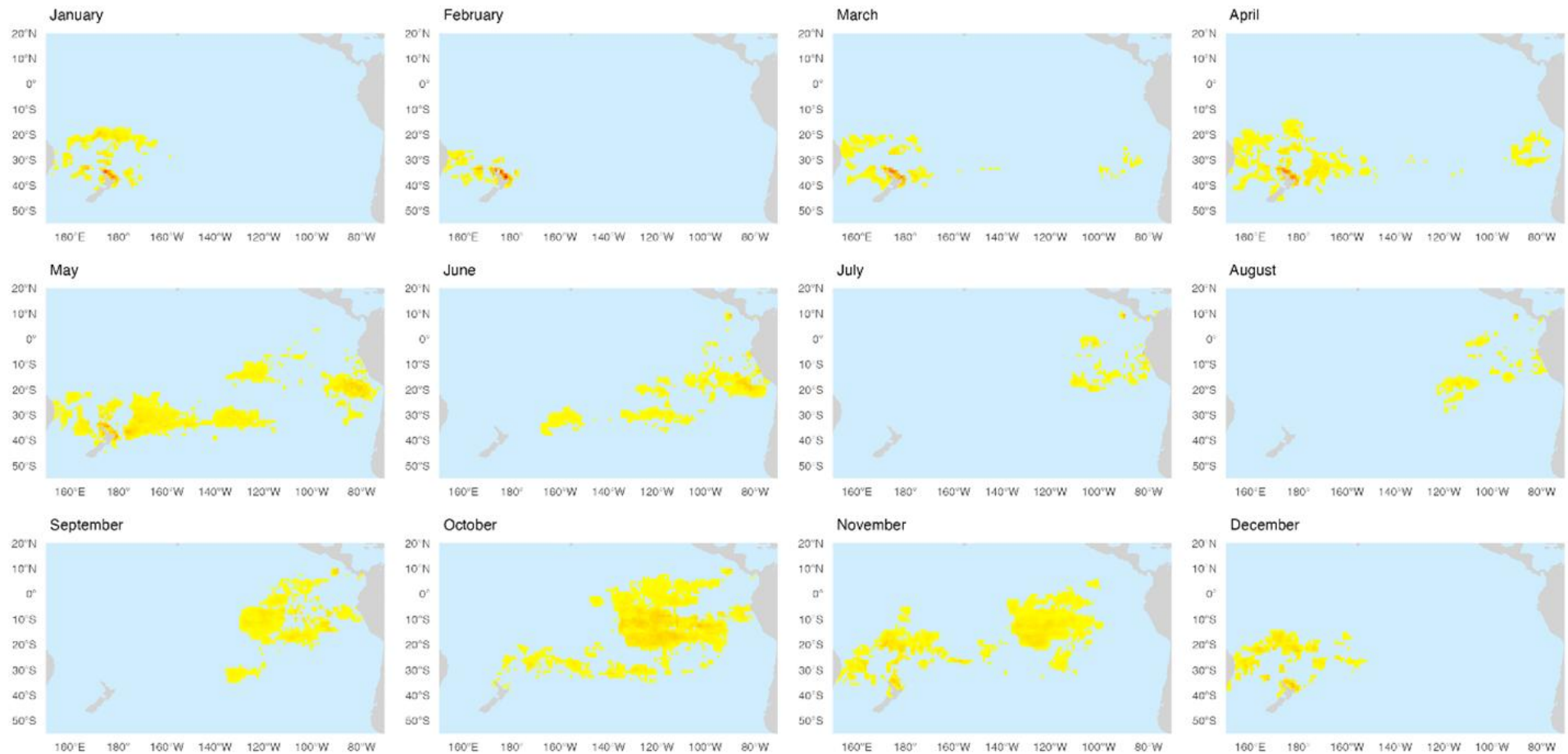


Figure 6. Range-wide overlap between Black Petrel and pelagic longline fisheries. Heatmaps illustrate the degree of relative overlap, with colours transitioning from yellow to red, where red indicates the highest levels of bird-vessel interaction.

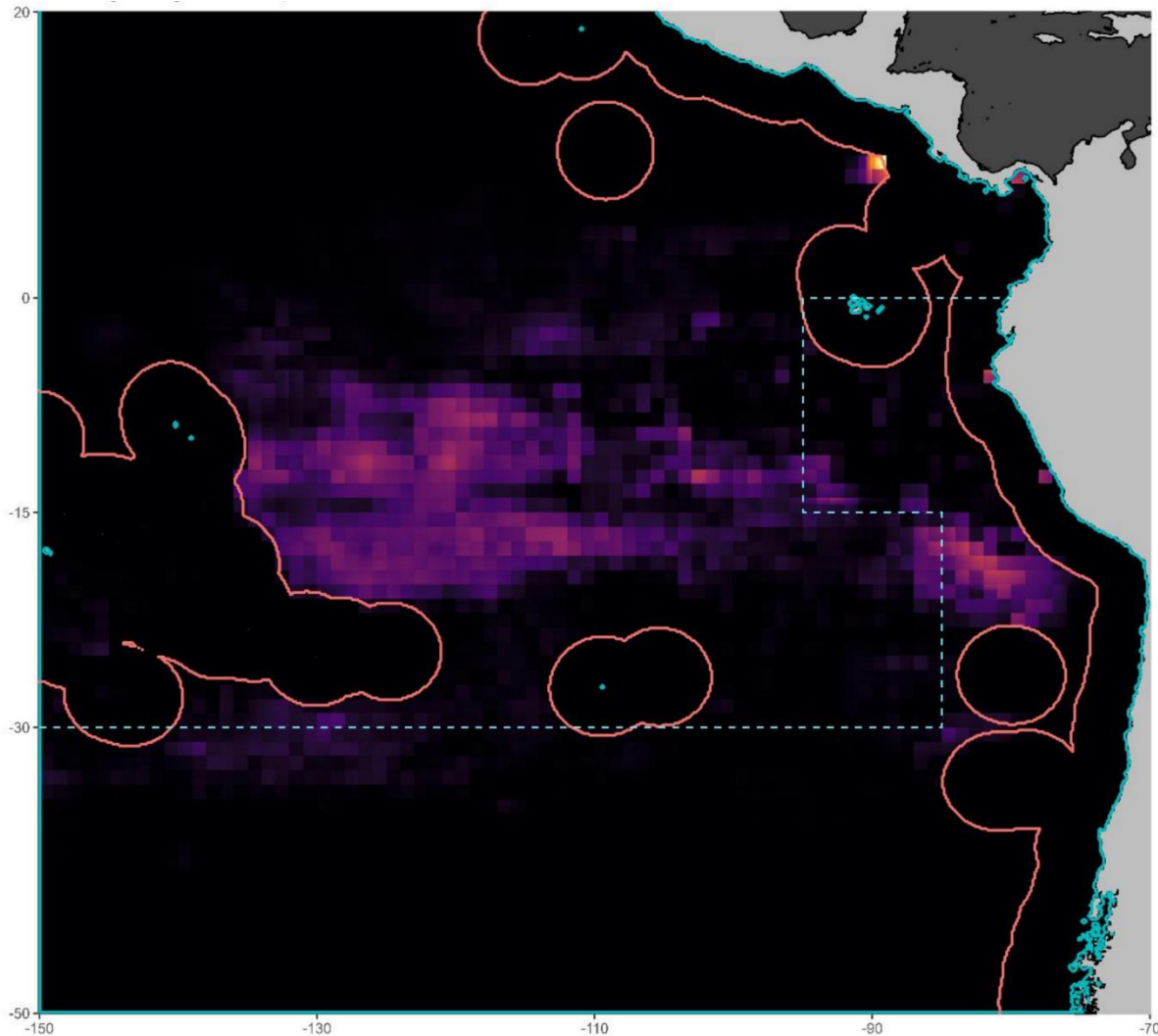


Figure 7: Black Petrel overlap with pelagic longline fishing effort in the Inter-American Tropical Tuna Commission (IATTC) Convention Area. Intensity of colour is representative to degree of relative overlap. The dotted border delineates the spatial extent of seabird bycatch mitigation use required under IATTC Resolution C-11-02.

4. Discussion

The pronounced seasonal shift in Black Petrel distribution, combined with the strong spatial structuring of overlap with pelagic longline fisheries, highlights the shared responsibility of both national jurisdictions and Regional Fisheries Management Organisations (RFMOs) in mitigating bycatch risk. During the breeding season, nearly all tracked adults remained within the New Zealand EEZ and adjacent areas of the WCPFC Convention Area. As a result, the effectiveness of New Zealand's domestic mitigation measures, together with the implementation and enforcement of WCPFC seabird bycatch requirements, plays a central role in determining adult survival during this period. High overlap around Aotea Great Barrier Island and in nearby high-seas areas underscores the importance of consistent implementation of simultaneous use of branch with branch line-weighting, night-setting, and bird scaring lines, or the use of hook-shielding devices, particularly given the species' central-place constraints and limited ability to avoid fishing activity while provisioning chicks.

However, the species' considerable diving capabilities suggest that weighted branch lines alone may be insufficient to prevent access to baited hooks, particularly in regions where only a single mitigation method is mandated. Black Petrels have been recorded diving to 38.5, well beyond the depths at which many mitigation measures are assumed to be effective, and they forage and dive at night, meaning night setting alone is unlikely to eliminate risk (Düssler et al. 2026). These behavioural traits indicate that a combination of all three mitigation methods, or the use of hook-shielding devices, is likely necessary at least up to 25°S to provide adequate protection for this vulnerable, deep-diving, highly mobile species. However, as lines can return to the surface during the soak period (Goad et al. 2025), further efforts are required to identify options to prevent bycatch, particularly of these proficient divers, post-set.

Within the WCPFC Convention Area, the spatial pattern of overlap aligns closely with areas where mitigation requirements vary substantially by latitude. South of 30°S, vessels must employ two mitigation methods (weighted branch lines, night setting, or bird scaring lines) or alternatively use hook-shielding devices. Between 30°S and 25°S, currently only a single mitigation method is required (but this will be extended to two by 2028), and north of 25°S, mitigation is recommended but not mandatory. Our results show that overlap is highest south of 30°S, where birds are afforded the strongest protection. However, 78% of tracked birds spent time north of 25°S within the WCPFC Convention Area, where mitigation is not mandatory and overlap with longline effort is substantial. Notably, when birds are foraging further north, they are much more likely to be co-occurring with fishing effort due to the increased effort closer to the equator, and thus improved bycatch mitigation requirements in lower latitudes are required as well.

Following the breeding season, Black Petrels migrate eastward and their distribution shifts almost entirely into the Peru EEZ and the IATTC Convention Area. This transition marks a second, equally important management window: the non-breeding period, when birds rely heavily on the Peruvian upwelling system and surrounding high-productivity waters, but migrate through a large area with considerable fishing effort. Our analyses show that the greatest overlap with pelagic longline fisheries during this period occurs within the IATTC Convention Area, particularly outside the Peru EEZ across a large diffuse area across the convention area, and in a distinct hotspot off Costa Rica and Nicaragua. Notably, considerable proportions of this overlap occur in areas where seabird bycatch mitigation is not required under IATTC Resolution C-11-02, creating a clear spatial mismatch between regulatory coverage and biological risk. Although the tracked breeding adults use this region primarily during the non-breeding season, juveniles, immatures, and potentially other non-breeding individuals are known to occur in the eastern Pacific at different times of the year (Quiñones et al. 2020, Fischer et al. 2023). Their movement patterns remain insufficiently tracked, highlighting a key gap in understanding demographic-specific exposure to bycatch risk, which may be more elevated than that of adults as high-risk fisheries, such as the mahi mahi artisanal pelagic longline fisheries, move closer to the coast during Nov-Feb, i.e., during the Black Petrel breeding period.

A major finding of the overlap analysis is the pronounced hotspot of Black Petrel co-occurrence with pelagic longline effort off the coast of Mesoamerica. Importantly, this region is also used by several other vulnerable seabird species, underscoring its broader conservation significance. Pink-footed Shearwaters (*Ardenna creatopus*), an aggressive species, vulnerable to bycatch, undertake extensive migrations through the eastern Pacific and frequently transit this zone during the non-breeding period, relying on continental shelf and slope waters from

Peru northward into Mexico and beyond (Felis et al., 2019). Studies have also documented Waved Albatrosses (*Phoebastria irrorata*) reaching as far north as Costa Rica, providing clear evidence that this critically endangered species can occur within the wider Mesoamerican region (Arias, 2024, Awkerman et al., 2014). In addition, recent at-sea surveys in the eastern Pacific have highlighted the presence of further at-risk species, including Flesh-footed Shearwaters (*A. carneipes*) (Arias & Vargas-Masis, 2025) and Salvin's Albatross (*Thalassarche salvini*) (Arias, 2024). Though these two species occur in higher densities in other parts of the Pacific (e.g., Quiñones et al. 2021), jointly these records indicate that multiple threatened taxa may be exposed to elevated levels of fisheries interactions in this broader offshore area. Despite the ecological importance and multi-species use of this region, the Mesoamerican hotspot lies entirely outside the areas in which IATTC Resolution C-11-02 mandates seabird-bycatch mitigation. As a result, vessels operating here are not required to implement bycatch mitigation measures, leaving seabirds exposed to unmitigated bycatch risk. The combination of high seabird overlap, and a complete absence of mandated mitigation substantially elevates the likelihood of harmful interactions with pelagic longline gear. Addressing this gap will require not only the extension of seabird-protection measures into this high-risk region but also increased research leadership from Mesoamerican nations. In particular, systematic monitoring of seabird occurrence, seasonal use of regional waters, and fisheries-interaction patterns is needed to fill critical knowledge gaps and support evidence-based, regionally grounded management.

Taken together, these patterns demonstrate that Black Petrel conservation cannot be achieved through isolated national actions alone. Instead, coordinated management across New Zealand, Peru, WCPFC, and IATTC is essential to ensure consistent protection throughout the species' annual cycle. The near-complete seasonal segregation between WCPFC-dominated and IATTC-dominated regions provides a clear framework for such coordination: New Zealand and WCPFC measures are most influential during the breeding season, while IATTC, Peru, and other coastal range states' measures dominate during the non-breeding period. Addressing demographic gaps, particularly through tracking of juveniles and immatures, will further refine understanding of population-level exposure and help ensure that management actions across all jurisdictions reflect the full spatial ecology of the species.

Finally, achieving a full understanding of Black Petrel exposure requires not only coordinated management but also comprehensive and complementary data streams. A key strength of our approach lies in the integration of AIS-derived fishing effort with domestically sourced data, which together provide a more complete representation of the fisheries operating across the Black Petrel range. AIS offers broad spatial coverage across the high seas and larger industrial fleets, enabling consistent tracking of longline activity throughout the WCPFC and IATTC Convention Areas. However, AIS alone cannot capture the full extent of fishing effort, as many smaller or near-shore vessels, particularly those operating within national EEZs, are not required to carry AIS transmitters or may transmit intermittently. By incorporating high-resolution, enforced data from New Zealand and Peru, we were able to resolve fine-scale coastal effort that would otherwise be underestimated or entirely absent from AIS-based analyses. This alignment of global AIS data with detailed domestic VMS records therefore provides a more accurate and spatially complete picture of fishing pressure, ensuring that both offshore industrial fleets and smaller coastal vessels are represented in assessments of bycatch exposure. Such integrated datasets are essential for evaluating risk across the full annual range of Black Petrels and for informing management decisions that depend on understanding the cumulative impact of multiple fleets operating at different spatial scales

5. Conclusion

Black Petrels experience substantial and seasonally shifting exposure to pelagic longline fisheries, with risk concentrated in the New Zealand EEZ and WCPFC Convention Area during the breeding season and in the Peru EEZ and IATTC Convention Area during the non-breeding period. These patterns reveal a clear division of responsibility across jurisdictions: New Zealand and WCPFC measures are most influential when adults are central-place foragers, while Peru and IATTC measures dominate during the months when birds rely on eastern Pacific upwelling systems. The mismatch between areas of highest overlap and areas where mitigation is currently required, particularly within the eastern IATTC region, highlights a critical vulnerability for this deep-diving, highly mobile species, and should be a management priority.

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