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Overlap between pelagic longline fisheries and Black Petrels in the WCPFC Convention Area

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ABSTRACT

Black Petrels are endemic to New Zealand, exclusively breeding on two island colonies. This species is highly vulnerable to bycatch in commercial fisheries, including in commercial pelagic longlines. Bycatch of Black Petrels in New Zealand fisheries is well monitored, and estimated mortality levels place this species at a relatively high risk level. However, this species' range extends well beyond New Zealand's jurisdiction. Little is known about bycatch risk beyond New Zealand's EEZ both during the breeding period when Black Petrels forage widely, and when birds migrate across the Pacific during the non-breeding period. This study aims to estimate overlap between Black Petrels and commercial pelagic longline fishing effort across the WCPFC Convention Area, as a proxy for bycatch risk. To achieve this, fine- and coarse-scale Black Petrel tracking data were combined with fishing effort data, inferred from Automatic Identification System data sourced from the Global Fishing Watch, to calculate year-round fisheries overlap in the WCPFC Convention Area. While the highest density of commercial pelagic longline overlap occurred close to New Zealand and south of 30°S, considerable overlap was evident in latitudes where fewer bycatch mitigation methods are required (30°S - 25°S) or not mandated (north of 25°S). Additionally, relative overlap of Black Petrels with commercial pelagic longline fishing effort was highest north of 25°S. Therefore, though this species spends reduced time north of 25°S in the WCPFC Convention Area, overlap with commercial pelagic longline fishing, and potential bycatch risk, is high when they do. We conclude that year-round tracking of this species has shown high overlap with bycatch-prone fisheries in areas of the WCPFC Convention Area with reduced bycatch mitigation efforts.

1. Introduction

Black Petrels (*Procellaria parkinsoni*) are a Vulnerable species (IUCN 2018), with a breeding population of ~5,500 pairs distributed across two island breeding colonies in Hauruki Gulf, New Zealand (Bell *et al*. 2016, 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, with substantial numbers caught annually in commercial pelagic longline fisheries (hereafter pelagic longline fisheries) (Edwards *et al*. 2023). Comparing the spatial distribution of Black Petrels and fisheries is therefore essential to understand high-risk areas for bycatch and to pursue effective bycatch mitigation methods (Debski *et al*. 2016).

Previous tracking work of breeding Black Petrels shows that, even while central-place constrained, 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 to the waters off Central and South America (Fischer *et al*. 2023), so it is necessary to consider fisheries overlap across the full range of this species to fully understand the bycatch risk of this species.

Here, we combine fine-scale tracking data from breeding Black Petrels (GPS) with coarse-scale tracking data covering the full annual cycle (geolocator), standardising locations from each source and creating a distribution estimate for each calendar month. In this use-case, we create comparable distribution estimates for pelagic longline fishing effort and compare overlap across the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area to help inform the review of WCPFC CMM 2018-03.

2. Methods

2.1. Data collection

Geolocators (C330, Migrate Technology Ltd; 1g) were deployed on 55 adult Black Petrels in March 2018 on Aotea | Great Barrier Island (36.21°S, 175.45°E), of which 46 were successfully retrieved in January 2019. Birds didn't exhibit negative effects of carrying geolocators, and an average weight change of +86 grams was observed between deployment and retrieval. For full tracking details, see Bell *et al*. (2020). To supplement coarse scale distribution estimates from geolocators, and to fill in periods during which geolocator data were not available (i.e. February) or when data are impacted by activity at the colony (Halpin *et al*. 2021), GPS devices were also deployed on breeding Black Petrels between December 2023 and May 2024. GPS loggers were parameterised to take fixes every 5 minutes for shorter deployments (n = 6, 2 – 22 days) and 10 minutes for longer deployments (n = 6, 59 – 78 days). Devices were iGotU GT120 (17g) or customised PathTrack NanoFix (9g) and fixed to the mantle feathers of birds using Tesa tape 4752. Total device and attachment weight was always < 3% of the bird's body weight. All data collection was collected with the permission of Ngāti Rehue Ngātiwai ki Aotea and the New Zealand Department of Conservation.

2.2. Location data processing

Data processing and analyses were completed using R version 4.4.0 (R Core Team 2024). Geolocator data were processed into location estimates twice daily using the *probGLS* package, which uses a probabilistic algorithm incorporating saltwater immersion and sea-surface temperature to overcome issues of inaccuracy in geolocator-based location estimation (Merkel *et al*. 2016). This method applies a land mask, preventing location estimates over land. Trace spurious location jumps to the equator and across land into the Caribbean were subsequently further filtered by applying simple location masks. Geolocator-derived locations generated using this method are assumed to have a median error of up to 185km at the solstices and equinoxes, during which the error associated with this method is highest. Location data were grouped from GLS and GPS sources, with a weight applied to each data point by calculating the programmed temporal resolution 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

Location data were then used to calculate monthly distributions by extracting locations to a 1x1 degree spatial surface using the *raster* package (Hijmans 2023), with locations summed and weighted by values in table 1 in each grid cell. The resulting raster described bird days per grid cell as a unit across the range of this species. These data were then aggregated by a factor of 3, to smooth across errors of locations generated from geolocator data, then disaggregated using bilinear interpolation to a achieve a final resolution of 1/12 of a degree squared. A land mask was then applied to remove density estimates that fell over land using bathymetry data generated using the *marmap* package (Pante *et al*. 2023). Because different months had varying levels of tracking data available (e.g. supplement of GPS data in austral summer, or missing locations due to processing protocols), total summed data for each month's distribution layer was standardised.

2.3. Fisheries overlap

Automatic Identification System (AIS) data from fishing vessels are curated on a global scale by Global Fishing Watch (Kroodsma *et al*. 2018). 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. For each calendar month, overlap between pelagic longline fishing and Black Petrels was calculated by multiplying the Black Petrel distribution raster by the corresponding fishing effort raster. The product of these two values, i.e. bird days times fishing days per month per grid cell, provided the overlap metric used for further analyses, hereafter "days / month". Within the WCPFC Convention Area, overlap was assessed south of 30°S, between 30°S and 25°S, and north of 25°S, as bycatch mitigation methods required under WCPFC CMM 2018-03 (WCPFC 2018) vary based on these latitudinal thresholds.

3. Results

3.1. Black Petrel distribution

Annual range of Black Petrels extended from Eastern Australia in the east to the Gulf of Panama in the west (Figure 1A). Breeding Plack Petrels also ranged considerable distances on foraging trips during the breeding period, often travelling well over 1000km from the colony (Figure 1B). Distribution is densest around the colony and waters north of New Zealand from January to May during the breeding season while the birds are central-place constrained (i.e., when they are spatially restricted to areas near breeding grounds due to the need to attend to eggs or chicks). However, considerable hotspots were also evident around the Peruvian coastal upwelling system and west of the Galapagos Islands during the non-breeding season, from June to September (Figure 2).

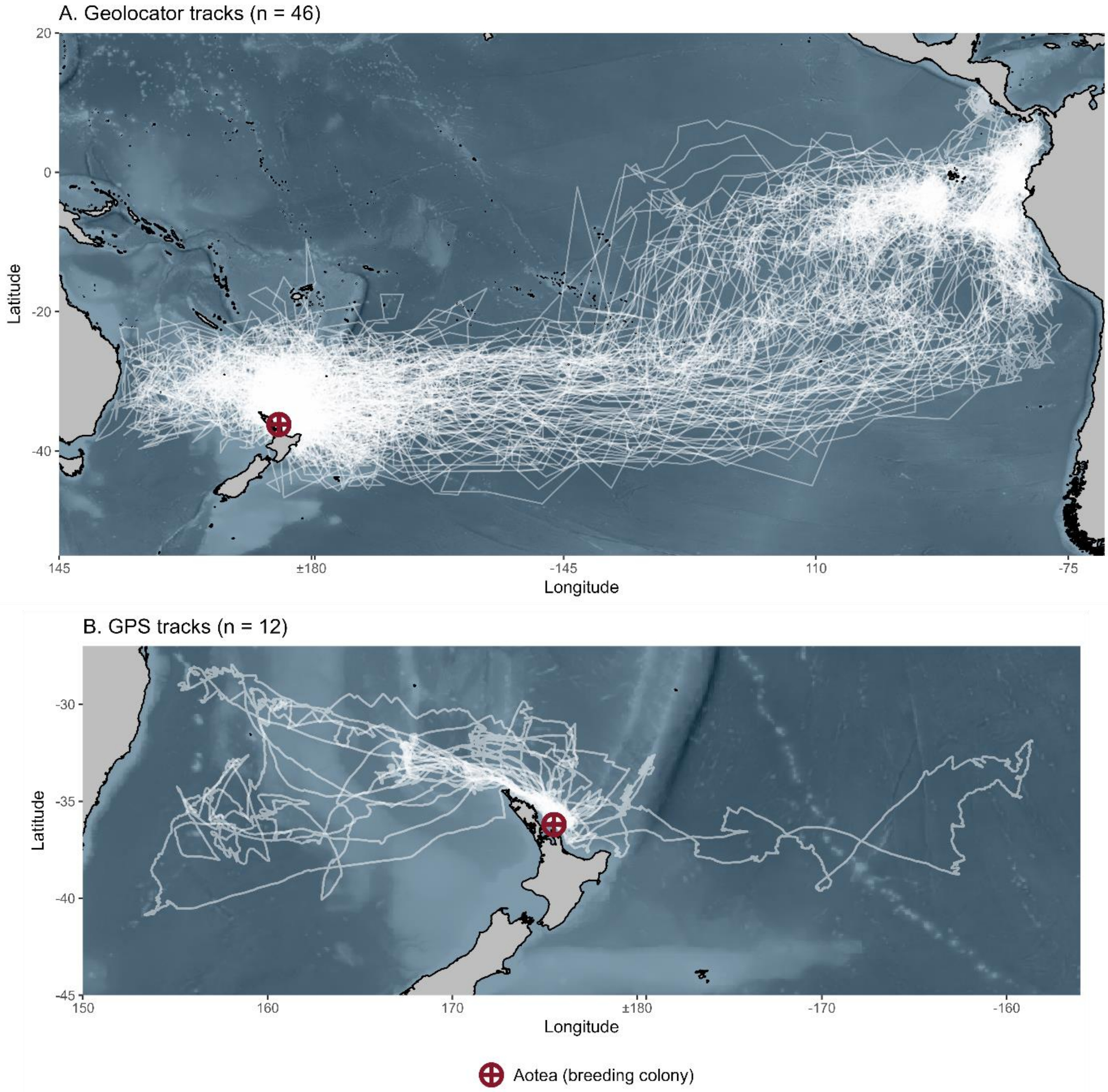

Figure 1: Tracks from Black Petrels equipped with geolocators (A) and GPS devices (B).

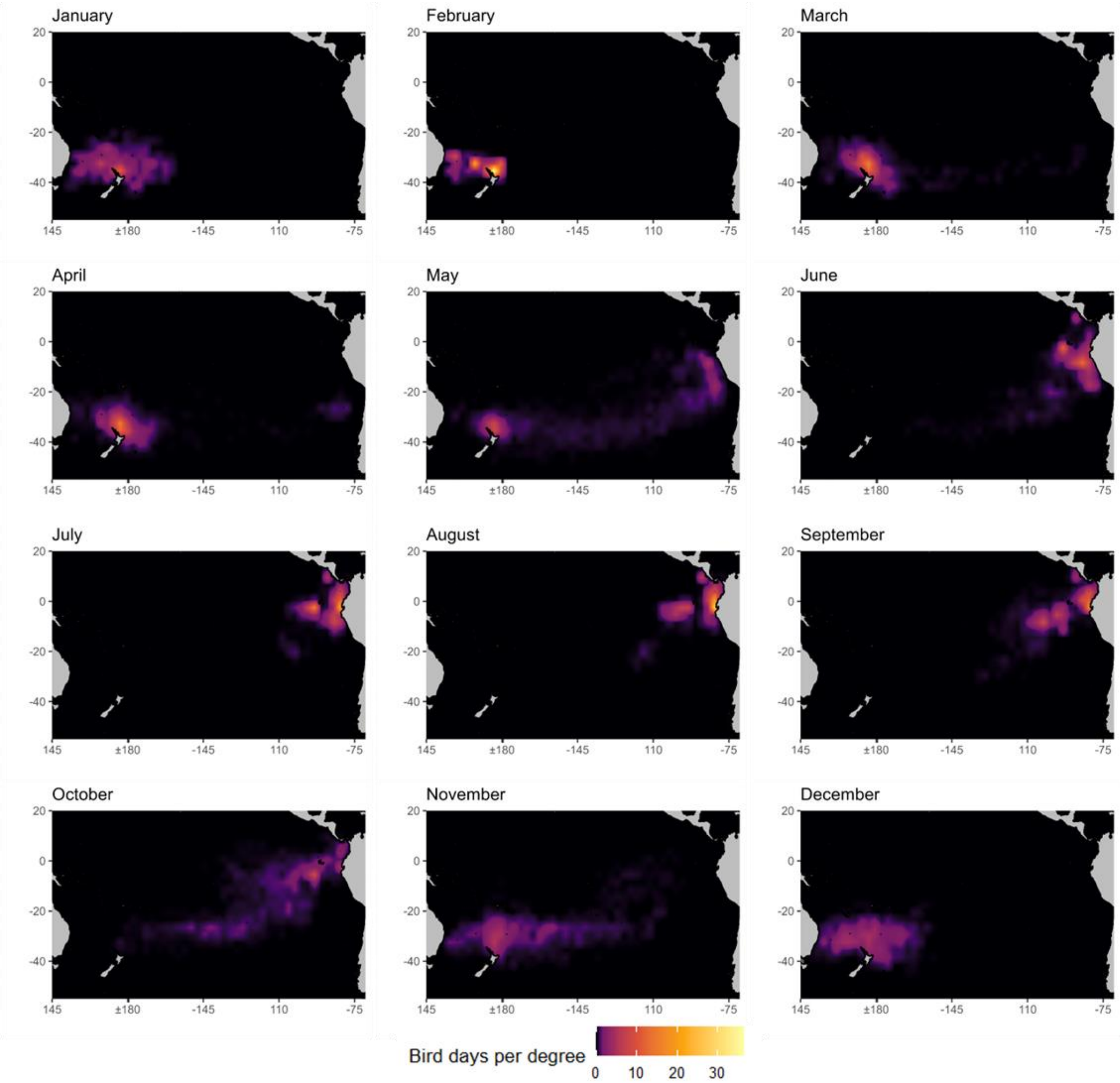

Figure 2: Processed monthly distribution, created using a combination of geolocator and GPS data.

3.3. Fisheries overlap in the WCPFC Convention Area

Black Petrels overlapped extensively with pelagic longlines across large sections of the WCPFC Convention Area (Figure 3A). High densities of overlap occurred close to the breeding colony, but also in the high seas south of 30°S in the Tasman Sea and east of New Zealand (Figure 3A). In addition, considerable overlap occurred between 30°S and 25°S in the high seas and the Australian EEZ, as well as north of 25°S in the high seas and various EEZs (Figure 3C), where bycatch mitigation methods are reduced, or not mandatory, respectively. Relative overlap, or overlap per occurrence, was highest north of 25°S (Figure 3D). This suggests that, though birds spend less time in these latitudes (Figure 3B), the overlap with pelagic longlines fisheries, and therefore potential bycatch risk, during that time is likely very high.

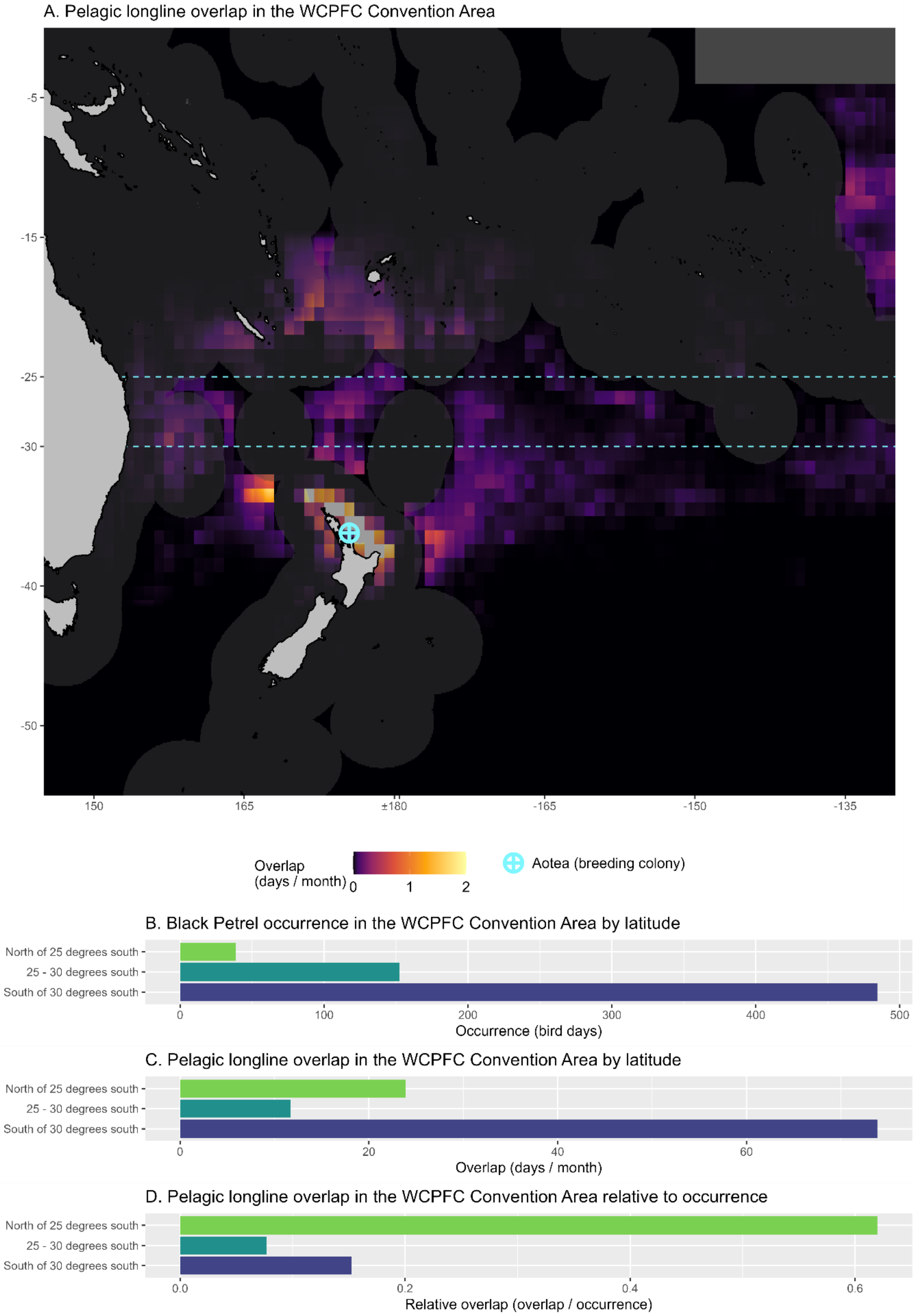

Figure 3: Black Petrel overlap with pelagic longline fishing effort in the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area (A). Exclusive Economic Zones areas are highlighted by a reduced opacity. Occurrence and overlap are compared for three latitudinal groups in B and C, respectively. D shows the fisheries overlap relative to occurrence, i.e. the expected overlap per occurrence in each latitudinal sector.

4. Discussion

According to WCPFC CMM 2018-03, pelagic longline vessels south of 30°S must employ two of three seabird bycatch mitigation methods; weighted branch lines; night setting; tori lines. Another option available is to use hook-shielding devices, in which case no other method is required. Between 30°S and 25°S, a single bycatch mitigation method of those listed above (excluding night setting) is required, while north of 25°S, bycatch mitigation methods are recommended, but not mandatory. Overlap analyses with bycatch-prone fisheries is considered a suitable proxy for potential bycatch risk in areas where observer coverage on vessels is limited (Clay *et al*. 2019). According to our annual tracking of Black Petrels, overlap is highest in the area south of 30°S, where they are afforded the most the protection from bycatch in pelagic longline fisheries. Yet, recent research suggests that the bycatch mitigation requirements in this area, and the area between 30°S and 25°S can be substantially improved (Fischer *et al.* 2024). However, 78% of birds tracked spent time north of 25°S within the WCPFC Convention Area, and according to our analyses, overlap heavily with longline fishing effort while in these areas. Edwards *et al*. (2023) shows that, within the New Zealand EEZ, at least 25% of Black Petrel bycatch risk stems from pelagic longline fishing. While overlap with pelagic longline fishing is high within the New Zealand EEZ, other areas of high overlap must be considered, in which the likelihood of bycatch may be higher due to reduced bycatch mitigation methods.

Bull (2007) advises that weighted branch lines should be used in combination with other methods such as tori lines to reduce bycatch during pelagic longline sets, since many commonly bycaught seabird species are proficient divers that may access baited hooks below the water's surface (Robertson *et al*. 2004). In addition, *Procellaria* petrels, like Black Petrels, are also able to retrieve hooks and return them to the surface, placing other seabirds, including albatrosses, at risk as well (Jimenez *et al*. 2012). Though Black Petrels usually limit their dives to within the upper 5m of the water column, dives have been recorded to 38.5m depth (Düssler *et al*. 2024). This suggests that these birds can access baited lines deep underwater, and weighted branch lines alone may not be wholly effective without additional mitigation methods. Given that only one bycatch mitigation method is required by WCPFC between 30°S and 25°S, current efforts appear to fall short of reducing Black Petrels' access to baited hooks in this area. Additionally, Black Petrels have been shown to forage and even dive at night, albeit to shallower depths (Bell 2016). Night setting is suggested as a mitigation method for pelagic longline bycatch south of 30°S by WCPFC CMM 2018-03, provided it is used in combination with another mitigation method. Results therefore indicate that a combination of all three mitigation methods, or hook-shielding devices, at least up to 25°S could provide the protection from pelagic longline bycatch that this vulnerable, deep-diving, highly mobile species requires.

5. Acknowledgements

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