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

Swakopmund, Namibia, 26 May 2026

Westland Petrel overlap with New Zealand domestic fishing effort

Te Arawhetu Waipoua, Jonathan Rutter, Kate Simister, Samhita Bose, Graeme Taylor, Olivia Rowley, Igor Debski, Johannes H. Fischer

SUMMARY

Seabird bycatch is a major conservation concern globally, yet fine-scale evaluations of overlap remain limited for many species. Tāiko/Westland petrel (*Procellaria westlandica*) are endemic to Aotearoa (New Zealand) and this species is vulnerable to bycatch in domestic fisheries. To quantify tāiko overlap with domestic fishing effort, we combined four consecutive years of broad-scale GLS tracking (2021-25; *n* = 146) with two years of fine-scale GPS tracking (2024-25; *n* = 37). We applied two complementary analyses: (i) raster-based overlap, aggregating GLS tracking and fishing data into gridded surfaces to evaluate co-occurrence intensity across space and time, and (ii) point-based spatiotemporal overlap, measuring direct coincidence between bird locations and E-logbook recorded fishing events. We contrasted these approaches with recorded bycatch events (*n* = 120; 2020-25). GLS data revealed strong seasonal connectivity between Aotearoa and South America, but surprisingly, some tāiko occurred in Aotearoa waters year-round. Broad-scale raster-based analyses indicated year-round overlap with domestic fisheries, peaking in austral mid-winter off the Westcoast, dominated by deepwater hoki trawl and deepwater ling bottom longline fisheries. Fine-scale point-based analyses showed incubating birds spent an average of 2.1 hours per day within 3 km of actively fishing vessels, with >98% of co-occurrence time near trawlers. Contrasting with co-occurrence patterns, recorded bycatch predominantly originated from deepwater ling bottom longline fisheries. Our findings underscore that co-occurrence does not always directly translate to risk and that fleet-specific nuances should be considered. Our results also highlight tāiko bycatch within the ling bottom longline fishery, and that further efforts to reduce bycatch of this endemic species in this fishery are required. Additionally, the deepwater trawl fishery would benefit from improved data collection, particularly to quantify warp strike risks. Our approach combining multiple data sources thus provided insights to guide bycatch reduction strategies.

RECOMMENDATIONS

We recommend that the Joint SBWG13/PaCSWG9:

1. Note the updated spatial information for Westland Petrels, including significant of time spent in both Chilean and Argentinian.
2. *Recommend* that AC15 encourage Parties, and others, undertaking assessments of seabird bycatch in waters off either coast of southern South America consider the need for species-specific identification of *Procellaria* species, noting the challenging identification between co-occurring species.
3. *Acknowledge* that relatively simple overlap analyses, combined with spatial insights into bycatch, can offer rapid management change without necessarily the need for advanced risk assessment modelling approaches.

Superposición de Procellaria westlandica con el esfuerzo pesquero nacional de Nueva Zelanda

RESUMEN

La captura secundaria de aves marinas es una gran preocupación para la conservación en todo el planeta. Sin embargo, las evaluaciones a escala fina de la superposición siguen siendo limitadas para muchas especies. La especie Procellaria westlandica es endémica de Aotearoa (Nueva Zelanda) y es vulnerable a la captura secundaria en las pesquerías nacionales. Para cuantificar la superposición de Procellaria westlandica con el esfuerzo pesquero nacional, combinamos cuatro años consecutivos de rastreo con GLS a gran escala (2021-2025; n = 146) con dos años de rastreo con GPS a escala fina (2024-2025; n = 37). Empleamos dos análisis complementarios: (i) superposición de rásteres, agregando el rastreo con GLS y los datos de pesca en superficies cuadriculadas para evaluar la intensidad de la ocurrencia simultánea en el espacio y el tiempo, y (ii) superposición espaciotemporal de puntos, que mide la coincidencia directa entre las ubicaciones de las aves y los eventos de pesca registrados en la bitácora electrónica. Contrastamos estos enfoques con los eventos de captura secundaria registrados (n = 120; 2020-2025). Los datos de GLS revelaron una fuerte conectividad estacional entre Aotearoa y América del Sur, pero, sorprendentemente, algunos ejemplares de Procellaria westlandica se quedaban en las aguas de Aotearoa durante todo el año. Los análisis de rásteres a gran escala indicaron una superposición durante todo el año con las pesquerías nacionales, con un pico a mediados del invierno austral frente a la costa oeste, dominado por las pesquerías de arrastre de merluza de cola de aguas profundas y la pesquería de palangre de fondo de maruca de aguas profundas. Los análisis de puntos a escala fina mostraron que las aves que están incubando pasaron un promedio de 2,1 horas por día a hasta 3 km de las embarcaciones de pesca activas, y un >98 % del tiempo de coexistencia cerca de los arrastreros. En contraste con los patrones de ocurrencia simultánea, la captura secundaria registrada provino predominantemente de las pesquerías de palangre de fondo de maruca de aguas profundas. Nuestros hallazgos subrayan que la ocurrencia simultánea no siempre se traduce directamente en riesgo y que se deben considerar los matices específicos de cada flota. Nuestros resultados también destacan la captura secundaria de Procellaria westlandica en la pesquería de palangre de fondo de maruca, y que se requieren más esfuerzos para reducir la captura secundaria de esta especie endémica en esta pesquería. Además, la pesquería de arrastre de aguas profundas se beneficiaría de una mejor recopilación de datos, particularmente para cuantificar los riesgos de choques con los cables de arrastre. Así, nuestro enfoque, que combina múltiples fuentes de datos, proporcionó información para guiar las estrategias de reducción de la captura secundaria.

RECOMENDACIONES

Recomendamos que la reunión conjunta de GdTCS13 y GdTPEC9:

1. Tome nota de la información espacial actualizada sobre Procellaria westlandica, incluida la cantidad de tiempo que esta especie pasa en aguas chilenas y argentinas.
2. Recomiende que la CA15 anime a las Partes y a otros a realizar evaluaciones de la captura secundaria de aves marinas en las aguas frente a ambas costas del sur de Sudamérica, teniendo en cuenta la necesidad de una identificación específica de las especies de Procellaria y señalando la dificultad de identificación entre las especies que coexisten.
3. Reconozca que los análisis de superposición relativamente simples, combinados con información espacial sobre la captura secundaria, pueden ofrecer un cambio rápido en la ordenación sin necesidad de recurrir a enfoques avanzados de modelado de evaluación de riesgos.

La Chevauchement spatial du pétrel de Westland avec l’effort de pêche domestique en Nouvelle-Zélande

RÉSUMÉ

Les captures accessoires d’oiseaux marins constituent une préoccupation majeure à l’échelle mondiale en matière de conservation, mais les évaluations fines du chevauchement restent limitées pour de nombreuses espèces. Le tāiko/pétrel de Westland (Procellaria westlandica) est endémique d’Aotearoa (Nouvelle-Zélande) et cette espèce est vulnérable aux captures accessoires dans les pêcheries domestiques. Pour quantifier le chevauchement du tāiko avec l’effort de pêche domestique, nous avons combiné quatre années consécutives de suivi GLS à grande échelle (2021–2025 ; n = 146) avec deux années de suivi GPS à fine échelle (2024–2025 ; n = 37). Nous avons appliqué deux analyses complémentaires : (i) un chevauchement basé sur des rasters, en agrégeant les données de suivi GLS et de pêche en surfaces maillées afin d’évaluer l’intensité de co-occurrence dans l’espace et le temps, et (ii) un chevauchement spatio-temporel basé sur des points, mesurant la coïncidence directe entre les positions des oiseaux et les événements de pêche enregistrés dans les journaux de pêche électroniques (E-logbook). Nous avons comparé ces approches aux événements de captures accessoires enregistrés (n = 120 ; 2020–2025). Les données GLS ont révélé une forte connectivité saisonnière entre Aotearoa et l’Amérique du Sud, mais, de manière surprenante, certains tāiko étaient présents dans les eaux d’Aotearoa toute l’année. Les analyses à grande échelle basées sur

des rasters ont indiqué un chevauchement toute l'année avec les pêcheries domestiques, atteignant un pic au milieu de l'hiver austral au large de la côte ouest, dominé par les pêcheries au chalut de hoki en eaux profondes et les pêcheries à la palangre de fond ciblant le ling en eaux profondes. Les analyses à fine échelle basées sur des points ont montré que les oiseaux en incubation passaient en moyenne 2,1 heures par jour à moins de 3 km de navires en activité, avec plus de 98 % du temps de co-occurrence à proximité de chalutiers. Contrairement aux schémas de co-occurrence, les captures accessoires enregistrées provenaient principalement des pêcheries à la palangre de fond ciblant le ling en eaux profondes. Nos résultats soulignent que la co-occurrence ne se traduit pas nécessairement directement par un risque et que des nuances propres à chaque flotte doivent être prises en compte. Nos résultats mettent également en évidence des captures accessoires de tāiko dans la pêcherie à la palangre de fond ciblant le ling, et montrent que des efforts supplémentaires sont nécessaires pour réduire les captures accessoires de cette espèce endémique dans cette pêcherie. De plus, la pêcherie au chalut en eaux profondes bénéficierait d'une amélioration de la collecte de données, en particulier pour quantifier les risques de collision avec les câbles (« warp strike »). Notre approche, combinant plusieurs sources de données, fournit ainsi des éléments utiles pour orienter les stratégies de réduction des captures accessoires.

RECOMMANDATIONS

Nous recommandons que le SBWG13/PaCSWG9 conjoint :

1. Prenne note des informations spatiales actualisées concernant les pétrels de Westland, y compris le temps important passé dans les eaux chiliennes et argentines.
2. Recommande que le CC15 encourage les Parties et autres entités menant des évaluations des captures accessoires d'oiseaux marins dans les eaux situées de part et d'autre des côtes du sud de l'Amérique du Sud à prendre en compte la nécessité d'une identification spécifique des espèces de Procellaria, en raison des difficultés d'identification entre espèces coexistantes.
3. Reconnaisse que des analyses de chevauchement relativement simples, combinées à des informations spatiales sur les captures accessoires, peuvent permettre des ajustements rapides de gestion sans nécessiter nécessairement des approches avancées de modélisation des risques.

1. INTRODUCTION

Seabirds are among the most threatened taxa globally, with bycatch in commercial fisheries recognized as a major driver of population declines (e.g., Dias *et al*., 2019). Mortality associated with fishing operations has been documented across a wide range of gear types and ocean basins, and despite decades of research and mitigation efforts, bycatch remains a conservation challenge. The tāiko/Westland petrel (*Procellaria westlandica*) exemplifies this issue. Endemic to Aotearoa (New Zealand), this species breeds exclusively in a single colony of ~6,200 breeding pairs near Punakaiki on the West Coast of Te Waipounamu (South Island), rendering it particularly vulnerable to localised threats (Waugh *et al*., 2020). The species is currently listed as Endangered under the IUCN Red List (IUCN, 2025) and has been identified as the fifth most at-risk species bycaught in domestic fishing activity, with an estimated ~143 individuals killed annually in Aotearoa waters (Edwards *et al*., 2023). Specifically, the spatially-explicit risk assessment (SEFRA) approach used by Edwards *et al.* (2023) and Anon. (2025) found that tāiko are at risk from bycatch in a range of fisheries within the New Zealand Economic Exclusion Zone (EEZ) and internationally, respectively. Of the estimated New Zealand fishing related mortalities, 27% are attributed to bycatch in surface longline fisheries, 25% to bycatch in bottom longline fisheries, 46% to bycatch in trawlers, and 1% to bycatch in set nets.

Understanding the spatial and temporal distribution of tāiko throughout the annual cycle is critical for identifying areas in which specific fleets and tāiko co-occur, and to informing effective bycatch mitigation strategies. Previous tracking studies using geolocation (GLS) devices have provided valuable insights into broad-scale movements and migratory patterns, establishing a foundation for understanding year-round distribution patterns (Landers *et al*., 2011), yet these were based on small sample sizes (n = 10). In addition, GLS data are inherently coarse in resolution (e.g., Merkel *et al*., 2016) limiting their utility for quantifying fine-scale overlap with fishing effort. GPS devices provide higher resolution data and considerable amounts of GPS tracking has been conducted on tāiko (n = 101; Waugh *et al*., 2018). However, GPS data generally only provides insights during part of the breeding season due to the attachment methodologies and/or the need to recover devices, rather than year-round as is required for fisheries risk assessments. As a result, the specific areas and times where tāiko are most exposed to bycatch in different domestic fleets across the annual cycle could be better informed (e.g., Peatman *et al*., 2023) to improve the ability of managers to implement targeted mitigation efforts.

In this study, we build on earlier tracking efforts by combining a large-scale dataset of four years of year-round GLS tracking data (Simister *et al*. 2023) with two years of breeding period fine-scale GPS tracking data. Combined, these datasets enable the generation of monthly distribution estimates that capture both broad-scale migratory movements and detailed breeding-season foraging patterns. To assess exposure to fisheries, we evaluate overlap with domestic fishing effort based on E-logbook data across key gear types using complementary approaches: (i) raster-based overlap, which aggregates tracking and E-logbook-based fishing data into gridded surfaces to quantify co-occurrence intensity and (ii) point-based spatiotemporal overlap, which measures direct overlap between bird locations and fishing events. Together, these methods provide a robust, multi-scale assessment of tāiko-fishery overlap, allowing us to identify areas, periods, and fleets of high co-occurrence with greater precision.

2. METHODS

2.1 Tracking devices

A total of 194 adult tāiko were fitted with Intigeo-C330 GLS tags (Migrate Technology Ltd) between 2021 and 2024 with a relatively even spread between known males and females (Table 1). Tags were attached to the bird's metal leg band using two UV-resistant plastic cable ties to minimise movement and prevent damage. GLS tags were programmed to Mode 6B, recording light level (lux, unclipped) at one-minute intervals, saltwater immersion on a constructed scale every 10 minutes, and sea-surface temperature (SST; in °C) when immersed in saltwater for >20 minutes. A total of 169 (87%) GLS tags were recovered in subsequent years until 2025, of which 146 provided data (86%; but three tags retrieved in 2025 still require data extraction by the manufacturer, potentially increasing the percentage to 88%). Some GLS tags were retrieved within the same year, only yielding shorter tracks (34%), but most tracks (66%) were year-round.

Table 1: Summary of GLS tag deployments on tāiko 2021 – 2024.

	Sex			**GLS**		
Year	Female	Male	Unknown	Deployed	Retrieved	Downloaded
2021	23	26	1	50	49	39
2022	39	45	8	92	75	69
2023	13	14	0	27	23	18
2024	8	10	7	25	22	20
Total	**83**	**95**	**16**	**194**	**169**	**146**

To complement the GLS deployments, 58 i-gotU GT120 GPS loggers, with a custom epoxy casing were deployed on incubating adult tāiko in May-June 2024 and 2025 (Table 2). GPS loggers were attached using the tail-mount method and programmed to record positional fixes at intervals of 10-60 minutes, providing fine scale resolution of breeding-season movement. Equipped birds were recaptured approx. one month after deployment during the early chick-rearing, resulting in a 48 (83%) retrieved devices of which 37 (77%) provided suitable data. Per chance, these tags were more likely to be deployed on males than females, but still a decent sample size of females was obtained.

All tag weights were below the 3% of the birds' body weight (GLS: ~1g, 0.08%, i-gotU: ~21 g, 1.75%) above which seabirds are believed to experience negative effects (Phillips *et al*. 2004) and no negative impacts were observed in the field.

Table 2: Summary of GPS tag deployments on tāiko 2024-2025.

	Sex			**GPS**		
Year	Female	Male	Unknown	Deployed	Retrieved	Downloaded
2024	8	16	4	28	23	20
2025	7	15	8	30	25	17
Total	**15**	**31**	**12**	**58**	**48**	**37**

2.2 Tāiko tracking data processing

All data were processed and analysed using custom scripts in R version 4.5.1 (R Core Team, 2024). GLS locations were obtained from the 146 recovered tags that provided us with data and processed using the *probGLS* package, which applies an iterative forward step selection probability algorithm incorporating light-level, sea-surface-temperature (SST) and saltwater immersion (dry/wet activity) data to estimate two bird positions per day (Merkel *et al*., 2016). To constrain location estimates and improve accuracy, the distributional range of tāiko was defined by 120°E and 50°W longitudes as the western and eastern limits and 0°S and 65°S as the northern and southern limits based on previous tracking work (Landers *et al*., 2011). Further processing parameters (based on similar GLS processing exercises; Bell *et al*. (2020) and Fischer *et al*. (2023) were provided to *probGLS*: (i) a land mask, (ii) a 100% sea-ice mask, (iii) a dry speed (flying) filter of 10 m/s (with a SD of 5 m/s, and a max speed of 50 m/s), (iv) a wet speed (swimming) filter of 1 m/s (with a SD of 1.3 m/s, and a max speed of 5 m/s), and (v) a maximal allowable deviation of 3°C between bird-borne logger recorded SST values and satellite SST values. We ran the *probGLS* algorithm per track for 100 iterations with 1,000 particles per run (Merkel *et al*. 2016). To further clean the derived median tracks, an additional speed filter of 40 m/s was applied. The final tracks generated consisted of 46,896 locations, which were separated into long (year-round) and short track datasets (see above), which can be viewed through 2236 and 2237, respectively, on the seabird tracking database (Carneiro *et al*. 2024).

GPS location data from 37 tags were filtered to exclude positions where estimated flight speed exceeded 100 km/h, as such speeds are considered unrealistic (e.g., Landers *et al*. 2011), and where locations were located over land. The final tracks consisted of 103,192 locations, which can be viewed through 2505 (2024) and 2506 (2025) on the seabird tracking database (Carneiro *et al*. 2024).

2.3 Domestic commercial fishing effort and bycatch data

Daily commercial fishing effort data were obtained by the E-logbook system (Fisheries New Zealand, 2025) from the New Zealand Ministry for Primary Industries. The dataset spanned the period from 2021 to June 2025, and consisted of detailed information per individual fishing event, including event ID, start date and time, gear type, coordinates of start and end locations, number of hooks or tows and target species. For all analyses, we focused on the major fishery methods and thus excluded vessels that were not trawlers or longliners (e.g., Dahn line, troll).

Fishing effort data were disaggregated by gear type (trawl, bottom longline and surface longline) and fishery classification (inshore, deepwater and highly migratory species; HMS). Trawl events encompassed four method types: bottom trawl, midwater trawl, precision bottom trawl and precision midwater trawl. Assignment of fishing events to fisheries followed species classification criteria defined by the Ministry for Primary Industries (n.d.). To more specifically identify which specific fisheries and fleets overlapped most with tāiko, fishing effort data were further disaggregated by fishing method and target species (Fig. 1). For target species associated with multiple fisheries classifications (e.g. inshore vs deepwater), classification was determined by the location of the fishing event, specifically the fisheries management area (FMA) in which it occurred. For example, ling (*Genypterus blacodes*) bottom longline fisheries were considered inshore for FMA 1 and 2, but deepwater for all other FMAs. These classifications were used to define the final groupings applied in the overlap analysis. Surface longline events were exclusively classified as HMS due to their operational characteristics and target species.

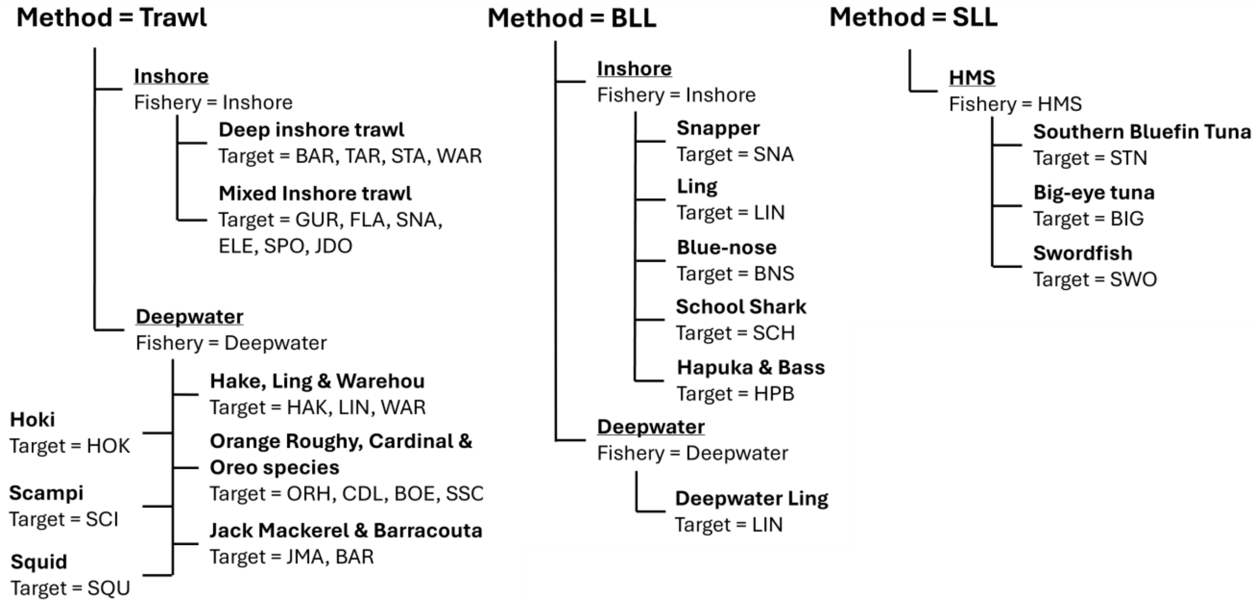

Figure 1: Decision tree classifying trawl, bottom longline (BLL) and surface longline (SLL) fishing events into final groupings.

In addition to the commercial fisheries effort data, Westland Petrel bycatch data, as reported by fishers, and recorded by human observers or electronic monitoring systems, were also obtained from the New Zealand Ministry for Primary Industries. The obtained bycatch dataset spanned January 2009 to December 2025, but we truncated this to January 2020 to December 2025 to ensure that bycatch data were adequately representative of current effort and mitigation practices and approximated the tracking duration. This truncated dataset consisted of 96 bycatch events of 120 individual Westland Petrels (93.3% mortalities) for which we had detailed information on capture location, time, condition, fishing method, target fish species, and where available capture type (i.e., net capture vs warp strike for trawl fisheries and set vs haul for line fisheries). For a summary of the bycatch data, including by key fisheries disaggregations (Fig. 1), see Table 3.

Table 3: Summary of bycaught Westland Petrels (individuals) across 2020-2025 (calendar years), disaggregated by key fisheries as per Fig. 1. BLL: bottom longline, SLL: surface longline, HMS: highly migratory species, HOK: hoki, LIN: ling, STN: southern bluefin tuna.

Year	**Trawl**				**BLL**				**SLL**	
	Total				Total				Total	
		Inshore	Deepwater			Inshore	Deepwater		HMS	
				HOK				LIN		STN
2020	3		3		10		10	10	2	2
2021	2		2	2	7	2	5	5	1	1
2022					11		11	11	4	4
2023	8		8	4	13		13	13		
2024	6	1	5	4	10	1	9	9	2	2
2025	9		9	8	32	7	25	25		
Total	**28**	**1**	**27**	**18**	**83**	**10**	**73**	**73**	**9**	**9**

2.4 Data analysis

2.4.1 *GLS-based bird density*

To quantify tāiko density, the approx. twice-daily bird locations derived from GLS data (see above) from GLS tags were used. Each location was weighted as 0.5 bird-days to reflect daily effort. Monthly distribution estimates were calculated by assigning the weighted locations to a 1° x 1° raster, using the *raster* package (Hijmans, 2025). Within each grid cell, weighted locations were summed and subsequently standardised to account for variation in tracking effort across months using:

$$Bird\ days\ per\ cell = \left(\frac{\sum bird\ days}{Total\ bird\ days\ (month)}\right) \times Days\ in\ month$$

Monthly rasters were then averaged across all four years to produce a composite monthly distribution of bird density, while ensuring comparability among cells.

2.4.2 Geopolitical responsibilities

To assess geopolitical responsibilities for tāiko, the jurisdiction (i.e., range state or high seas) for each location per year-round track was identified (i.e., excluding non-year-round GLS tracks). The percentage of time within each jurisdiction was calculated per individual per year and then averaged and summarised to obtain a species-level estimate. In addition, the percentage of time spent within the Aotearoa EEZ per month per individual was also calculated and summarised (calculation of means and 95% CIs) as this is a key input to the New Zealand SEFRA (Peatman *et al*. 2023, Edwards *et al*. 2023).

2.4.3 Domestic commercial fishing effort

Domestic commercial fishing effort was quantified in the number of hooks for bottom and surface longlines, and as the number of tows for trawl fisheries. Monthly effort distributions were calculated by assigning effort values to a to 1° x 1° raster grid. Within each grid cell, effort was summed and standardised to account for variation in month length, ensuring comparability across months, using:

$$Effort\ per\ cell = \frac{\sum effort\ (number\ of\ hooks/tows)}{Days\ in\ month}$$

Monthly rasters were then averaged across all four years to produce a composite monthly distribution of fishing effort for each fishery group.

2.4.4 Raster-based overlap estimation

To evaluate spatial overlap between tāiko distribution and commercial fisheries, the bird density rasters (Section 2.4.1) and commercial fishing effort rasters (Section 2.4.3) were multiplied together on a cell-by-cell basis. Overlap rasters were then generated for each fisheries disaggregation (Fig. 1) and bycatch data (Table 3) were mapped on top of these monthly rasters to contrast co-occurrence with recorded interactions. Bycatch data were mapped at 0.1 degrees to meet confidentiality requirements associated with these data.

2.4.5 Point-based overlap estimation

We quantified fine-scale fisheries co-occurrence rates by overlapping bird GPS tracks with E-logbook vessel locations in space and time. We derived vessel tracks during active fishing activities from E-logbook locations, which were available for the start and end of each vessel's set and haul period. As E-logbook data were truncated from July 2025 onward, we had to exclude bird data that extended beyond this data, which meant that ultimately, the retained bird dataset for the point-based overlap consisted of 29 tracks. We linearly interpolated both bird and vessel tracks at 5-min intervals. For each 5-min timestep, we considered a bird to be interacting with a vessel if its location was within 3 km of a concurrent vessel location. This distance threshold has been used to define both trawler and longline vessel attendance, for other Procellariiform seabird species (Orben *et al*., 2021, Collet *et al*., 2017). We calculated co-occurrence rate CR in units of minutes per bird-day as follows:

$$\mathrm{CR} = \frac{\sum_{b\in B}\sum_{t\in T} v_{bt} * 5\ min}{D}$$

Where V is the number of vessels of a given type within 3 km at that timestep, T is the set of all timesteps t for a single bird track, B is the set of all birds b, v_{bt} is the number of vessels of a given type within 3 km of bird b at timestep t, and D is the total number of tracked bird-days for a given analysis. Co-occurrence duration was calculated additively, meaning if a bird was within 3 km of 2 vessels simultaneously for 1 hr, the co-occurrence duration ($\sum_{t\in T} v_{bt} * 5\ min$) would be 2 hr. We calculated CRs by fishery, both across the whole study period and by time of day as the twice-daily GLS data would be unable to elucidate diel patterns. We also mapped co-occurrence locations, classified by the fishery of the nearest vessel.

3. RESULTS

3.1 Tāiko GLS distribution

Tāiko utilised waters surrounding Aotearoa throughout the year and while some birds showed clear seasonal migrations, others surprisingly stayed in Aotearoa waters (Fig. 2). During January-February, most birds were associated with waters in the southeast Pacific, particularly along the southern Chilean and Argentinian coast. From March-April, individuals transitioned across the South Pacific, towards Aotearoa, after which, birds were present throughout the Aotearoa EEZ, with core areas along the West Coast of the South Island, reflecting breeding activities during the breeding season (i.e. when birds are constrained by central-placed foraging). Following breeding, some birds dispersed again back to South America from September-December, while other remained in Aotearoa waters.

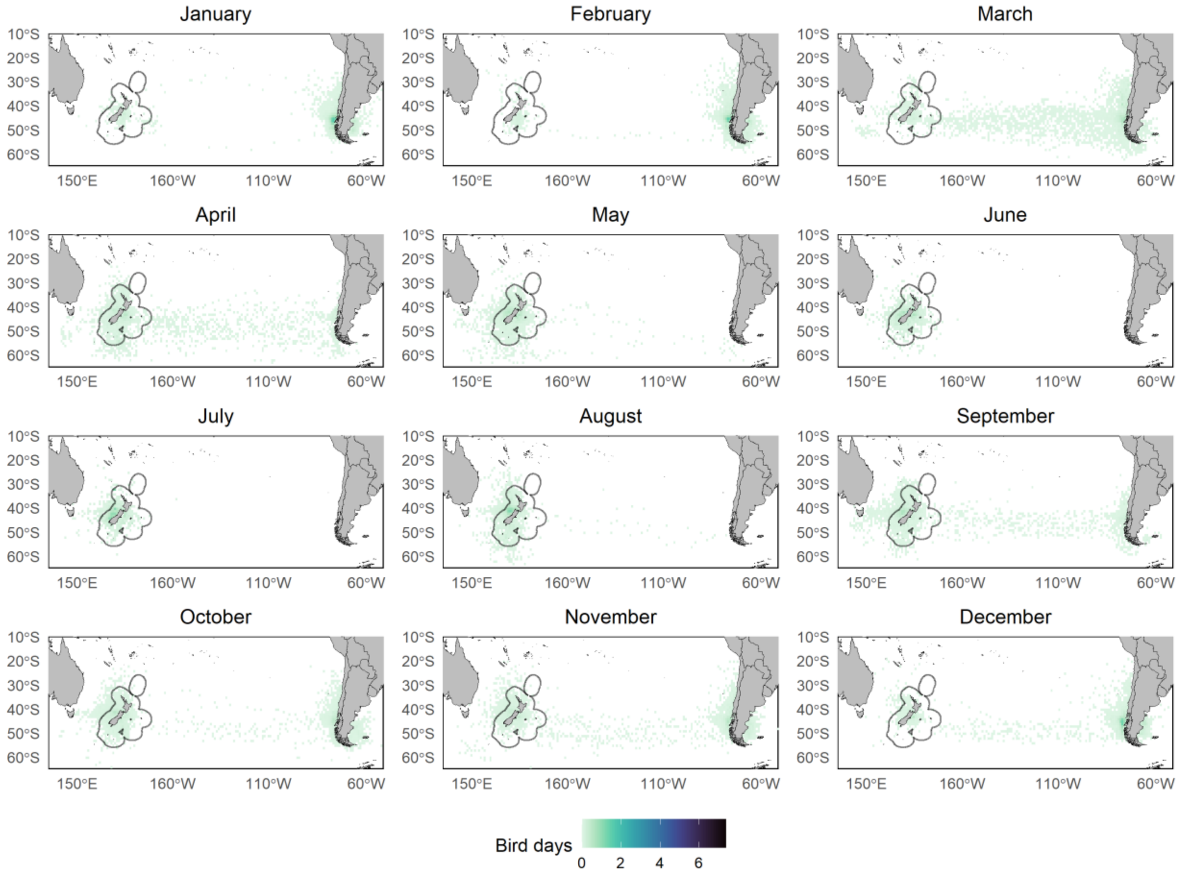

Figure 2: Monthly distribution of tāiko based on year-round GLS tracks.

3.2 Geopolitical responsibilities

Tāiko were recorded in 12 different EEZs and in areas outside of national jurisdiction, i.e., the high seas. They spent the largest proportion of their annual cycle within the jurisdiction of Chile (39%), followed by Aotearoa (36%), the high seas (19%), Argentina (5%), and other EEZs (1%) (Fig. 3). Within the Aotearoa EEZ, tāiko were present throughout the year, with monthly proportions ranging from 8% to 81%. The highest presence occurred in May (81%) followed by June (73%). The lowest presence was recorded in February (8%) and January (9%) (Table 3).

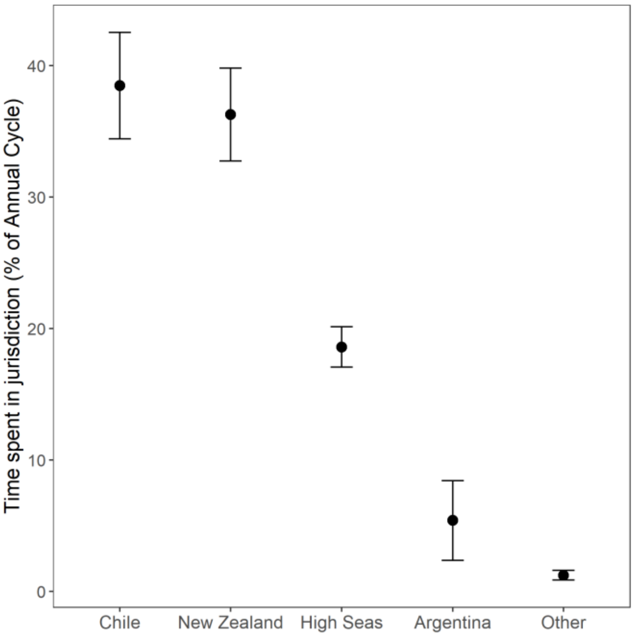

Figure 3: Percentage (%) of time tāiko spent in EEZs and high seas within the annual cycle. Data are presented as means with 95% CIs.

Table 3: Percentage (%) of time spent in Aotearoa EEZ per month (means with 95% CIs).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9 (3-14)	8 (3-14)	12 (7-17)	60 (53-67)	81 (78-85)	73 (68-79)	51 (43-60)	72 (67-77)	64 (58-70)	46 (38-54)	37 (29-45)	11 (5-17)

3.2 Raster-based overlap with domestic fishing effort and bycatch events

Monthly raster-based overlap analyses revealed strong seasonal and spatial patterns in overlap between tāiko and domestic fisheries. Overlap occurred year-round with the highest concentrations along the West Coast of the South Island during austral mid-winter where and when birds are breeding. In general, these spatiotemporal overlap patterns matched those of recorded bycatch events during 2020-2025, with most being located along the West Coast during the Austral winter as well. However, some more distant bycatch events, e.g., in the Aotearoa Subantarctic or north of Taranaki, were also recorded (Fig 4, 6, and 8).

Trawl fishing effort showed the highest overlap during June-August, primarily along the West Coast of the South Island (Fig. 4), with smaller areas of overlap detected along the Chatham Rise, Northland, and subantarctic waters. Within trawl fisheries, overlap was dominated by deepwater trawl, particularly the hoki (*Macruronus novaezelandiea*) fishery which accounted for most of the overlap (Fig. 5; Supplementary Fig. S2). These overlap patterns were strongly mirrored by the recorded bycatch, with most (64%) individuals recorded as bycaught in trawl fisheries were caught in deepwater hoki trawl along the West Coast and Cook Strait (Table 1, Fig 4, Supplementary Fig. S2). However, trawl bycatch only accounted for 23% of all recorded individuals. Of the recorded trawl bycatch, 96% were recorded as net captures and none were recorded as warp strikes.

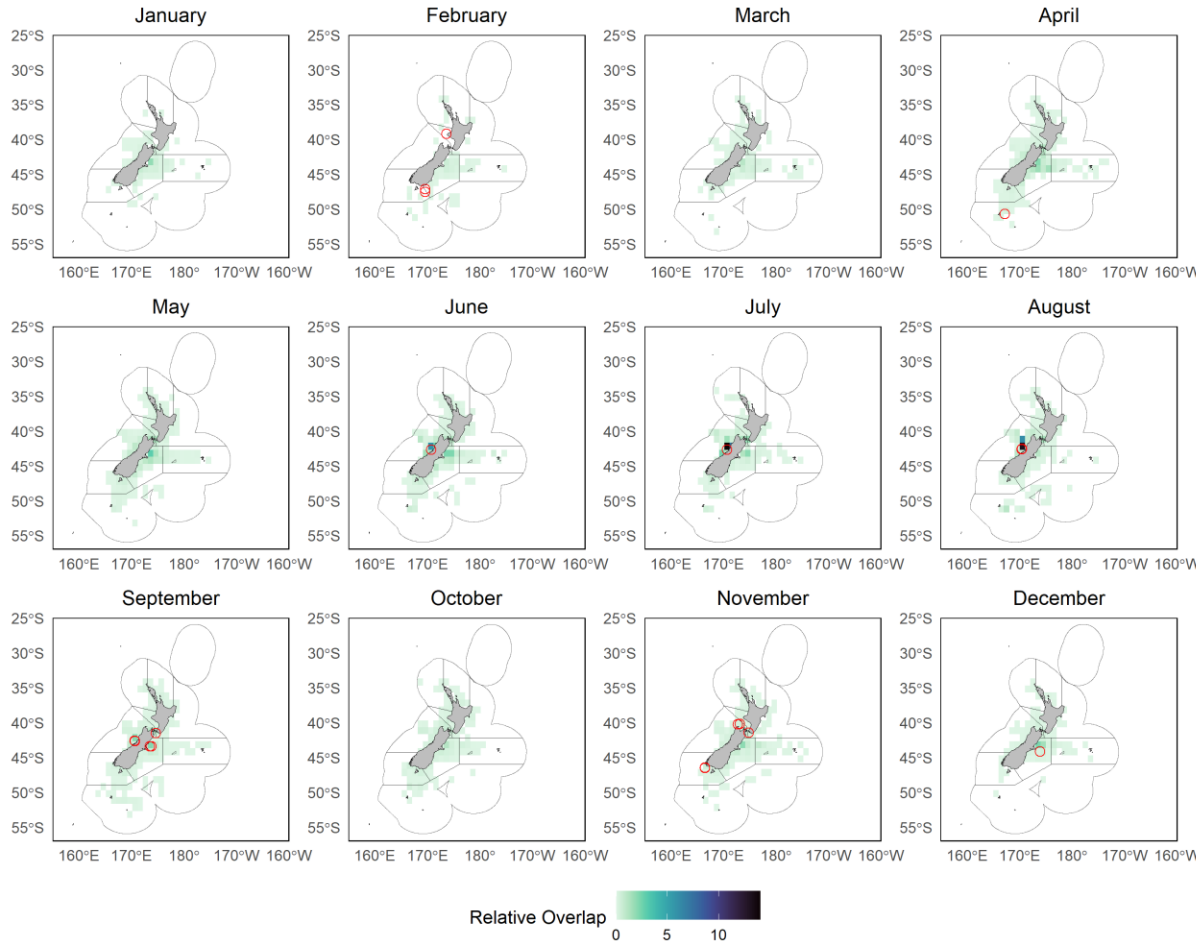

Figure 4: Tāiko overlap with trawl fisheries. Relative overlap is represented as (bird-day x number of tows). Bycatch events (2020-2025) are illustrated by red circles.

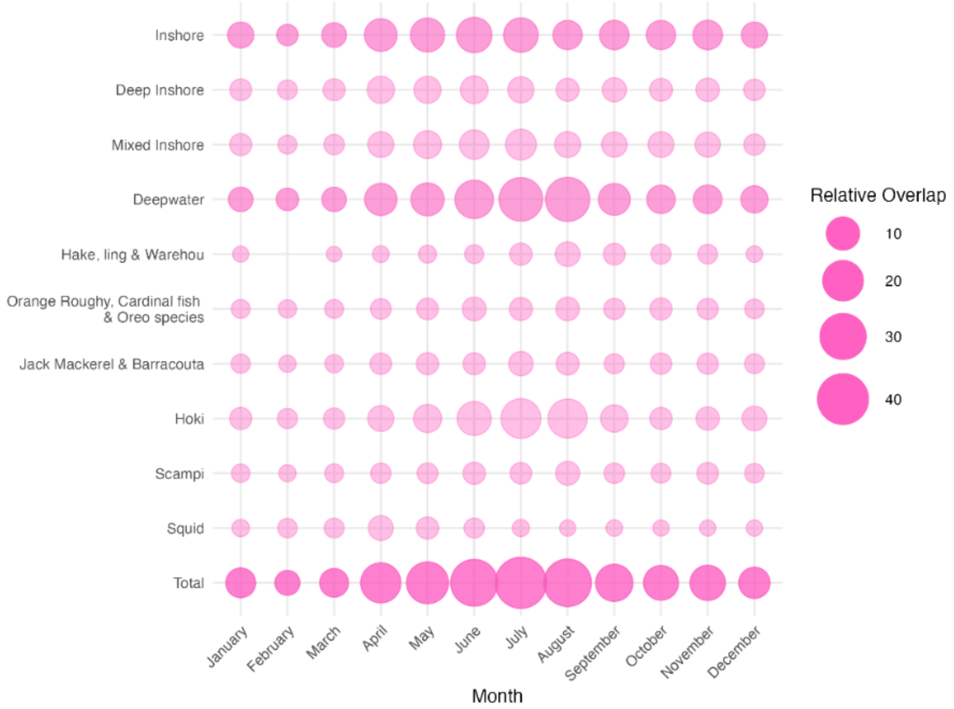

Figure 5: Tāiko overlap per trawl fishery. Relative overlap is presented as (bird-day x number of tows**.**

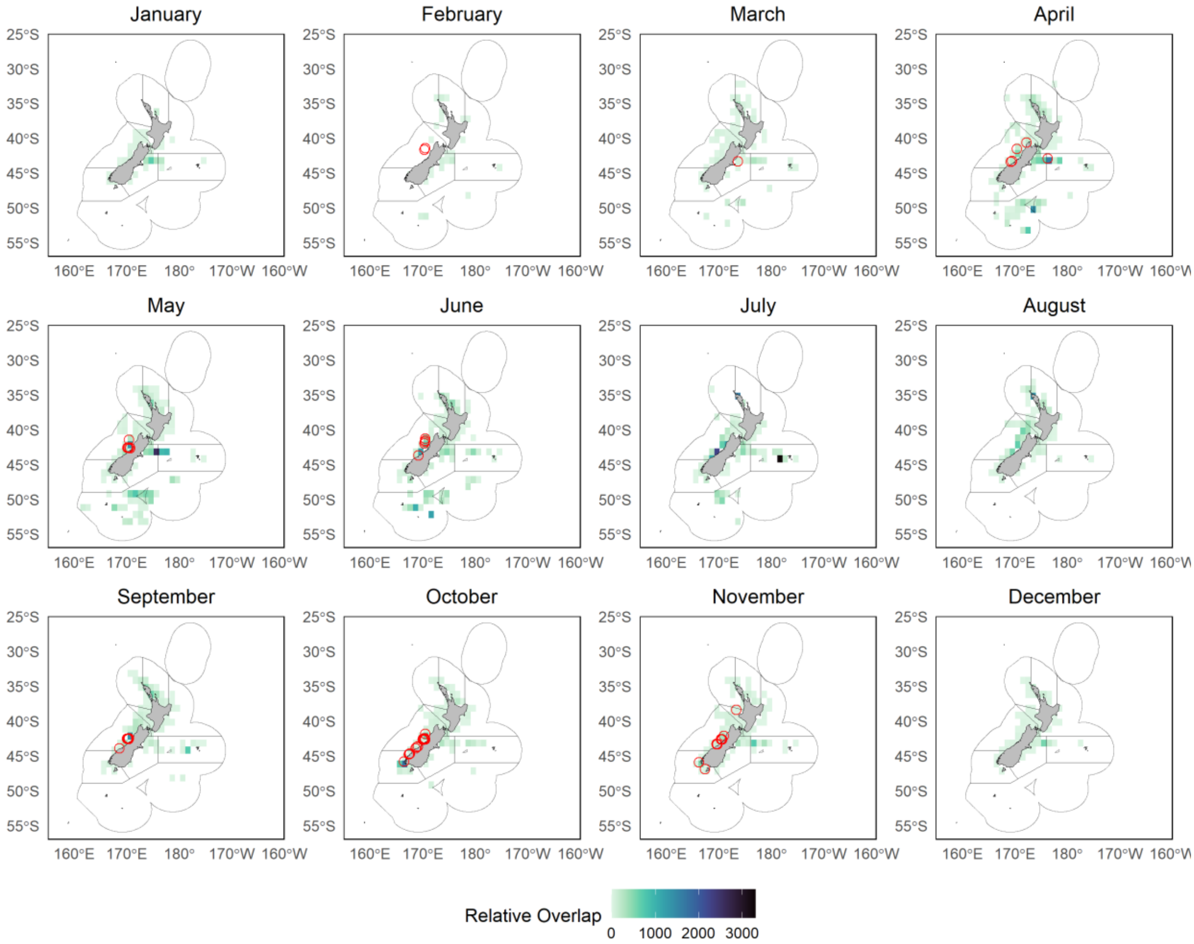

Figure 6: Tāiko overlap with total bottom longline fisheries. Relative overlap is represented as (bird-day x number of hooks)**.** Bycatch events (2020-2025) are illustrated by red circles.

Figure 7: Tāiko overlap per bottom longline fishery. Relative overlap is presented as (bird-day x number of hooks)**.**

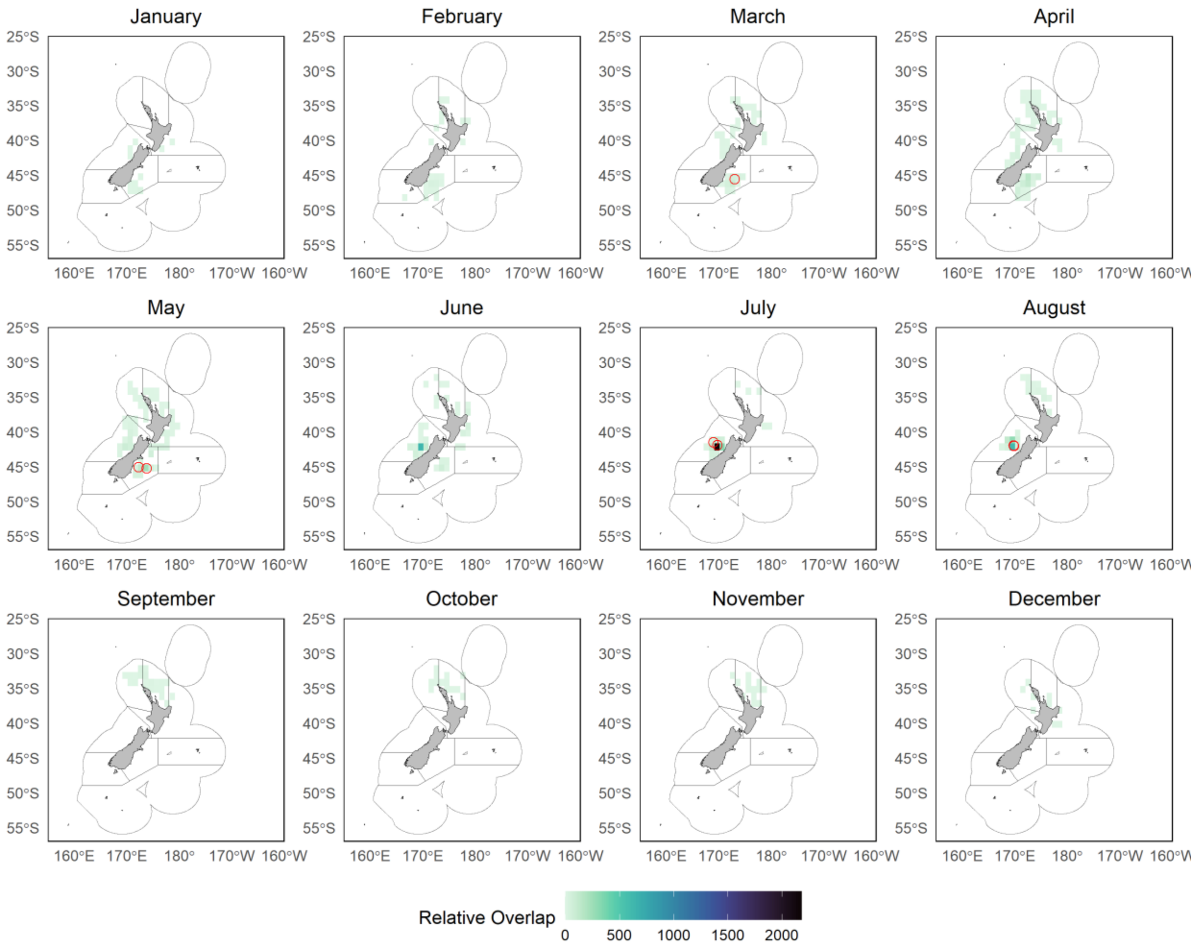

Figure 8: Tāiko overlap with total surface longline fisheries. Relative overlap is represented as (bird-day x number of hooks)**.** Bycatch events (2020-2025) are illustrated by red circles.\

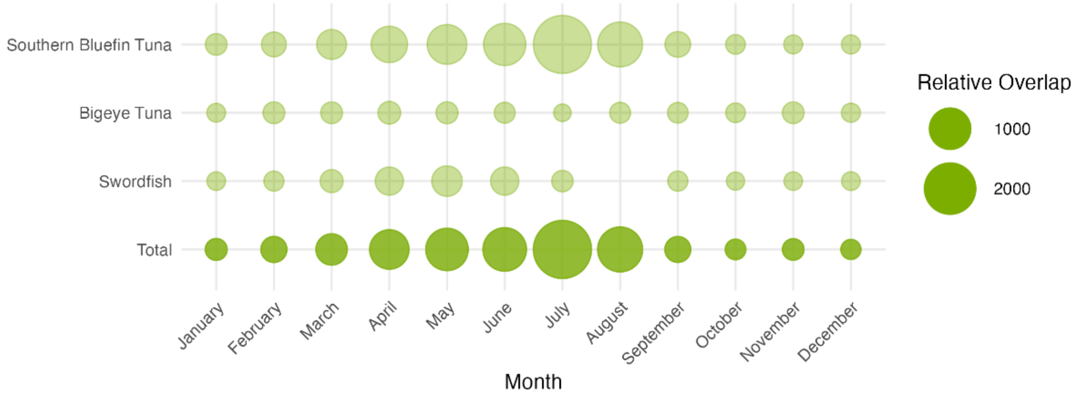

Figure 9: Tāiko overlap per surface longline fishery. Relative overlap is presented as (bird-day x number of hooks).

Overlap with bottom longline fisheries was highest during April–July, primarily along the West Coast, Chatham Rise, some parts of the Subantarctic waters, and a small area near Fiordland (Fig. 6). This overlap was primarily driven by deepwater bottom longline fisheries, particularly deepwater ling (Supplementary Fig. S3), with inshore bottom longline effort contributing only to a small proportion of overlap (Fig. 7). The bottom longline overlap patterns were strongly mirrored by recorded bycatch, with the vast majority (88%) of bycaught individuals being recorded as bycaught in the deepwater ling bottom longline fisheries along the West Coast and, to a lesser extent, the Chatham Rise and Fiordland (Table 1, Fig 6, Supplementary Fig. S3). No bycatch in any bottom longline fishery was recorded, however, during July-August despite considerable overlap. Notably, the deepwater ling bottom longline fishery accounted for 61% of all recorded bycatch events between 2020-2025 (with all bottom longline fisheries accounting for 69%). Of the recorded bottom longline bycatch, 65% was recorded as caught on the set, while 24% was recorded as caught on the haul (yet all were recorded as mortalities).

Surface longline overlap was less than bottom longline, with overlap occurring around the West Coast and Northland. Overlap peaked during June – August off the West Coast of the South Island, dominated by fisheries targeting southern bluefin tuna (*Thunnus maccoyii*) (Table 1, Fig. 8-9; Supplementary Fig. S4). Again, overlap patterns were strongly mirrored by recorded bycatch, and all surface longline bycatch records originated from the southern bluefin tuna fishery off the West Coast and to a lesser extent, the east coast of the South Island. Southern bluefin tuna surface longline bycatch accounted for 8% of all bycatch records between 2020-2025. Of the recorded surface longline bycatch, 22% was recorded as caught on the set, 11% was recorded as caught on the haul, but most capture types were not specified (all recorded as mortalities).

3.3 Point-based overlap with domestic fishing effort

Out of 627 days of GPS tracking, the 29 tāiko retained in the GPS dataset spent over 53 total days within 3 km of trawl and longline fishing vessels. Thus, on average, each bird spent 2.1 ± SD 2.0 hours per day co-occurring with fishing vessels (Supplementary Fig. S5). Co-occurrence was predominantly with trawl vessels around the West Coast, Cook Strait, and the Chatham Rise, with some deepwater trawl co-occurrences located >100 km from shore (Fig. 10). Through early May tāiko co-occurred with both deepwater and inshore trawl fisheries and as the season progressed into June, a larger proportion of co-occurrence was with deepwater trawlers (Fig. 11). Deepwater trawlers targeting hoki had the highest CR of any fishery (~55 mins per bird-day), followed by deep inshore trawl (Fig. 12; Supplementary Fig. S6). Notably, co-occurrences took place throughout all hours of the day, particularly with deepwater trawl. Co-occurrences with inshore trawlers were more common during the afternoon and relatively rare overnight, likely as this fleet more often operates using day trips (Fig. 13). Co-occurrence with bottom and surface longline fishing effort comprised only ~1.4% of all co-occurrence time, although we did not account for potential interactions with surface longlines drifting >3 km from the vessel (i.e., during the soak; Goad *et al*. 2025). Contrasting with the raster-based overlap analyses, the point-based overlap analyses did not detect any co-occurrences between tracked Westland Petrels and deepwater ling bottom longliners.

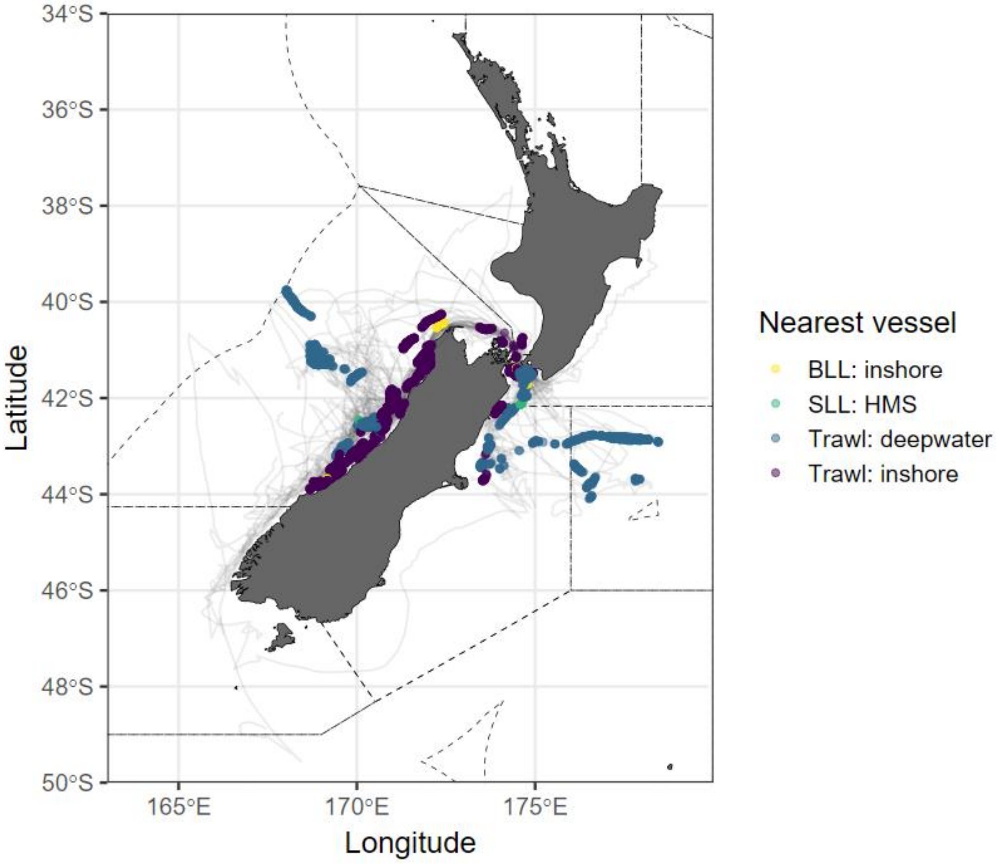

Figure 10: Map of co-occurrence between incubating tāiko and various fisheries. Bird tracks are shown in light grey, coloured points indicate that a bird was within 3 km of a linearly interpolated vessel position at a single timestep (5-min intervals). Vessels were actively fishing at all locations. Dotted lines delineate Aotearoa Fishery Management Areas.

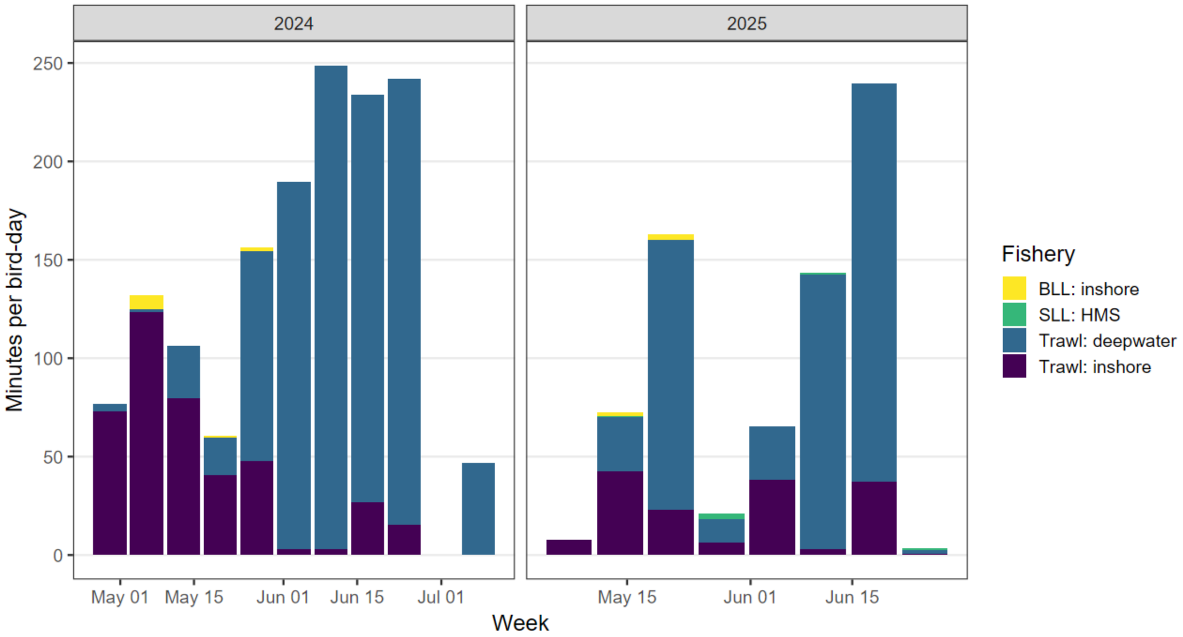

Figure 11: Weekly bird-vessel co-occurrence rates. See Supplementary Fig. S1 for the total number of bird-days tracked per week.

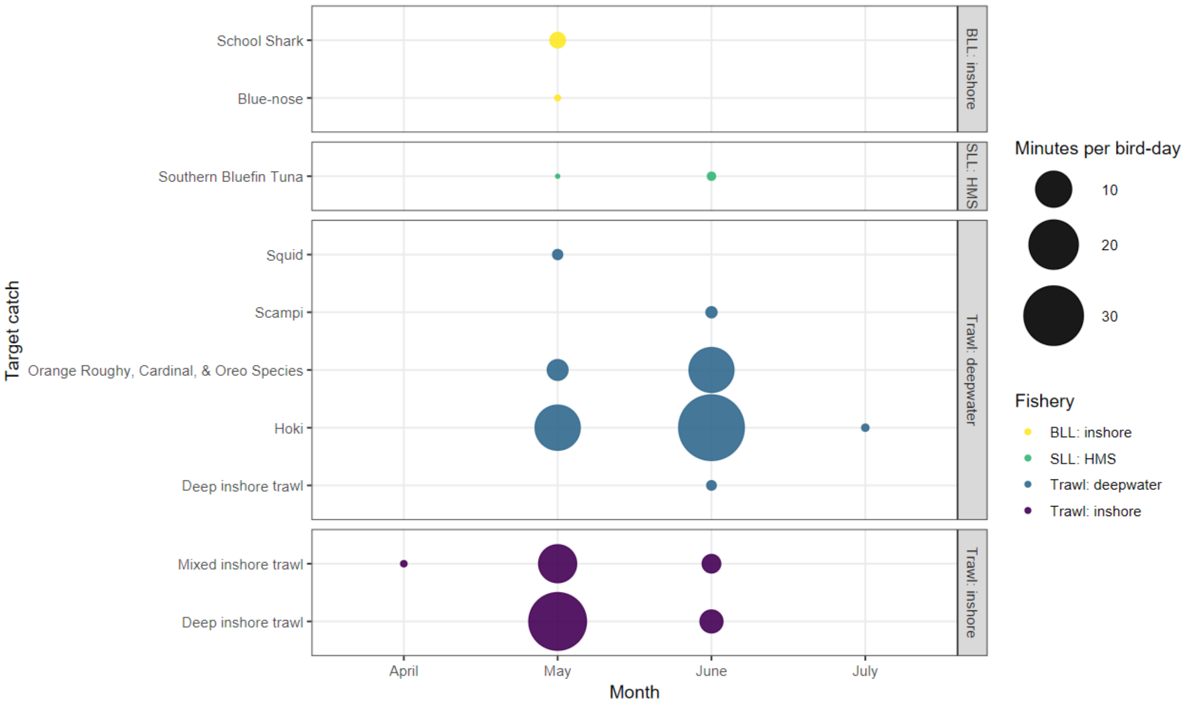

Figure 12: Bird-vessel co-occurrence rates by fishery and target. See Supplementary Fig. S6 for a breakdown by individual target species.

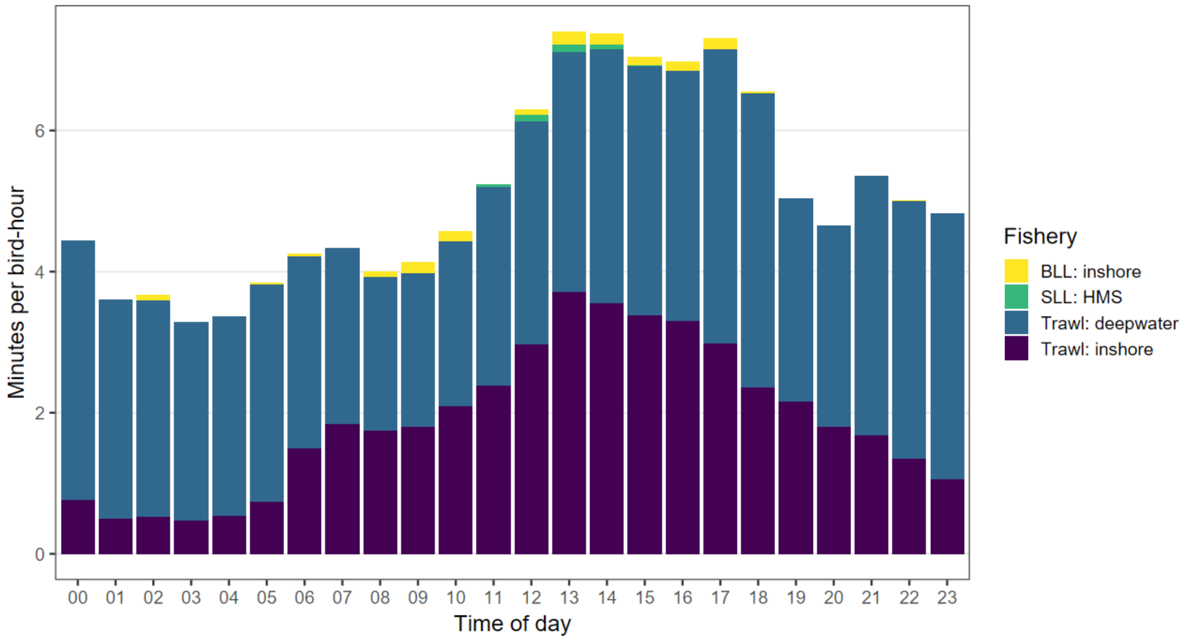

Figure 13: Bird-vessel co-occurrence rates (CR) by time of day. For ease of interpretation, CRs are calculated in units of minutes per bird-hour, rather than minutes per bird-day as in other figures.

4. DISCUSSION

This study examined the spatial ecology of tāiko and their co-occurrence with domestic fisheries in Aotearoa. Using the extensive multi-year GLS tracking effort, we captured the year-round movements across the South Pacific, highlighting strong seasonal connectivity between Aotearoa and South America, consistent with previous GLS studies (Landers *et al.* 2011; Simister *et al.* 2023). These movements were also reflected in the percentage of time spent in different jurisdictions, with tāiko being recorded in 12 EEZs and the high seas, surprisingly spending the largest part of their annual cycle in Chilean waters, followed by Aotearoa. During the non-breeding period (January-February), tāiko primarily occupied the southeast Pacific off southern Chile and the Patagonia Shelf off Argentina, before migrating across the South Pacific in March-April and remaining within Aotearoa waters during the breeding season (until approx. November). Westland Petrel occurrence on the Patagonian Shelf has largely gone unnoticed, presumably due to the very high abundance of the closely-related, and phenotypically similar, White-chinned Petrels (*P. aequinoctialis*) (Rexer-Huber *et al.* 2025). However, some tāiko remained in Aotearoa waters year-round, a crucial and novel insight. Within Aotearoa waters, monthly percentages peaked in May-June during incubation, while percentages in January-February were the lowest. Core areas during breeding were concentrated along the West Coast of the South Island, with broader distribution extending throughout the EEZ. Although GLS provides coarse-scale resolution, GPS data from this study and earlier work (Waugh *et al.* 2018) confirm the high use of continental slope and canyon habitats along the West Coast near the colony, the Cook Strait, the east coast near Kaikōura, and the Chatham Rise, oceanographic features known to enhance productivity and prey aggregation (Murphy *et al.* 2001; Pinkerton, 2016). Following breeding (September-December), birds dispersed back to South America, completing a trans-Pacific migration along the Pacific flyway (Morten *et al.* 2025) that underscores the species' reliance on both domestic and international waters.

4.1 Spatiotemporal patterns of co-occurrence and bycatch records

Raster-based monthly overlap showed that tāiko distribution overlapped with domestic fisheries throughout the year, with the greatest overlap across all gear types occurring during austral mid-winter along the West Coast of the South Island. This period coincides with the breeding season, when birds are constrained by central-place foraging, particularly during incubation and chick-rearing, when they repeatedly commute between the colony and foraging grounds. Overlap with trawl was dominated by deepwater trawl fisheries, particularly the hoki fishery, consistent with earlier findings of tāiko frequently associating with hoki trawl fleet (Freeman & Wilson, 2002; Waugh *et al.* 2018). Bottom longline overlap was primarily with deepwater ling fisheries, not only along the West Coast but also the Chatham Rise and Fiordland, all of which are areas with persistent fronts and slope habitats where prey and fishing activity congregate (Bost *et al.*, 2009). Overlap with surface longline was smaller and involved fleets targeting southern bluefin tuna, peaking during June-August off the West Coast and the east cost of the South Island, as would be expected given the seasonal tuna fishing effort (Holdsworth, 2025).

Our raster-based overlap provided a broad spatial perspective and identified regions of overlap, yet this approach cannot attribute overlap with specific fleets on a high spatiotemporal resolution. To address this gap, we included point-based overlap using fine-scale inferences from GPS tracking. This additional analysis revealed that incubating birds spent an average of 2.1 hours per day within 3 km of fishing vessels, with >98% of co-occurrence time attributed to trawlers (both inshore and deepwater) and a small proportion with to surface and bottom longliners. Deepwater trawlers targeting hoki had the highest co-occurrence rates of any fishery, followed by deep inshore trawl. These patterns are consistent with those observed through the raster-based overlap analyses as well as previous work showing that trawl fisheries constitute most fishing activity encountered in foraging areas (Waugh *et al.* 2018), and hoki fishery discards have been identified in the diet of tāiko chicks (Freeman, 1998; Freeman & Wilson 2002). Our work, driven by large sample sizes across two tracking device types, further provides confidence in these patterns. However, we add to previous analyses by showing that interactions of tāiko with fisheries occur throughout both day and night, underscoring that this species actively forages throughout the diel cycle (Düssler *et al.* 2026) and that co-occurrence appears to be driven by fisheries activity, rather than bird activity. Furthermore, our fine-scale point-based overlap indicate that time interacting with deepwater trawl fisheries increases as the breeding season progresses to up to ~4 hrs per day during chick-rearing. Our results thus underscore the considerable and consistent co-occurrence of tāiko with the domestic deepwater fleet, and the hoki fleet in particular.

Both broad-scale and fine-scale insights have been gained from our raster-based overlap and point-based overlap analyses, respectively, but inferring bycatch risk directly from tāiko-fishery co-occurrence has remained challenging. Both of our overlap analyses have highlighted the extensive and consistent co-occurrence between tāiko and the deepwater hoki trawl fishery, particularly off the West Coast during the breeding season. Yet, recorded bycatch of tāiko in these fisheries has remained relatively low (15% of all recorded bycaught individuals during 2020-2025; Table 3) despite high observer rates in this fleet (e.g., Edwards *et al.* 2023). In stark contrast, while deepwater ling bottom longline fisheries have shown relatively high overlap in our raster-based overlap analyses, this fleet did not overlap at all with GPS-tracked tāiko in our point-based overlap analyses, and yet this fleet was the main fishery in which tāiko have been recorded as bycatch (61% of all individuals; Table 3). Finally, despite limited, highly seasonal overlap between the southern bluefin tuna surface longline fleet, this fleet was the third-most prominent fishery in which tāiko were bycaught (8%; Table 3). This is particularly notable when considering that observer coverage in this fleet has been low up until the roll-out of electronic monitoring in 2024. However, despite these fleet-specific differences, for each of the different fleets individually, times and locations where overlap was highest was usually where bycatch occurred most.

4.2 Potential drivers of mismatch between co-occurrence and bycatch records

There are likely several underlying drivers that cause the differences between the fleet-specific levels of overlap documented here and the corresponding bycatch records.

Firstly, catchability between surface longliners, bottom longliners and trawlers are fundamentally different (Edwards *et al.* 2023), which, at least partially, will have driven lower bycatch in trawlers compared to the longliners, despite higher rates of co-occurrence. The attraction of seabirds (particularly of *Thalassarche* albatrosses and *Procellaria* petrels) to large factory trawlers is significantly higher than for both surface and bottom longline fisheries (e.g., Richard et al. 2011). Abundance of food available, visual and sound cues for from nets being hauled, odour from onboard meal plants and multiple vessels operating within a small area all contribute to high abundance of seabirds near the large trawl fleets.

Liners operate more solitary, at least in New Zealand, generally have low levels of available food, and have more discrete cues for attraction however each interaction, i.e. diving on baited hooks, can be more consequential.

Secondly, cryptic mortality is notoriously difficult to estimate, is considerably higher for trawl fisheries than for both longline fisheries, subject to ongoing discussions, and as thus complicates bycatch estimation (e.g., Pierre *et al.* 2013, Baker *et al.* 2020). Most notably, all trawl bycatch records were net captures, with no recorded warp strikes, despite the known risk warps pose, even to medium-sized petrels such as tāiko (Phillips *et al*. 2024). This could either be interpreted as highly successful implementation of bycatch mitigation methods in the trawl fleets, or as limited recording of warp interactions in these fleets, or as tāiko being excluded from the risk areas around warps by more aggressive species (e.g., *Thalassarche* albatrosses). While warp mitigation is being implemented in New Zealand deepwater trawl fisheries, there is no mechanism in place that could reliably detect warp strikes, particularly of smaller seabirds such as tāiko, as there is no electronic monitoring on these fleets, nor can human observers access the stern to obtain clear observations of warp strikes due to health and safety concerns.

Thirdly, our point-based overlap analyses were cut-off at 3 km radii, which may considerably underestimate co-occurrence with surface longliners as birds could interact with lines during soak, dozens of km away from the vessel (Goad *et al*. 2025) and the linear 5-min interpolation of sets could further underestimate interactions. Similarly, our linear interpolation for bottom longline fishing events or trawling events is not perfect either. In the same vein, the time spent co-occurring with deepwater trawlers as calculated through our point-based overlap analyses could be inflated due to the additive nature of our calculations and the habit of trawlers, including those targeting hoki, to be operating in reasonably close vicinity.

Fourth, observer coverage is uneven between the different fleets, which would result in differing bycatch recording. However, human observer coverage in the deepwater fleets is traditionally high, providing confidence in the deepwater hoki trawl and deepwater ling bottom longline bycatch records. Surface longline coverage has traditionally been poor, but this fleet is now covered by 100% electronic monitoring and thus future records will provide more clarity.

Finally, *Procellaria* petrels are notoriously difficult to identify and thus some of the bycatch records could be misidentified, as these records do include identifications made by fishers, despite some existing mechanisms to support identification (Bell & McLaren 2025, Blommaart-Klay 2025). Potentially, geographic location of the bycatch events had previously been used erroneously to assign *Procellaria* petrels under the assumption that Westland Petrels do not range as widely as documented here.

These different key considerations are all likely interacting to result in the documented discrepancies between co-occurrence, the recorded bycatch, and the latest iteration of SEFRA (in which ~46% of tāiko mortalities were assigned to trawl, ~27% to surface longline ~27%, and 25% to bottom longline fisheries; Edwards *et al*. 2023). It should be noted that our analyses and the latest iteration of SEFRA do cover a different time period as well, further challenging direct comparisons. The next step forward from our analyses would be a species-specific application of SEFRA to infer tāiko bycatch risk as a function of overlap and recorded bycatch (c.f. Richards *et al.* 2024) or an update of the current New Zealand wide SEFRA (c.f. Edwards *et al*. 2023). However, such exercises are beyond the scope of this project. Instead, we here provided all the necessary information to use the updated insights into spatiotemporal movements of tāiko and the latest bycatch records and gain the most accurate understanding of tāiko bycatch possible.

4.3 Management implications

Although further analyses would provide more insights into the bycatch risk of tāiko and its underlying drivers, our analyses provide clear insights into how management could improve towards addressing bycatch of this species already, without the need of further modelling. Specifically, our insights underscore:

(i) Due to the relatively high level of overlap, and more importantly, the high number of bycatch records in the deepwater ling bottom longline fishery, improved, targeted bycatch mitigation efforts are required in this fleet. Our analyses show that tāiko forage throughout day and night, supporting previous insights (Düssler *et al*. 2026). Moreover, tāiko dive >5 m deep at high speeds (>1 m/s; Düssler *et al*. 2026) and thus to prevent bycatch of tāiko, bottom longline fisheries should implement strategies to sink baited hooks below 10 m within the aerial extent of one or two paired bird scaring lines (as set out in the voluntary Mitigation Standards for this fleet), while adhering to strict bait and offshore management protocols to reduce attraction. The use of integrated weighted lines can assist in obtaining more consistent sink rates in bottom longline fisheries (ACAP 2024A). The implementation of these targeted mitigation methods should be particularly focused during the high-risk period when birds are constrained by central-place foraging (i.e., April-November off the West Coast, in the Cook Strait and over the Chatham Rise; Supplementary Figure S3). Targeted research (e.g., quantifying current sink rate profiles) should be undertaken to identify exactly where current gaps lie within this fleets in terms of bycatch mitigation efficacy, yet additional research should not delay the implementation of improvements over current mitigation.

(ii) To improve understanding of tāiko bycatch in the deepwater trawl fleets in the light of very high levels of co-occurrence and zero observed warp strikes, improved monitoring protocols (either through human observers or electronic monitoring systems) are required to better quantify bycatch of tāiko in these fleets. Furthermore, adherence to best practice bycatch mitigation would minimise tāiko bycatch in trawlers. ACAP (2024B) recommended retention of fish waste (or highly effective discard management where this is not possible), highly effective warp mitigation (e.g., bird scaring lines with the correct specifications), and no use of third wires. Improved monitoring to understand (petrel) warp strikes would also facilitate the assessment of relative effectiveness of the current bycatch mitigation options used, which has not been possible using data collected by routine observer protocols (Large *et al*. 2024).

(iii) To better quantify tāiko bycatch in general in the light of the identification challenges associated with the *Procellaria* genus, all bycaught *Procellaria* petrels should be photographed appropriately (i.e., clear photograph of head and bill), but ideally, returned for identification by specialists (Bell & McLaren 2025, Blommaart-Klay 2025) within the core area where multiple *Procellaria* species overlap (i.e., the West Coast, Cook Strait, and Chatham Rise), at least until a suitable feather DNA sampling protocol has been developed (c.f., Polanowski *et al*. 2024). Additionally, less reliance on geographic location should be placed during identification of this tricky genus as tāiko clearly range more widely than previously assumed.

(iv) The recent improvements of bycatch mitigation requirements within the Aotearoa EEZ for surface longline fisheries, aligning requirements with ACAP best practice advice for these fisheries (ACAP 2024C), will likely be beneficial for tāiko, especially as our results underscore corroborate previous findings of tāiko foraging throughout both day and night (Düssler *et al*. 2026).

5. CONCLUSION

This study demonstrates the value of integrating broad-scale distribution data, fine-scale tracking, and bycatch data to assess seabird co-occurrence with fisheries and guide mitigation implementation without the need for more complex modelling exercises. By combining the different approaches, we captured both potential exposure and realized interactions, offering progress in terms of targeted fisheries management while providing more accurate data for future risk assessments. Our findings highlight how seasonal movements, breeding constraints, and fleet-specific dynamics influence overlap patterns and recorded bycatch, reinforcing the importance of tailoring mitigation to periods and fleets of greatest conservation interest. More broadly, this work illustrates how multi-scale analyses can inform conservation strategies that balance ecological needs with fishing activity.

While our analyses focused on domestic New Zealand fisheries, the trans-Pacific migration, the fact that the species spends more time in Chilean than Aotearoa waters, and the more regular occurrence of this species over the Patagonian Shelf than previously documented all jointly emphasize that effective conservation requires both national and international action to address bycatch across the species' range (c.f. Rowley *et al*. 2026). Considering the high abundance of White-chinned Petrels in South American waters (Rexer-Huber et al. 2025), ensuring that tāiko bycatch is detected in not just Chilean (e.g., Adamse et al. 2019), but also Argentinian waters, and integrated into local bycatch assessments (e.g., Hernandez et al. 2025, 2026) appears to be the first step towards a more holistic understanding of range-wide tāiko bycatch. Beyond the coastal waters in these EEZs however, bycatch should also be better documented in fleets across the high seas, particularly in surface longline fisheries given their high catchability, but this remains an ongoing challenge globally. Seabird bycatch remains a leading global conservation challenge (e.g., Dias et al. 2019) and thus advancing joint analyses like ours and subsequently implementing evidence-based mitigation measures will be critical to reducing mortality and supporting the persistence of vulnerable seabird populations.

6. FUNDING STATEMENT

These analyses were funded via the Department of Conservation's Conservation Services Programme (INT2024-08). GLS, GPS, and field trips associated with the deployment and retrieval of tags for tāiko were partially funded through the Conservation Services Programme (POP2021-08) and (POP2022-07) as well, with additional support directly from the Department of Conservation. The Conservation Services Programme is partially funded by the Aotearoa fishing industry and thus we thank fisheries for their contribution.

7. ACKNOWLEDGEMENTS

We thank Ngāti Waiwai for allowing us to work on their taonga. We are grateful to all the field crew that put in the time and effort of deploying and retrieving tracking devices. Thanks to RDM for servicing the various data requests, including the bycatch data request (ID 17218). We also thank Ben Steele-Mortimer and Dave Goad whose insights improved a previous version of this manuscript.

8. REFERENCES

ACAP. 2024A. Review of mitigation measures and best practice advice for reducing the impact of demersal longline fisheries on seabirds. 14th Advisory Committee, Agreement for the Conservation Albatrosses and Petrels, Lima, Peru.

ACAP. 2024B. Review of mitigation measures and best practice advice for reducing the impact of pelagic and demersal trawl fisheries on seabirds. 14th Advisory Committee, Agreement for the Conservation Albatrosses and Petrels, Lima, Peru.

ACAP. 2024A. Review of mitigation measures and best practice advice for reducing the impact of pelagic longline fisheries on seabirds. 14th Advisory Committee, Agreement for the Conservation Albatrosses and Petrels, Lima, Peru.

Adamse, L.M., et al. 2019. Incidental seabird mortality and discarded catches from trawling off far Southern Chile (39-57°S). *ICES Journal of Marine Science 76:* 848-858.

Anon. 2025. CCSBT collaborative risk assessment for seabird bycatch with surface longlines in the Southern Hemisphere 2025. CCSBT, Canberra, Australia.

Baker, G.B., *et al*. 2020. Improving estimates of cryptic mortality for use in seabird risk assessments: loss of seabirds from longline hooks. New Zealand Aquatic Environment and Biodiversity Report No. 268. Fisheries New Zealand, Wellington New Zealand.

Beal, M., *et al*. 2021. Global political responsibility for the conservation of albatrosses and large petrels. *Science Advances*, *7*(10). https://doi.org/10.1126/sciadv.abd7225

Bell, B., *et al*. 2020. Population trends, at-sea distribution, and breeding population size of black petrels (*Procellaria parkinsoni*) – 2018/19 operational report. New Zealand Aquatic Environment and Biodiversity Report No 246. Fisheries New Zealand, Wellington New Zealand.

Bell, E.A,, & McClaren, D. 2025. INT2022-02: Identification of seabirds captured in New Zealand fisheries: 1 July 2023 to 30 June 2024. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Blommaart-Klay, A. 2025. INT2024-02: Port-based data collection and specimen retention programme. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Bost, C. A., *et al.* 2009. The importance of oceanographic fronts to marine birds and mammals of the southern oceans. *Journal of Marine Systems*, *78*(3), 363–376.

Carneiro, A.P.B., *et al*. 2024. The BirdLife Seabird Tracking Database: 20 years of collaboration for marine conservation. *Biological Conservation* 299: 110813.

Collet, J., *et al.* 2017. A comparative analysis of the behavioral response to fishing boats in two albatross species. *Behavioral Ecology,* 28(5), pp. 1337-1347.

Delord, K., *et al.* 2005. Seabird mortality in the Patagonian toothfish longline fishery around Crozet and Kerguelen Islands, 2001–2003. *CCAMLR Science* 12: 53–80.

Dias M.D., *et al*. 2019. Threats to seabirds: a global assessment. Biological Conservation 237: 525-537.

Düssler, M.R, *et al*. 2026. Diving ecology of *Procellaria* petrels highlights the necessity of combining bird-scaring lines, weighted branch lines, and night setting in pelagic longline fisheries. Animal Conservation. https://doi.org/10.1111/acv.70057.

Edwards, C.T.T., *et al.* 2023. Update to the risk assessment for New Zealand seabirds. *New Zealand Aquatic Environment and Biodiversity Report* No. 314.

Fischer, J.H., *et al*. 2023. Combining tracking with at-sea surveys to improve occurrence and distribution estimates of two threatened seabirds in Peru. *Bird Conservation International* 33: e41. https://doi.org/10.1017/S0959270922000442.

Fisheries New Zealand. 2025. *Fisheries (E-logbook Users Instructions and Codes) Circular.* Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz/dmsdocument/70593-Fisheries-E-logbook-Users-Instructions-and-Codes-Circular-2025

Freeman, A. N. D. 1998. Diet of Westland Petrels *Procellaria westlandica*: The importance of fisheries waste during chick-rearing. *Emu.*98: 36–43.

Freeman, A. N. D., & Wilson, K.-J. 2002. Westland petrels and hoki fishery waste: opportunistic use of a readily available resource? *Notornis*, *49*(3), 139–139.

Goad, D., *et al*. 2025. Understanding and mitigating seabird and turtle bycatch during the pelagic longline soak period. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Hernandez, M.M., et al. 2025. Incidental mortality of black-browed albatross and white-chinned petrel in Argentine longline fisheries: A comprehensive estimation addressing spatial and temporal stratification and cryptic mortality. *Aquatic Conservation: Marine and Freshwater Ecosystems*: 35: e70127.

Hernandez, M.M., et al. 2026. Ecological risk assessment for the effect of commercial longline fisheries to black-browed albatross and white-chinned petrel populations in Argentina. *Marine Policy 184:* 106941.

Hijmans R. 2025. *raster: Geographic Data Analysis and Modeling*. R package version 3.6-32.

Holdsworth, J.C. 2025. Recreational harvest of southern bluefin tuna in New Zealand, 2023–24 New Zealand Fisheries Assessment Report 2025/04. 22 p.

IUCN. 2025. The IUCN Red List of Threatened Species. Version 2025-1. https://www.iucnredlist.org.

Landers, T. J., *et al.* 2011. Dynamics of Seasonal Movements by a Trans-Pacific Migrant, the Westland Petrel. *The Condor*, *113*(1), 71–79.

Large, K. *et al*. 2024. Warp strike mitigation in large-vessel trawl fisheries in New Zealand. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Merkel, B., *et al.* 2016. A probabilistic algorithm to process geolocation data. *Movement Ecology, 4*, 26.

Ministry for Primary Industries. (n.d.). NZ fish stocks and MPI team with responsibility for management. Retrieved from 19709-Fish-species-and-stocks-by-management-team

Morten, J. M., *et al*. 2025. Global marine flyways identified for long-distance migrating seabirds from tracking data. Global Ecology and Biogeography 34: e70004.

Murphy, R. J., M. H. *et al.* 2001. Phytoplankton distributions around New Zealand derived from SeaWiFS remotely-sensed ocean colour data. *New Zealand Journal of Marine and Freshwater Research* 35: 343–362.

Orben, R. A., *et al*. 2021. Across borders: External factors and prior behaviour influence North Pacific albatross associations with fishing vessels. *Journal of Applied Ecology*.

Rexer-Huber, K., *et al*. 2025. Metapopulation distribution shapes year-round overlap with fisheries for a circumpolar seabird. Ecological Applications 35: e70019.

Rowley, O., et al. 2026. Range-wide black petrel distribution and overlap with pelagic longline fisheries: Insights from global AIS and local vessel data. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Peatman, T., *et al*. 2023. Review of biological inputs for the New Zealand Seabird Risk Assessment*. New Zealand Aquatic Environment and Biodiversity Report* No. 312.

Phillips, R. A., *et al.* 2004. Accuracy of geolocation estimates for flying seabirds. *Marine Ecology Progress Series* 266: 265–272.

Phillips, R. A., *et al*. 2024. Incidental mortality of seabirds in trawl fisheries: A global review. Biological Conservation 296: 110720.

Piere, J.P., *et al*. 2013. Assessment of cryptic seabird mortality due to trawl warps and longlines. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Pinkerton, M. 2016. Ocean colour satellite observations of phytoplankton in the New Zealand EEZ, 1997–2016. *NIWA report no. WLG2016-19*. Prepared for Ministry for the Environment by NIWA, Auckland, New Zealand.

Polanowski, A.M., *et al*. 2024. The development of DNA markers to resolve uncertainties of seabird bycatch identification from longline fisheries in Australian waters. Ecology and Evolution 14: e70568.

Richards, Y., *et al.* 2011. Counts of seabirds around commercial fishing vessels within New Zealand waters. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Richards, Y., *et al*. 2024. Antipodean Albatross multi-threat risk assessment. New Zealand Aquatic Environment and Biodiversity Report No. 332. Fisheries New Zealand, Wellington New Zealand.

Simister, K., *et al*. 2023. Progress report on Westland Petrel projects (POP2021-08) and (POP2022-07) investigating burrow occupancy, foraging behaviour and at-sea movement. Conservation Services Programme, Department of Conservation, Wellington, New Zealand.

Waugh, S. M., *et al.* 2018. Environmental factors and fisheries influence the foraging patterns of a subtropical seabird, the Westland Petrel (*Procellaria westlandica*), in the Tasman Sea. *The Condor*, *120*(2), 371–387.

Waugh, S., *et al*. 2020. Changes in population density and response to storm damage for Westland petrels 2007-2019. *Marine Ornithology* 48: 273-281.

SUPPLEMENTARY MATERIAL

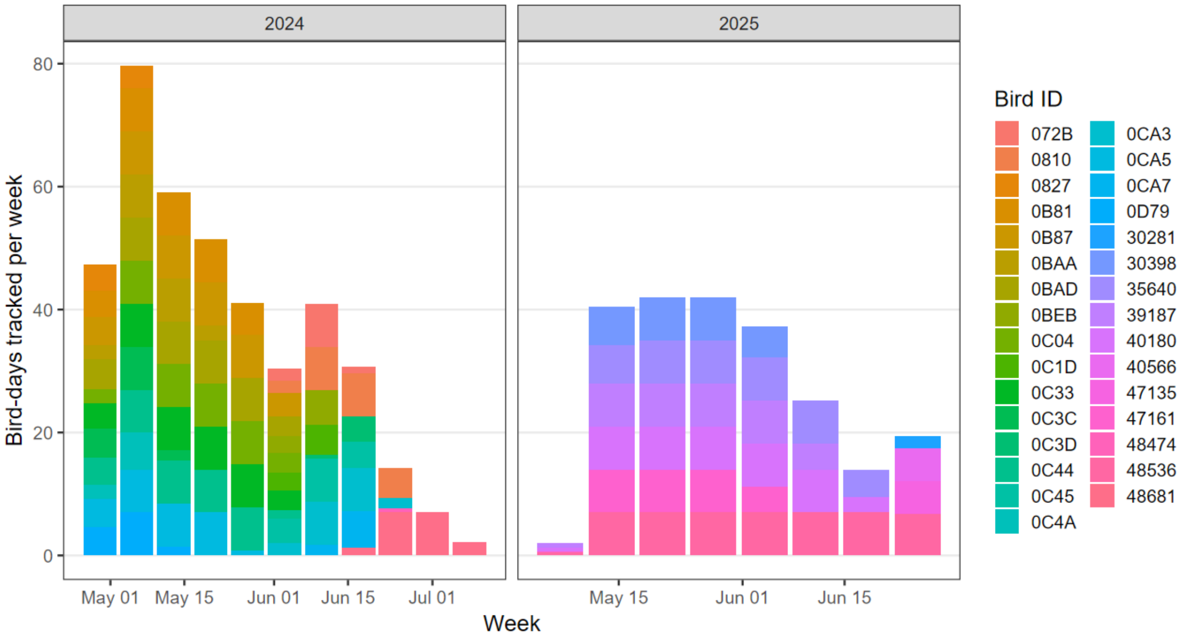

Figure S1: Tāiko GPS tracking effort by week in 2024 and 2025. Colours represent individual birds. Although some tracking continued into July, we did not have access to fisheries data after 30 June (NZ time), hence our exclusion of GPS after that date.

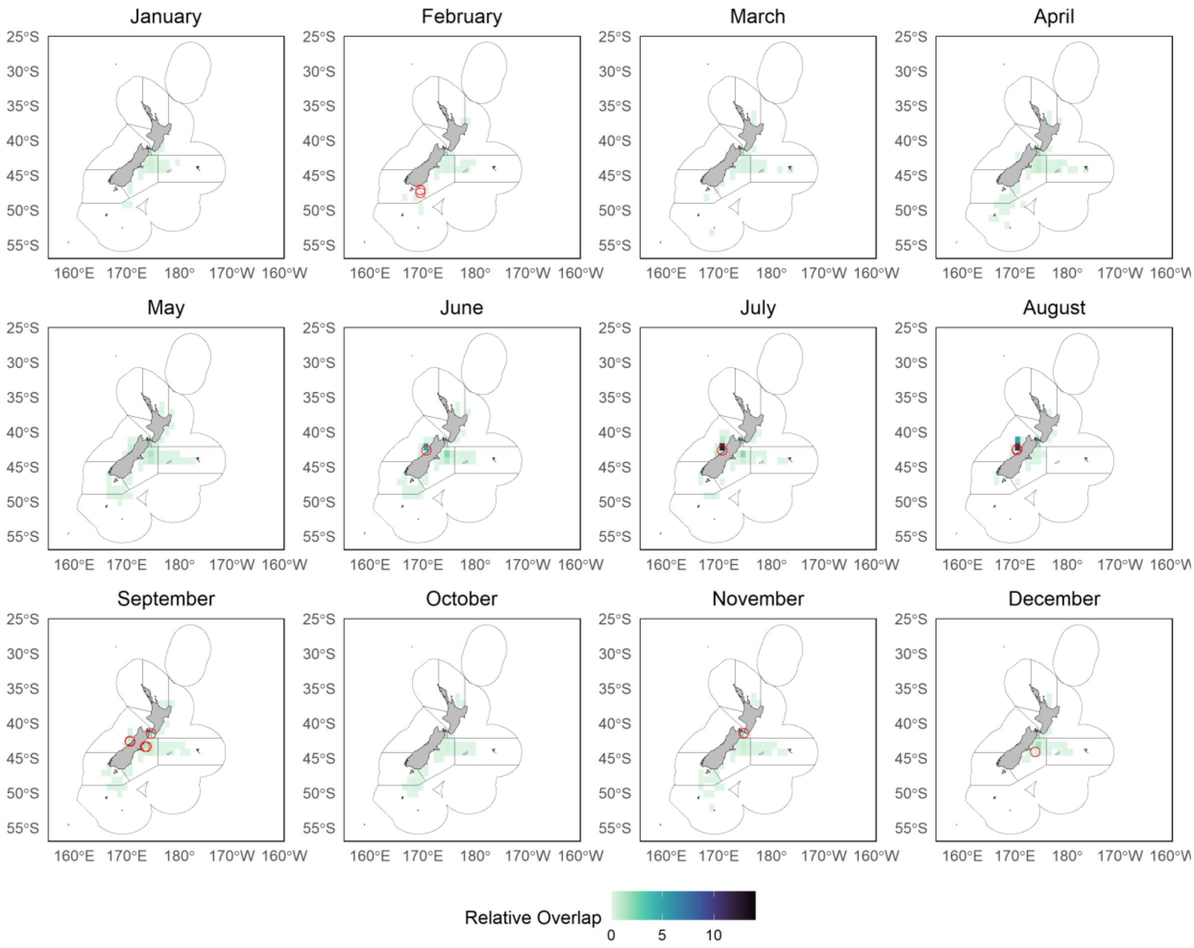

Figure S2: Tāiko overlap with deepwater hoki trawl fisheries. Relative overlap is represented as (bird-day x number of tows)

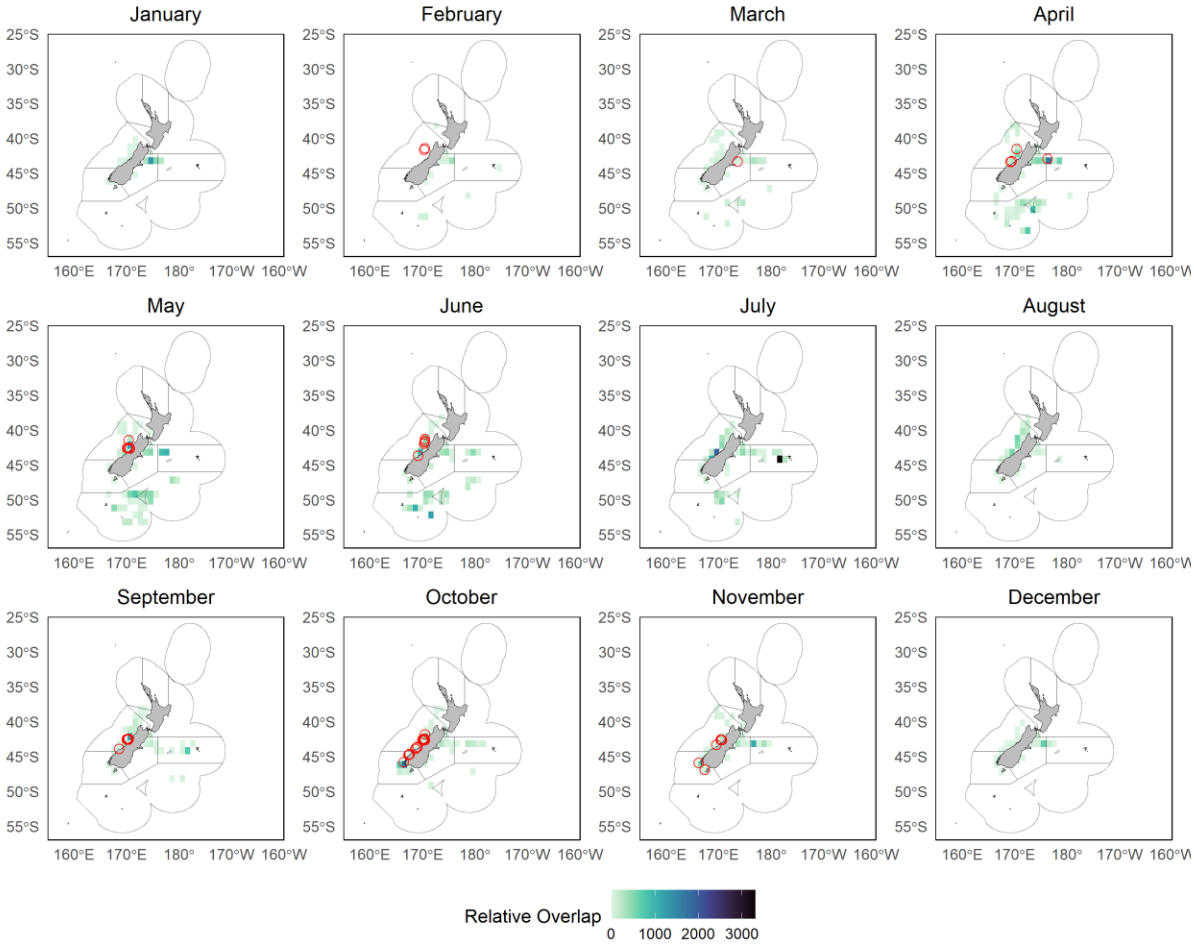

Figure S3: Tāiko overlap with deepwater Ling bottom longline fisheries. Relative overlap is represented as (bird-day x number of hooks)

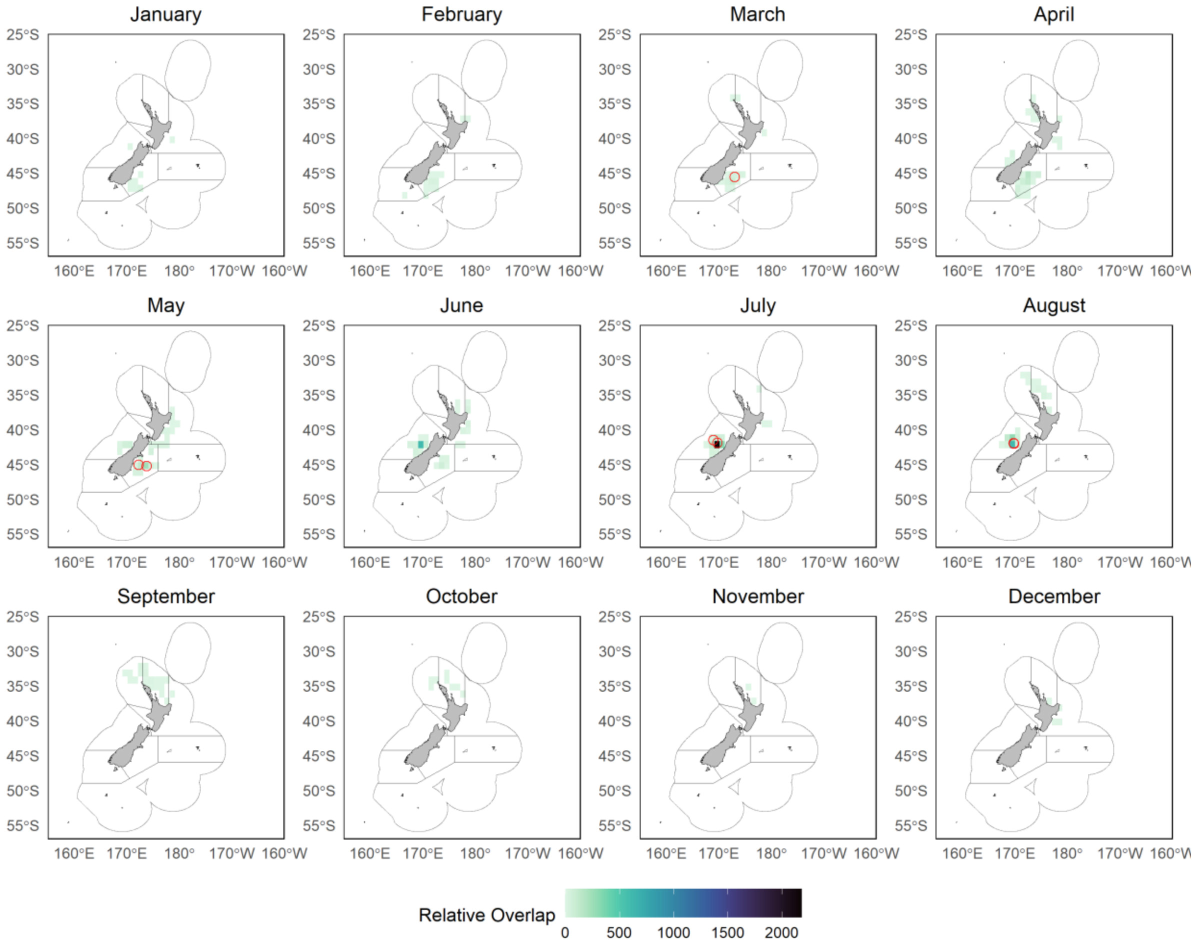

Figure S4: Tāiko overlap with southern bluefin tuna surface longline fisheries. Relative overlap is represented as (bird-day x number of hooks)**.**

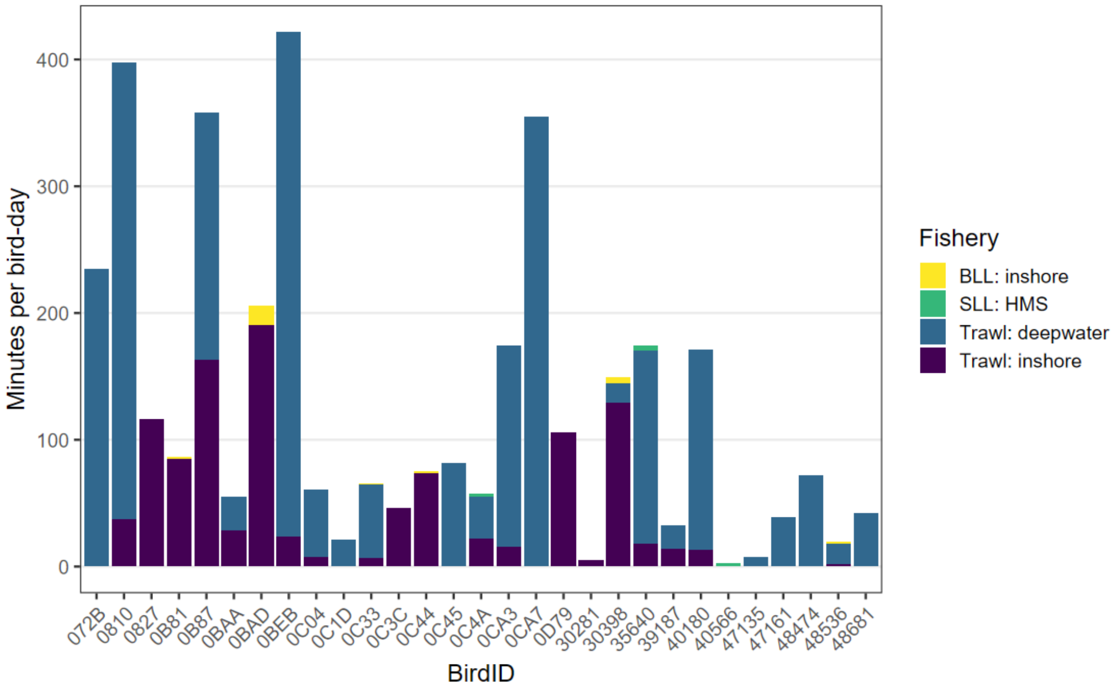

Figure S5: Bird-vessel interaction rates by individual. Birds spent on average 2.1 ± SD 2.0 hours per day within 3 km of trawl and longline vessels.

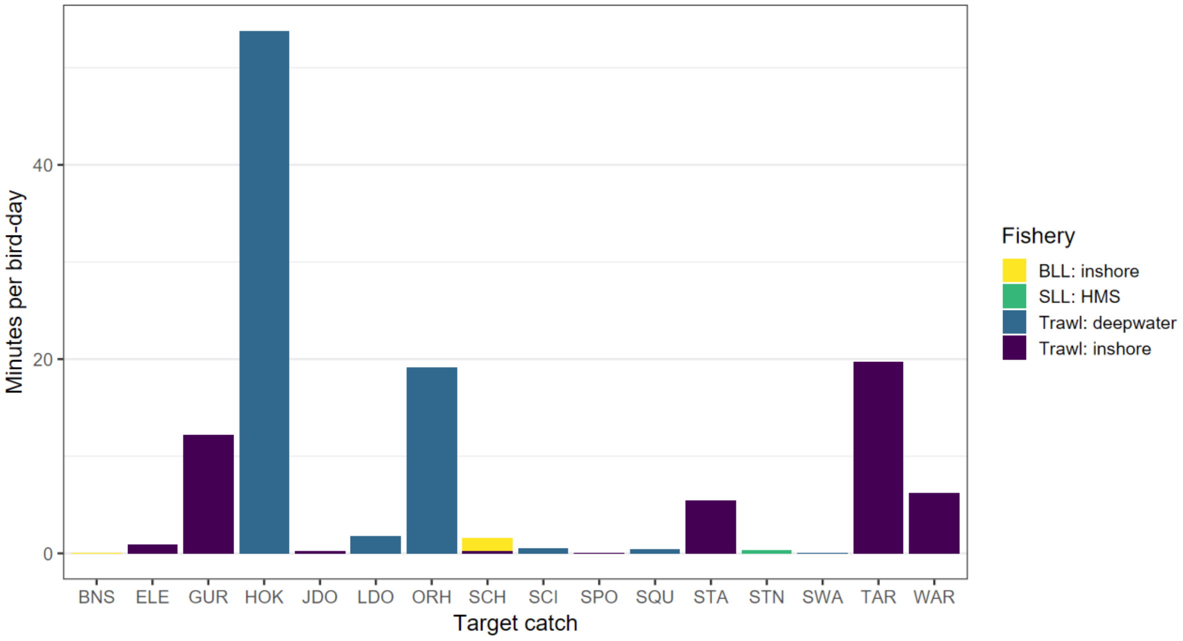

Fig. S6: Bird-vessel interaction rates by target catch (individual species).