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**An update on the New Zealand large-scale seabird monitoring and tracking programme  
with improved insights into trends, distribution, and overlap with pelagic longline fisheries**

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**WCPFC-SC20-2024/EB-WP-10**

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## ABSTRACT

New Zealand hosts a large proportion of the world's seabirds and maintains a large-scale monitoring and tracking programme to better understand population trends and distributions.

We analysed 184 population counts across 1945-2024 and 1,151 tracks for 11 New Zealand albatross and large petrel taxa vulnerable to longline fisheries bycatch. We estimated long-term population trends (annual growth rates  $r_t$ ) over various time periods using a Bayesian framework and generated year-round maps to improve understanding of the distributions of these seabirds within the Western and Central Pacific Ocean (WCPO). We expanded our spatial analyses and included 583 tracks of three Northern Hemisphere albatrosses to develop combined WCPO seabird distribution maps. Finally, we conducted fine scale overlap analyses for two taxa of particular concern, Antipodean and Gibson's Albatross, in which we assessed spatiotemporal overlap of 235 albatross tracks with commercial pelagic longline fishing effort inferred from automated identification system data, sourced from Global Fishing Watch.

Our results show that 73% of the studied New Zealand taxa have exhibited population declines, with biannually and semi-biannually breeding albatrosses showing the greatest rates of decline. Growth rates across taxa did not improve over time (mean  $r_{1990-2010} = -1.07\%$  (-1.56; -0.58), mean  $r_{post-2010} = -0.84\%$  (-1.29; -0.40).

Year-round distribution maps show that while the Southern Hemisphere taxa ranged widely around the globe, the WCPO is of crucial importance to vulnerable seabirds. All studied taxa occur extensively in the high seas. For Southern Hemisphere taxa, waters up to 25°S around New Zealand, the Tasman Sea, and the South Pacific east of New Zealand were of particular importance. Waters up to 20°S were frequented by four of the studied Southern Hemisphere seabirds as well. For Northern Hemisphere albatrosses, waters around breeding colonies, east of Japan and the Kuril Islands, south of the Aleutians, and some core areas in the central North Pacific were of particular importance.

Of the Antipodean and Gibson's Albatrosses subjected to fine scale analyses, 77% overlapped with commercial pelagic longline fishing effort. The areas of highest bird-vessel overlap were in the high seas within the Convention Area of WCPFC, particularly in the areas south of 30°S and 25°-30°S. Birds were more likely to overlap with commercial pelagic longline fishing effort the further north in the Southern Hemisphere they ventured, particularly in the high seas.

Other studies (e.g., WCPFC-SC20-EB-IP26) indicate that bycatch in longline fisheries across the WCPO is the most likely, and the most manageable, driver of the declines observed. The joint seabird distribution maps underscore the responsibility of the WCPFC for these seabirds and for addressing the threat of fisheries bycatch and to ensure effective seabird bycatch mitigation methods are in place where these vulnerable seabirds occur.

**It is recommended that WCPFC SC20:**

- **Notes** the analysis of New Zealand albatross and petrel populations, showing significant, long-term, population declines, most likely caused for some species by bycatch in commercial pelagic longline fisheries.
- **Notes** the analyses of the distribution of 11 New Zealand albatross and petrel taxa, the distribution of three Northern Hemisphere albatross taxa, and fine-scale tracking of Antipodean and Gibson's albatross, which all show an extensive coverage within the WCPO. These analyses highlight:
  - Key areas of importance in Southern Hemisphere waters up to 25°S around New Zealand, the Tasman Sea, and the South Pacific east of New Zealand (but several vulnerable taxa frequent waters further north up to 20°S); and
  - Key areas of importance in Northern Hemisphere waters around the Japanese and Hawaiian seabird colonies, east of Japan and the Kuril Islands, the Bering Sea, south of the Aleutians and some core areas in the central North Pacific.
- **Notes** that the majority of tracked Antipodean and Gibson's albatross overlapped with commercial pelagic longline fishing effort, including in areas with reduced (25°-30°S) or no mandatory bycatch mitigation requirements (20°-25°S).

## INTRODUCTION

The Pacific Ocean, and the Western and Central Pacific Ocean (WCPO) in particular, is a global seabird hotspot (e.g., Beal *et al.* 2021). A large proportion of the world's seabirds, and particularly a large proportion of the world's large Procellariiform seabirds (albatrosses and petrels) occur in the WCPO (e.g., Croxall *et al.* 2012, Beal *et al.* 2021). For example, 17/22 (77%) albatross taxa rely on this ocean basin (ACAP 2022). Consequently, the Western and Central Pacific Fisheries Commission (WCPFC) holds a considerable global responsibility for the conservation of these species. Population trends of many seabirds globally, and within the WCPO in particular, are in decline. Only six out of 23 (26%) ACAP species that frequent the WCPO have positive population trends (ACAP 2022).

New Zealand holds a particular responsibility for seabirds, and especially albatrosses and petrels, as no other country holds a higher variety of seabirds or a higher level of endemism (Croxall *et al.* 2012). For example, 11/22 (50%) albatross species breed on the shores of New Zealand, of which eight (36%) are endemic.

New Zealand has been coordinating a large-scale seabird population monitoring and tracking programme for decades (Fig. 1). The aim of these programmes is to better understand population dynamics, trends, and distributions of New Zealand seabirds. To inform the review of CMM 2018-03, we have synthesized all available information provided through these programmes and present analyses of:

- I. Long-term population trends for and across selected New Zealand taxa, and
- II. Distribution of selected New Zealand taxa vulnerable to bycatch in commercial pelagic longline fisheries (hereafter pelagic longline fisheries).
- III. Fine scale overlap analyses of the two most well-studied taxa (Antipodean Albatross and Gibson's Albatross) with pelagic longline fisheries

## METHODS

### Selection of seabird taxa

We selected Albatross (Diomedidae) and Petrel (Procellariidae) taxa breeding in the Southern Hemisphere for inclusion in our analyses based on:

- I. The presence of significant breeding populations in New Zealand (taxa endemic to New Zealand were considered high priority, while for taxa that also breed outside of New Zealand, only the New Zealand breeding population was included),
- II. Their known threat status (e.g., ACAP listing, IUCN Red List Status, and New Zealand Threat Classification System Status; ACAP 2024, IUCN 2024, Robertson *et al.* 2021)
- III. Their vulnerability to pelagic longline bycatch (e.g., as illustrated by Edwards *et al.* 2023a,b),
- IV. The availability and quality of year-round tracking data (based on the BirdLife International Seabird Tracking Database; [www.seabirdtracking.org](http://www.seabirdtracking.org) and unpublished datasets) and population count data at representative colonies (based on the ACAP database and existing reports published by the New Zealand Department of Conservation; DOC).

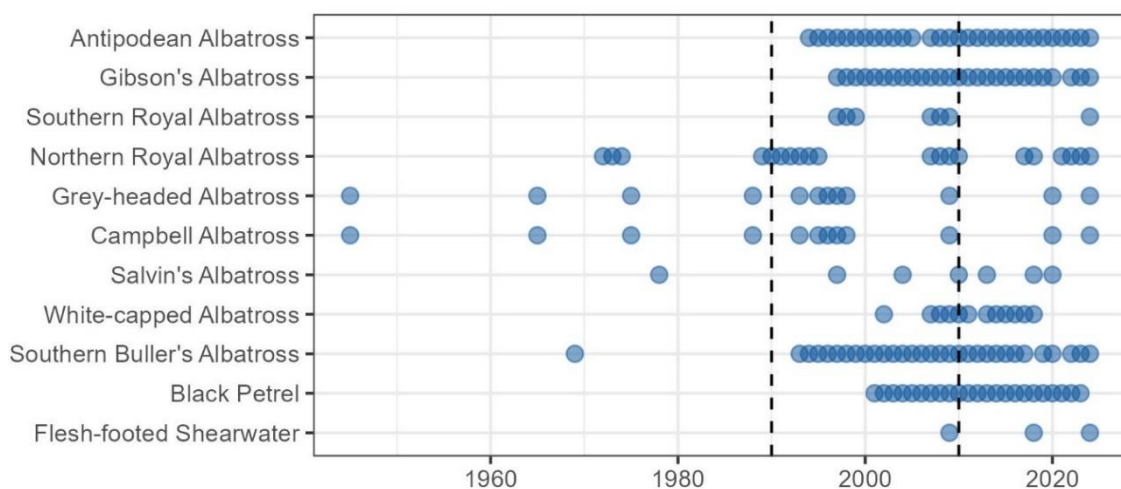
Following this approach, we selected 11 taxa, ten of which are ACAP-Annex-1-listed taxa, and one is an ACAP-Annex-1 candidate taxon (Flesh-footed shearwater *Ardenna carneipes*), for our analyses. We treated Antipodean (*Diomedea antipodensis antipodensis*), Gibson's (*D. a. gibsoni*), and Southern Buller's albatross (*Thalassarche bulleri bulleri*) (Table 1) as separate taxa, in alignment with the New Zealand Threat Classification System (Robertson *et al.* 2021). Further details on selected taxa and the associated tracking and count data are presented in Table 1.

### New Zealand seabird count data

Following the selection of our focal taxa, we sourced population count data (in number of breeding pairs) from monitoring programmes at 11 colonies (one for each taxon) to assess population trends. We used count data because it was available in adequate quantity to assess both population and community-level trends. Other potentially more accurate and precise data sources, such as capture-recapture/resight data (e.g., Oppel *et al.* 2022, Richard *et al.* 2024a) were not as consistently available.

Population count data were sourced from both the ACAP database as well as published DOC reports (and unpublished DOC reports for 2024). Count data were generated both through full island counts (e.g., Frost 2022) as well as through counts from representative study/index sites (e.g., Rexer-Huber *et al.* 2023, Walker *et al.* 2023) depending on the study system. For systems that consist of several representative study sites/index sites (e.g., Antipodean, Gibson's, Southern Royal Albatross *D. epomophora* and Southern Buller's Albatross), only years in which all representative study sites were counted were included.

Reporting of uncertainty around population counts in the ACAP database and the original reports is often inconsistent or absent (e.g., Bell *et al.* 2023, Rexer-Huber *et al.* 2023, Walker *et al.* 2023, Sagar *et al.* 2024). This meant we could not include a uniform estimation process for the uncertainty surrounding each count in our modelling process (see below), and thus we only sourced reported means for counts that included uncertainty reporting. For taxa breeding over more than one calendar year (i.e., virtually all), we report year as the year in which chicks fledge, as per ACAP convention. In one case (White-capped Albatross *T. steadi*), two conflicting sources of count data exist (based on different correction factors applied to aerial counts; Walker *et al.* 2020, Baker *et al.* 2023). Here, we chose to select the more precautionary analysis (i.e., Walker *et al.* 2020). After compilation, our dataset consisted of 184 population counts for the 11 selected taxa (Table 1, Fig. 1).



**Fig. 1.** Count periods for the eleven taxa included in our analyses. Each symbol relates to a population count. Dotted lines indicate 1990 and 2010, relevant to time periods for population growth analyses.

## Estimating long-term population trends in New Zealand

To estimate the population trends of each taxon over time, we followed the approach of Paxton *et al.* (2016) and Fischer *et al.* (2020) and fitted Bayesian generalised linear mixed-effects models (GLMMs) with a Poisson error distribution to the population count data available. Specifically, we fitted the following model to the population count data:

$$1) \text{Log}(N_t) = \alpha + r_t + \varepsilon_t,$$

in which  $N_t$  refers to the population count (in breeding pairs) in year  $t$ ,  $\alpha$  is  $\text{log}(N_0)$  (the population count at year 0),  $r$  is the annual population growth rate (i.e.,  $\text{log}(\lambda)$ , in which  $\lambda$  is the finite rate of increase),  $t$  is the number of years between 0 and  $t$ , and  $\varepsilon_t$  is a random annual variation (Fischer *et al.* 2020). We thus assumed that population trajectories would follow exponential growth (positive  $r_t$ ) or decline (negative  $r_t$ ) trajectories. We fitted equation 1 to the data per taxon and estimated growth rates during five specific time periods:

- I. The total monitoring period available ( $r_{total}$ ),
- II. The monitoring period prior to 1990 (if available;  $r_{pre-1990}$ ),
- III. The 1990-2010 monitoring period (if available;  $r_{1990-2010}$ ),
- IV. The 2010-present monitoring period (if available;  $r_{post-2010}$ ), and
- V. The period following the highest population count (referred to as  $N_{max}$ ) ( $r_{N_{max}}$ ).

We only calculated growth rates if more than two counts were available in any given period. However, we allowed for some flexibility in the definitions of time periods II, III, and IV to maximize information gained from the available data. Specifically, if only two data points were available for a given period, but a datapoint existed one year preceding or following the period under assessment, we extended the period (i.e., we allowed some flexibility for Grey-headed Albatross *T chrysostoma*, Campbell Albatross *T. impavida*, and Flesh-footed Shearwaters for the post-2010 period; Fig. 1). In addition to our GLMMs, for visualisation purposes, we also generated plots of standardised population sizes over time in which we set  $N_{max}$  to 1 and scaled all other counts accordingly. Finally, to gain insights into community-level population trends, we calculated the community-level means for  $r_t$  for the same time periods as for the taxon-specific estimates, apart from V, as this period depended on a taxon-specific  $N_{max}$ .

We fitted our GLMMs in the Bayesian modelling programme OpenBUGS 3.2.3 (Spiegelhalter *et al.* 2014), which employs Markov Chain Monte Carlo (MCMC) algorithms to generate posterior distributions for parameters, while simultaneously allowing for uncertainty to be adequately propagated in those distributions. We used uninformative priors for  $\alpha$  and  $r$  ( $N[0,0.01]$ ) (Fischer *et al.* 2020). To obtain posterior distributions for our parameters of interest, we pooled two MCMC chains of 50,000 after a burn-in of 25,000 iterations. We evaluated trace plots and the Gelman-Rubin statistic ( $R < 1.05$ ) to confirm model convergence. For easy interpretation, we transformed all  $r_t$  estimates into percentages and report estimates as medians with 95% credible intervals, unless otherwise stated.

## Tracking data of New Zealand seabird taxa and data processing

To update the available information and improve the accessibility of the at-sea distributions of our 11 New Zealand taxa, we collated 1,151 tracks from 16 different colonies from either datasets published on the BirdLife International Seabird Tracking Database ([www.seabirdtracking.org](http://www.seabirdtracking.org)) or unpublished datasets currently held by DOC. Specifically, we sourced 48 datasets from the Seabird Tracking Database (reference numbers 427, 429, 430, 469- 472, 474, 476, 478, 479, 532, 533, 556, 618- 621, 624, 631, 632, 636, 640, 648, 658, 659,

666, 669, 949, 951, 999, 1082, 1257-1259, 1324, 1325, 2057, 2058, 2069, 2070, 2072, 2074, 2075, 2077, 2081, 2172, 2173) and compiled additional unpublished data (e.g., because tracking is still ongoing) for Gibson's Albatross, Southern Royal Albatross, Black Petrel, and Southern Buller's Albatross. We did not differentiate between breeding vs. non-breeding stages and included both adult and juvenile data (for 5/11 (45%) taxa juvenile tracking data was available to describe distributions as comprehensively as possible for each taxon).

The compiled location data originated from both GPS/PTT tracking as well as GLS tracking, which are characterised by fundamental differences. GPS and PTT tracking devices have high accuracy (~30-170 m for GPS devices, ~50-20,000 m for PTT devices; Hazel 2009, Irvine *et al.* 2020) at a variable temporal resolution (1-40 locations/day), but rarely provide year-round tracking data as devices either fall off when birds moult their feathers (almost all GPS/PTT devices are attached using feather mounts), their battery runs out, or their memory space is depleted. GLS tracking devices have lower accuracy (~145 km; Merkel *et al.* 2016) at a regular temporal resolution (2 locations/day) but have other benefits including low weights and battery and memory requirements. GLS devices can be deployed on birds' leg bands, providing data year-round and even across years. Our dataset contained 695 (60%) GPS/PTT tracking tracks and 456 (40%) GLS tracks (Table 1) and each taxon's dataset contained at least several tracks covering the full annual cycle (i.e., each dataset contained location data for each month of the year).

GPS/PTT and GLS data needed to be processed in different ways. For unpublished GPS/PTT data, we discarded PTT-derived locations with an Argos quality of A, B and Z and locations with an Argos-generated error ellipse variable of >10km error radius (Bose & Debski 2021). We subjected both published and unpublished GPS/PTT data to a visual inspection and a speed filter of >25 m/s to remove any erroneous positions, matching previous work (e.g., Carneiro *et al.* 2020). We then linearly interpolated all GPS/PTT data (i.e. re-discretization every 12 hours) to match GLS sampling frequency. For unpublished GLS datasets, we processed and cleaned data using an iterative probabilistic algorithm which includes several speed filters and spatial masks, fitted through *probGLS* (Merkel *et al.* 2016). For published GLS data, we removed locations around the equinoxes (March equinox: -21, +7 days; September equinox: -7, +21 days) prior to analysis where necessary. Consequently, we obtained cleaned data from various tag types, ready for integration into year-round distribution maps.

### **Generating year-round distribution maps for Southern Hemisphere seabird taxa**

To improve the accessibility of the at-sea distribution of the focal taxa, we generated single year-round distribution maps that accounted for I) different tracking data types, sample sizes, and the error associated with them, II) different colony sizes and therefore different representativeness of tracking data at a taxon level, and III) changes in sample size across the annual cycle (e.g., due to ceased data transmission). Specifically, we estimated utilization distributions (UDs) using kernel analyses in the *adehabitatHR* package (Calenge 2006) for each data group, which consisted of unique combinations of taxon, colony (e.g., island group), device type and calendar month. We used a fixed smoothing parameter (*h*) of 50 km for GPS/PTT data and 200 km for GLS data (Carneiro *et al.* 2020).

To control for differences in the number of trips per device type, we combined UD based on GPS/PTT data and UD based on GLS data by weighting each by the proportion of individuals represented. When data were available from several colonies of a single taxon, we combined UD for each colony into a single UD based on the percentage of the total population involved based on data sourced from ACAP (2024). We then summed monthly UD to generate balanced annual distributions per taxon. From these taxon-level year-round UD, we calculated the 50, 75, 95 and 99% isopleths to categorise different levels of intensity in use. We delineated core areas as those areas enclosed by the lowest percent of these isopleths.

### **Inclusion of Northern Hemisphere seabird species**

The WCPO is characterised by large Procellariiform communities in both the Southern and Northern Hemisphere and thus we repeated the processing and analysis steps for the three Pacific Northern Hemisphere Albatross taxa vulnerable to pelagic longline fishing. We sourced 346 tracks from three Laysan Albatross (*Phoebastria immutabilis*) colonies, 206 tracks from two Black-footed Albatross (*P. nigripes*) colonies, and 31 tracks from one Short-tailed Albatross (*P. albatrus*) colony (Table 1). All tracks were sourced from the Seabird Tracking Database (reference numbers 452, 453, 512, 513, 519-529, 964, 965, 1857, 1858, and 1927-1930). This 583-track dataset consisted of 388 (67% PTT/GPS tracks and 195 (33%) GLS tracks. We replicated the same data processing and analyses steps used for the New Zealand taxa to generate species-level year-round UD with the associated 50, 75, 95, and 99% isopleths to categorise different levels of intensity in use.

This inclusion ensured that our mapping exercise was more balanced across the WCPO as it now included 80% of the seabird taxa vulnerable to pelagic longline fishing that depend on the WCPO. The remaining taxa not included were taxa that did not meet our data requirements as specified above.

### **Generating year-round community-level distribution maps**

As even single maps for individual taxa can be challenging to interpret when considering over a dozen of maps, we combined the taxon/species-level maps into easy-to-use, accessible, community-level maps for both Hemispheres and the entire WCPO. We merged all 11 year-round taxon-level UD into a single year-round UD and calculated the same isopleths to present the combined distribution for the New Zealand Procellariiform community. We repeated this process for the three Northern Hemisphere taxa to generate a Northern Hemisphere distribution map. We then merged the Southern and Northern Hemisphere UD based on 1,734 individual tracks into a single WCPO seabird distribution map illustrating the occurrence and intensity of use of seabirds vulnerable to pelagic longline bycatch across the WCPFC Convention Area.

### **Fine scale overlap with pelagic longline fisheries in the Southern Hemisphere**

We assessed the spatiotemporal overlap with pelagic longline fishing effort of two Southern Hemisphere taxa that are of particular concern and for which the most data were available: Antipodean and Gibson's Albatross. Specifically, we overlapped GPS/PTT satellite transmitter tracks of 153 Antipodean Albatross and 82 Gibson's Albatross obtained over the course of 2019-2024 with fishing effort inferred from Automated Identification System (AIS) data, sourced from Global Fishing Watch (GFW; Kroodsmas *et al.* 2018). Following the cleaning process as described above, we retained, 61,412 Antipodean albatross and 53,918 Gibson's albatross locations. We then interpolated to these tracks to a 1-hour fix rate, with each position corresponding to 1 bird hour (bird hour being the geographical space occupied by a bird for every hour of tracked time), to obtain our final input datasets for our fine-scale overlap analyses.



We used these input datasets to generate insights into the relative occurrence of Antipodean and Gibson's Albatross within geopolitical areas, as calculated by the relative number of bird hours spent in an area per year. We quantified relative occurrence for various jurisdictions: Exclusive Economic Zones (EEZs) and the High Seas, as well as per Regional Fisheries Management Organisations (RFMOs) (including EEZs), including the Western and Central Pacific Fisheries Commission (WCPFC), but also the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), the Inter-American Tropical Tuna Commission (IATTC), and the Indian Ocean Tuna Commission (IOTC). As some RFMOs overlap, the total sum of the relative occurrence exceeded 100%.

To quantify spatiotemporal overlap of pelagic longline fishing effort per bird location, we identified vessels within a 100 km radius of albatross locations (based on the potential range in length of a pelagic longline; Bose & Debski 2021), acquiring vessel information (fishing effort and gear type) from GFW at a  $0.01^\circ \times 0.01^\circ$  daily resolution (Kroodsma *et al.*, 2018). We calculated total spatiotemporal overlap between a pelagic longline fishing vessel and bird location by dividing the total fishing effort value for that location by 24 and multiplying it by the mean bird hour for that location. To evaluate the relationship between overlap and latitude, we allocated relative overlap into separated into  $5^\circ$  latitudinal bands.

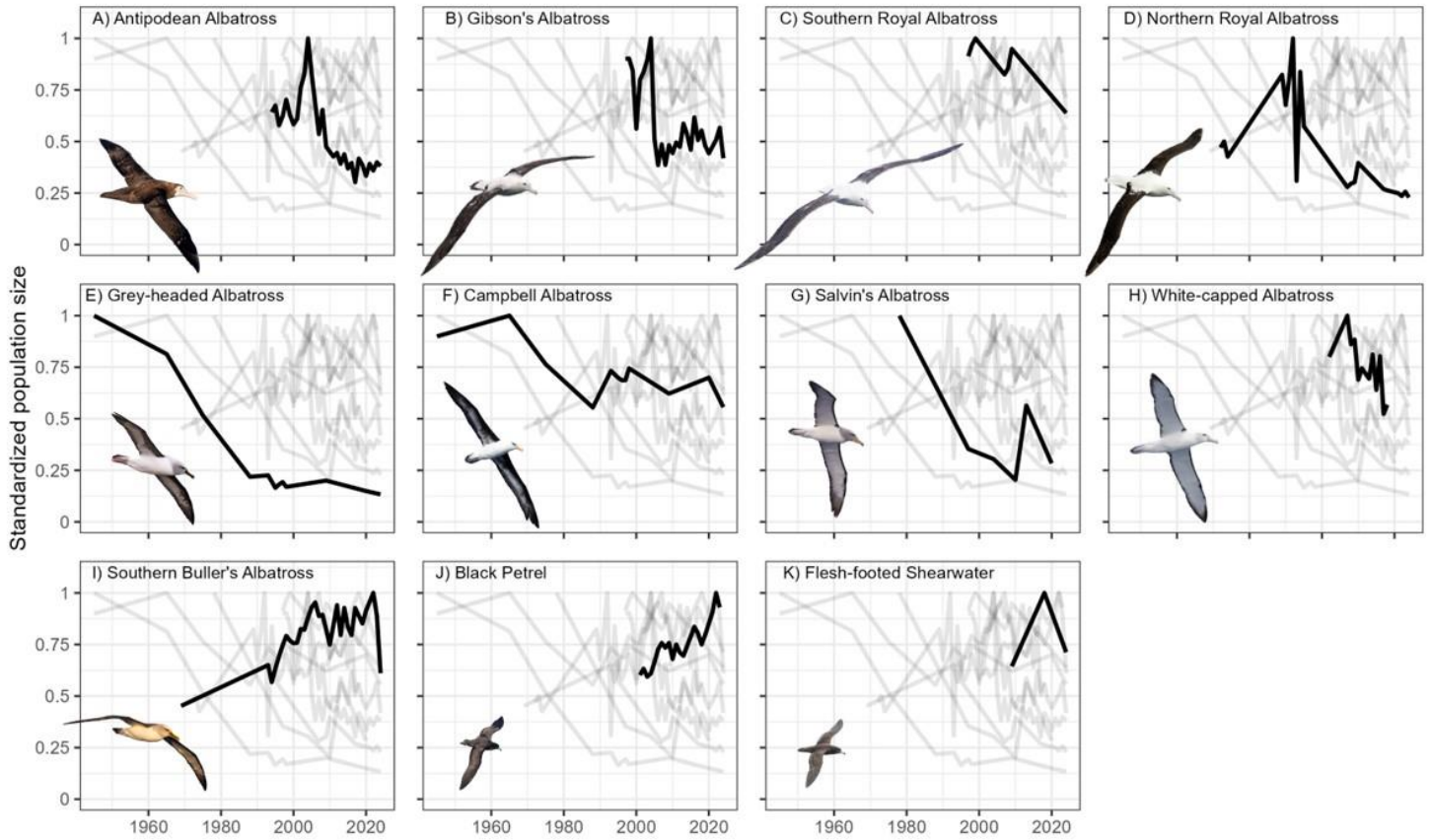
## RESULTS

### Long-term seabird population trends observed in New Zealand

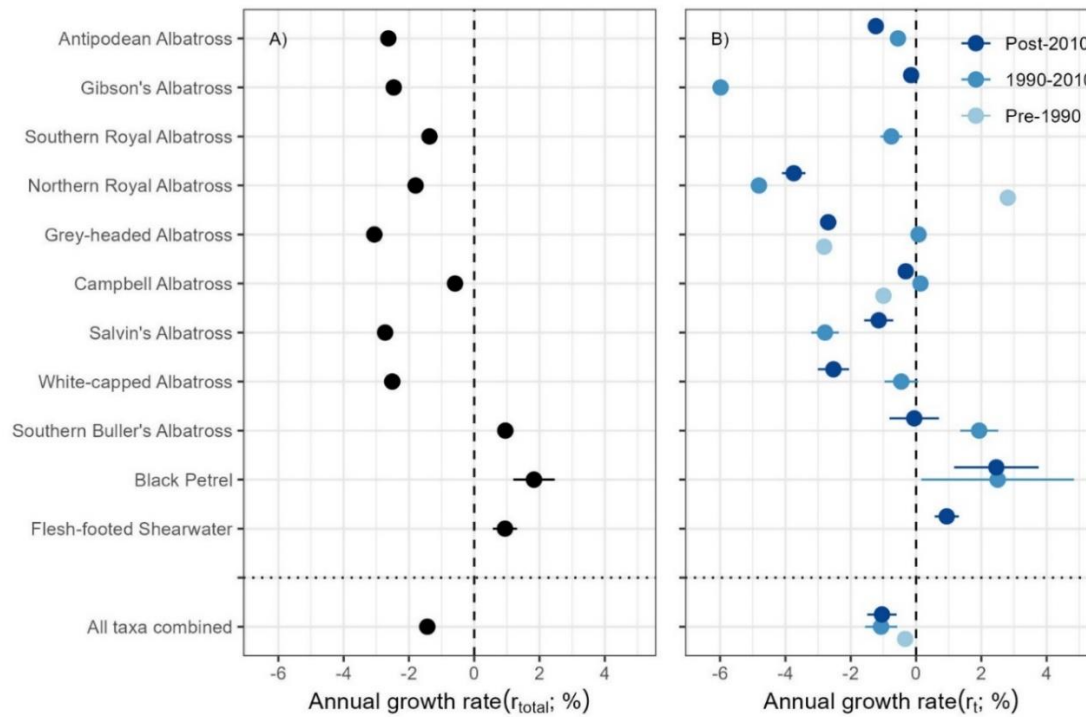
Our analyses have shown that 8/11 (73%) of the New Zealand focal taxa have declined over the monitoring period (Fig. 2). Biannually and semi-biannually breeding species (Antipodean Albatross, Gibson's Albatross, Southern Royal Albatross, Northern Royal Albatross *D sanfordi*, Grey-headed Albatross, and White-capped Albatross) and the annually breeding Salvin's Albatross (*T. salvini*), showed the greatest rates of decline (Fig. 3A). In contrast, Southern Buller's Albatross, Black Petrel (*P. parkinsoni*), and Flesh-footed Shearwater showed increasing or stable population trends over the monitoring period.

For most taxa, annual growth rates did not improve over time (Fig. 3B). Growth rates for Northern Royal Albatross deteriorated after 1990s, while for Grey-headed Albatross and Campbell Albatross, growth rates improved temporarily between 1990 and 2010, after which they deteriorated again. Reduction in growth rates post-2010 was evident in the Antipodean Albatross, White-capped Albatross, and Southern Buller's Albatross. Contrastingly, Gibson's Albatross and Salvin's Albatross population growth rates improved post-2010.

Across taxa, this group of albatrosses and large petrels has been declining by 1.22% (-1.39; -1.05) per annum for the monitoring period, and this decline has not slowed down. The estimated community-level rate of decline was -0.33% (-0.42; -0.25) pre-1990 (but note that sample size for this earlier period was limited), while the estimated rate of decline for 1990-2010 was -1.07% (-1.56; -0.58) and the estimated rate of decline post-2010 was -0.84% (-1.29; -0.40). The overlapping CIs for the latter two time periods indicate the absence of certainty in any improvements of the community-level trend.



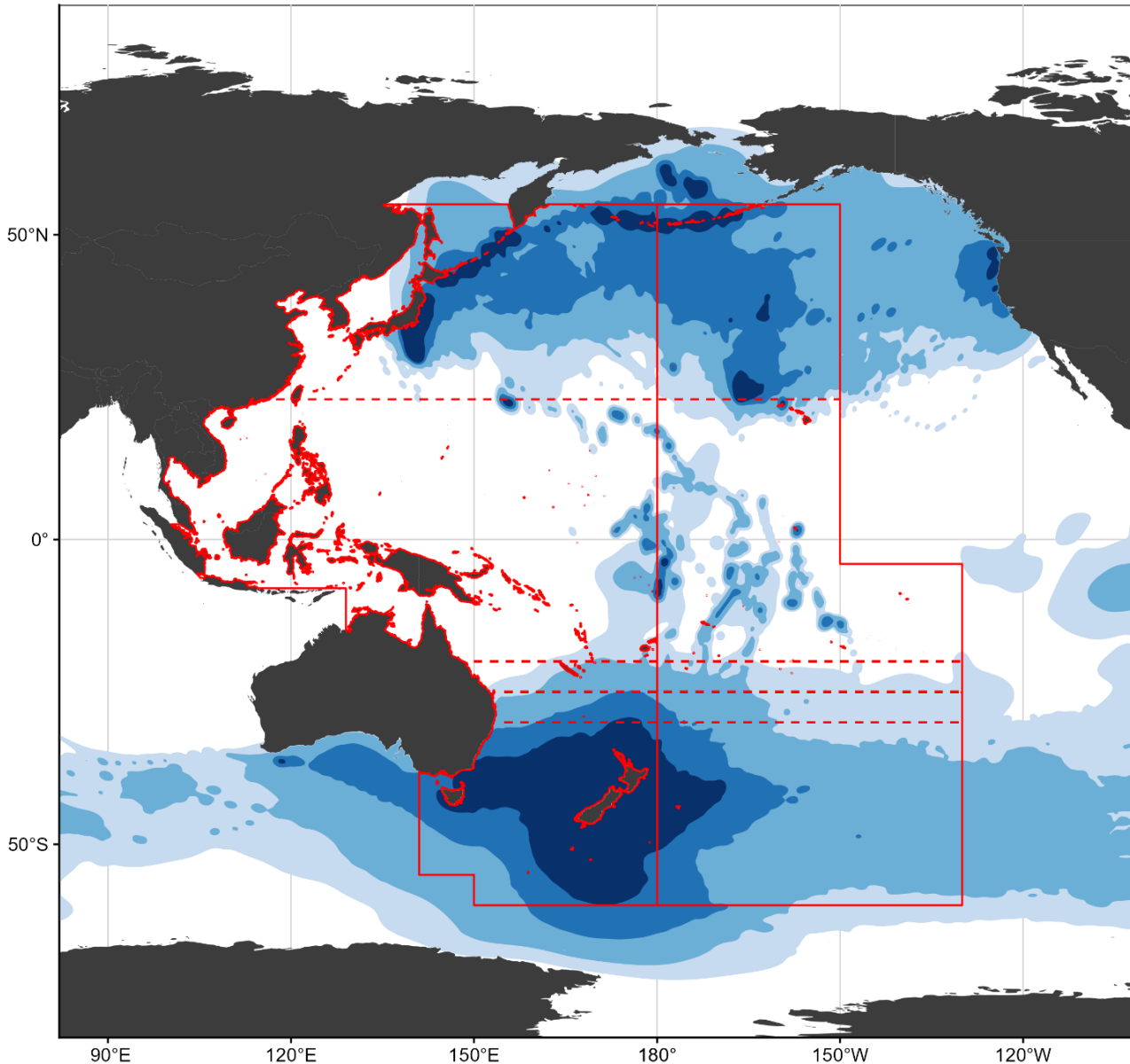
**Fig. 2.** Standardized population trajectories for the entire monitoring period available for the 11 focal taxa. Black lines represent the trajectory of the focal taxon per panel, translucent lines represent other taxa



**Fig. 3.** Annual growth rate estimates (in %) for the entire monitoring period available (A) and for specific time periods (B).

### Year-round distributions of selected seabird taxa in the WCPO

Year-round distribution maps for each of the 11 New Zealand taxa and the three Northern Hemisphere albatross species can be found in Supplementary Material 1. Results highlight that the 11 New Zealand taxa range widely around the world. Most of the oceans on Earth were utilized at least to some extent by some New Zealand taxa. A year-round distribution map for these Southern Hemisphere species combined can be found in Supplementary Material 2. Similarly, the combined distribution of the three Northern Hemisphere albatross species highlighting their wide range across the northern Pacific can also be found in Supplementary Material 2.



**Fig 4.** Distribution of all selected 14 Southern and Northern Hemisphere taxa combined, based on 1,734 tracks, in relation to the WCPFC Convention Area and the 23°N, 20°S, 25°S, and 30°S parallels. Shades of blue represent 99, 95, 75 and 50% UD<sub>s</sub> (from light to dark).

When data from the 11 Southern Hemisphere taxa and the three Northern Hemisphere albatross species is combined into a single, year-round, WCPO seabird distribution map, key hotspots remained evident (Fig. 4). Within the WCPO, key areas included the waters around New Zealand up to 25°S, the Tasman Sea including waters off Tasmania and south-eastern Australia, waters East of New Zealand including the Chatham Rise, and the New Zealand Subantarctic waters are of particular importance. Additionally, it should be noted that some taxa ventured further north in the Southern Hemisphere, up to 20°S, and some foraging hotspots within tropical waters also remained evident. For the Northern Hemisphere species, similar core areas of use also remained evident, including waters around the Japanese and Hawaiian colonies, waters east of Japan and the Kuril Islands, the Bering Sea, waters south of the Aleutians and some core areas in the central North Pacific.

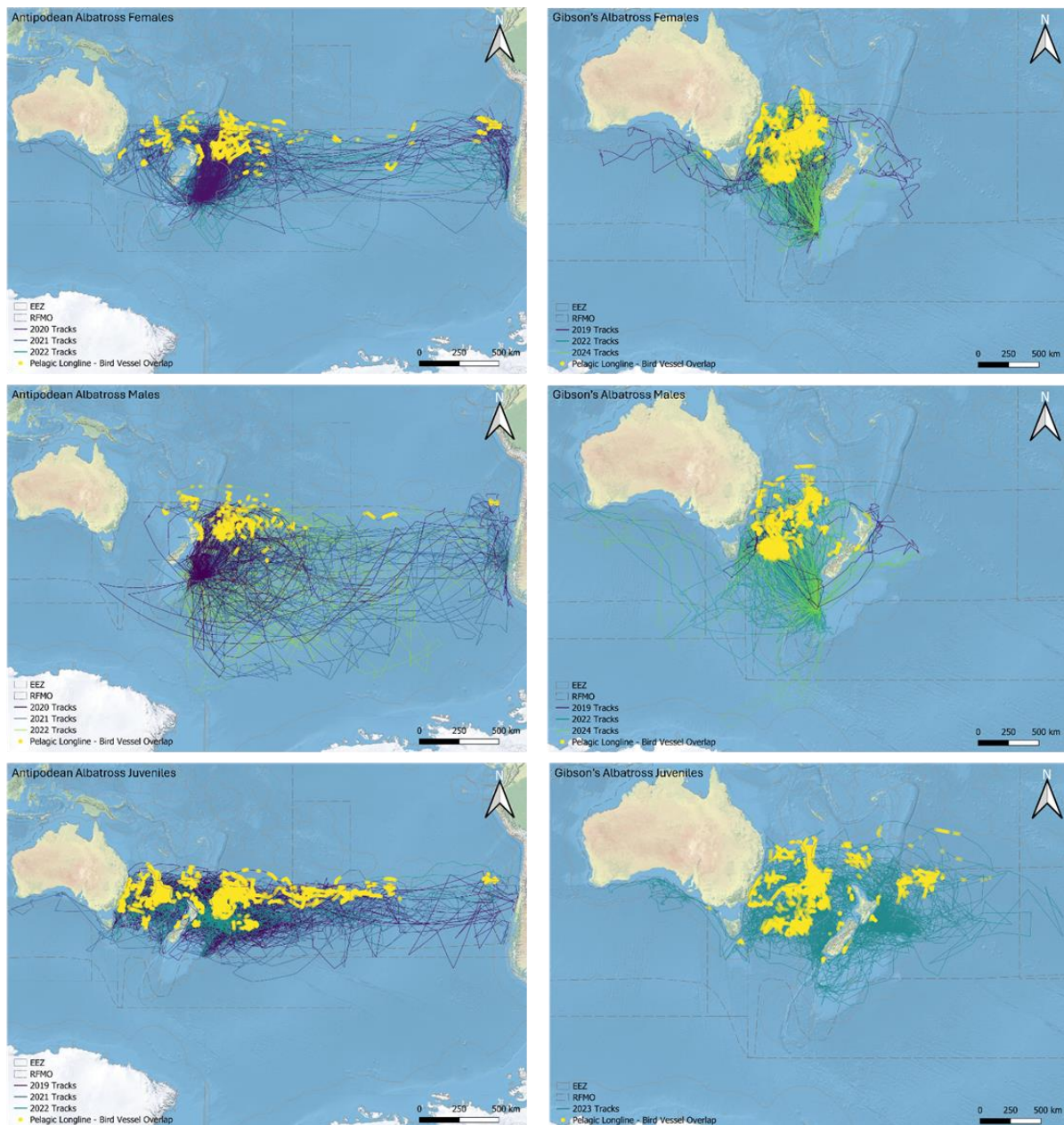
### **Fine scale overlap with pelagic longline fisheries in the Southern Hemisphere**

The distribution of the Antipodean Albatross extended from the east coast of Australia across the Pacific to the coast of Chile (Fig. 5). High occurrence areas were regions to the east of New Zealand bordering the edge of the New Zealand EEZ, the mid-Tasman Sea, and areas off the southern Chile coast. Both adult and juvenile Antipodean Albatross distribution largely fell within the high seas (48.2% across years and sex/stage; Supplementary Material 3). However, juveniles clearly ranged wider and utilized the Tasman Sea more. Antipodean Albatross heavily relied on both the Convention Areas of CCSBT and WCPFC (76%), with some use of the Convention Area of IATTC.

The distribution of Gibson's Albatross was consistently centered around the central and eastern Tasman Sea (Fig. 5). Adult Gibson's Albatross mostly occupied the high seas (60.2% and 57.9% for females and males, respectively) (Supplementary Material 3). Juvenile Gibson's Albatross dispersed further than adults and ventured further east and north, including into areas north of 25°S and spent almost 40% of their time in the high seas. Adult Gibson's Albatross distribution largely fell within the Convention Areas of CCSBT and WCPFC (73%), with some use of the Convention Area of IOTC, while juveniles occurred in several RFMO Convention Areas, primarily in CCSBT and WCPFC (94%) followed by IOTC, and IATTC.

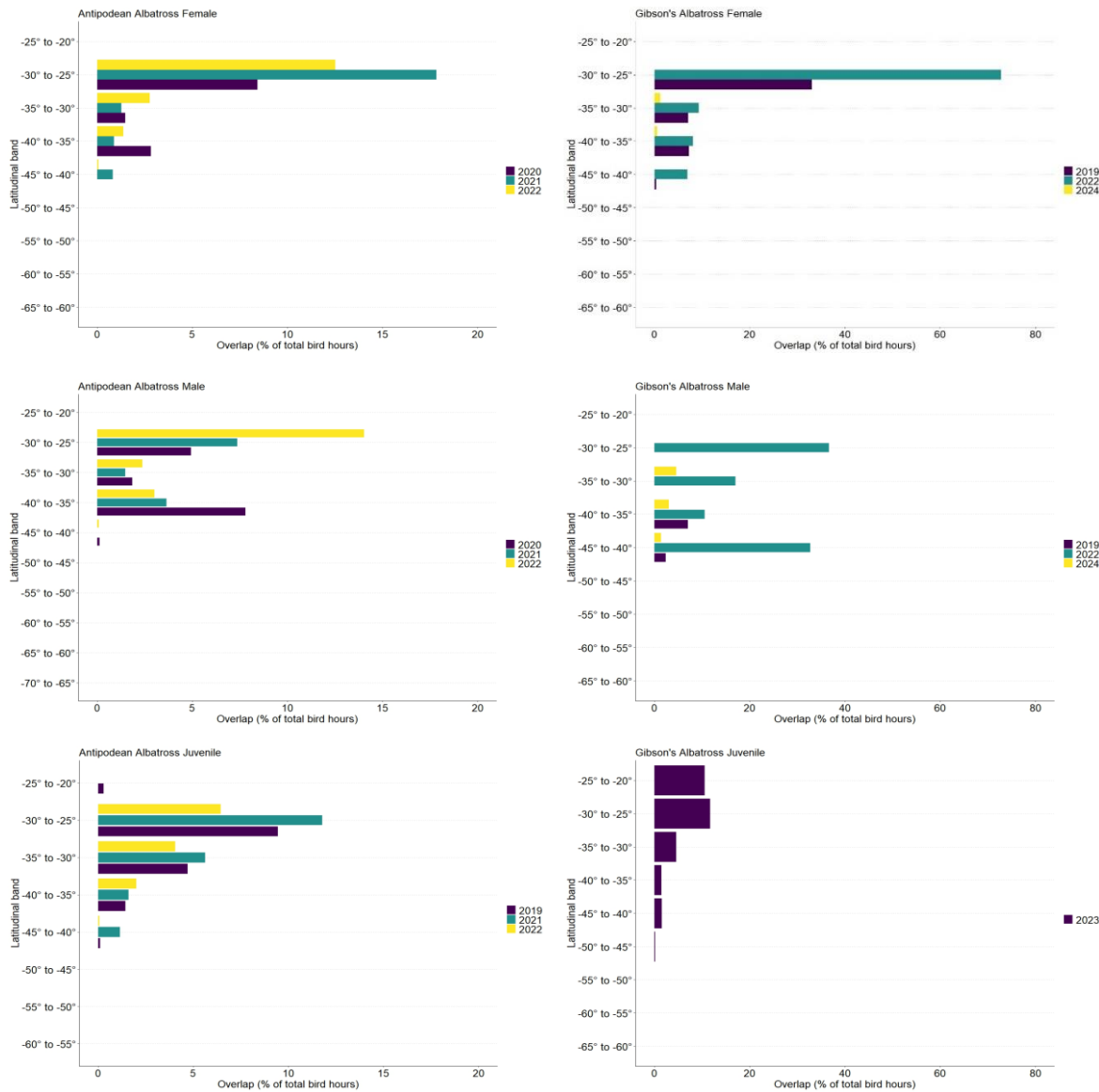
Spatiotemporal overlap of Antipodean and Gibson's Albatross with pelagic longline fishing effort varied over space and time. In total, 115/153 (69%) tracked Antipodean Albatross overlapped with pelagic longline fishing effort, translating to ~2% of all bird hours. For Gibson's Albatross, this proportion was higher with 65/83 (78%) of birds overlapping with pelagic longline fishing effort, equating to ~4.5% of all bird hours.

Overlap of Antipodean albatross with pelagic longline fishing effort was highest in the western (mid-Tasman Sea) and the eastern (adjacent to the New Zealand EEZ) high seas areas within the WCPFC and CCSBT Convention Areas. For juvenile Antipodean Albatross, overlap mainly occurred in the central Tasman high seas area between the EEZs of New Zealand and Australia. Most overlap of Gibson's Albatross occurred in the central Tasman Sea, and north of New Zealand, chiefly in the high seas. While overlap was highest in the high seas, there was overlap off the east coast of Australia within the Australian EEZ and some overlap around the coast of New Zealand within domestic waters.



**Fig 5.** Antipodean and Gibson's albatross overlap with pelagic longline fishing effort for different sex/age stages.

For both Antipodean and Gibson's Albatross, the probability of overlap between tracked birds and pelagic longline effort showed an inverse relationship with latitude (Fig. 5). In other words, while birds primarily utilised waters further south (e.g., south of 30°S), when birds ventured further north, they were more likely to overlap with fishing effort. Specifically, for both taxa, the probability of overlap was the highest between 30°S and 25°S (and between 25°S and 20°S for Gibson's albatross juveniles).



**Fig. 6.** Relative overlap of Antipodean and Gibson’s Albatross per latitudinal band.

## DISCUSSION

Our study presents updated estimates of long-term trends, both for the 11 selected New Zealand taxa, as well as for the Southern Hemisphere Procellariiform community that these taxa jointly form. This analysis is a detailed update from ACAP (2022) and highlighted that most of the studied taxa have suffered long-term and severe declines, and that these rates of decline have not been reduced over time.

We also generated easily accessible and interpretable distribution maps for the 11 New Zealand taxa and three additional Northern Hemisphere Albatross species, which we ultimately fused into one, single, year-round distribution map illustrating the core areas of use of WCPO seabirds vulnerable to longline fishing. For the New Zealand taxa, the distribution maps highlighted that these taxa connect New Zealand with virtually all of Earth’s oceans and underscore the importance of international cooperation to contribute to the conservation of these species. In general, the generated distribution map for all taxa combined highlights the key areas where seabirds vulnerable to pelagic longline fishing occur and where effective seabird bycatch mitigation methods should be applied.

In addition, we quantified the overlap of the two most data-rich, and among the most rapidly declining species, Antipodean and Gibson's Albatross, with pelagic longline fisheries. In doing so, we have highlighted a significant potential bycatch risk, particularly in the high seas within the southern Convention Area of WCPFC and identified that overlap increases at lower latitudes.

### **Long-term seabird population trends observed in New Zealand**

The analyses demonstrate the population declines of these New Zealand Procellariiform taxa over long time periods. Our approach utilised log-linear models similar to those in TRIM (Pannekoek & van Strien 2005; the ACAP recommended approach) and mirrors previous work by Paxton *et al.* (2016) and Shaw *et al.* (2024) on other community-level trend analyses (Hawaiian songbirds and African raptors, respectively). As such, we consider the methods applied appropriate for the data available.

However, it should be noted that count data is imperfect, and thus our results should be interpreted with this consideration in mind. While we endeavoured to generate uncertainty as appropriately as possible in our trend estimates, we did not specifically generate uncertainty around the count data, largely because of the inconsistent, or absent, reporting of uncertainty surrounding these data. This is particularly the case for long-term studies employing study/index sites (Bell *et al.* 2023, Rexer-Huber *et al.* 2023, Walker *et al.* 2023, Sagar *et al.* 2024). Consequently, the uncertainty surrounding some trend estimates was underrepresented.

Future extensions of the work presented here could include the generation of additional uncertainty surrounding individual count estimates using the ACAP reliability and accuracy categories and informative priors within a hierarchical modelling framework (e.g., following Fischer *et al.* 2020). The specification of such priors, however, would remain a subjective exercise. Despite these shortcomings, our analyses cover some of the most extensive seabird monitoring time periods on Earth (up to 80 years) and the best available count data. Additionally, for several taxa, these trends are supported by trends in demographic rates. For example, adult survival, breeding probability, and breeding success has been reduced in both Antipodean and Gibson's Albatross for several decades (Rexer-Huber *et al.* 2023, Walker *et al.* 2023, Richard *et al.* 2024a).

The population trend estimates are subject to the time period under consideration, a common challenge in trend analyses (e.g., Pannekoek & van Strien 2005). We attempted to address this challenge by not only analysing trends over one, but five different time periods. This exercise highlighted that there was no "one size fits all" period that best described the trend of a taxon. For instance, there are stark differences between the  $r_{N_{max}}$  estimates and the  $r_{post-2010}$  for Antipodean and Gibson's Albatross, most likely due to the different severities of the sudden declines that both taxa suffered around 2007 (Rexer-Huber *et al.* 2023, Walker *et al.* 2023). Consequently, for Gibson's Albatross, the  $N_{max}$  was treated more as an outlier, but not for Antipodean Albatross, resulting in an underestimate of the decline in the former, and a more adequate estimate in the latter. As all taxa are extremely long-lived  $k$ -selected species (species with high survival, high longevity, and low fecundity), the best way forward thus appears to be to analyse the full monitoring period available (or at least trends across three generations), while analysing sections of adequate length (e.g., 20 years, roughly corresponding to a generation time for these species) to detect changes in trends over time. This approach highlighted the significant, ongoing, and apparently unabated declines that these taxa are suffering.

### **Potential underlying drivers of population trends observed in New Zealand**

For Antipodean albatross, the most likely driver of the presented population declines, is bycatch in commercial fisheries, particularly pelagic longline fisheries, in the high seas (Richard *et al.* 2024a). For all studied taxa from New Zealand this research has highlighted significant potential bycatch risk from within the WCPO that needs to be managed as a likely driver of the presented population declines. Various detailed analyses have highlighted the ongoing pressure that bycatch risk is placing on the selected focal taxa (e.g., Abraham *et al.* 2019, Peatman *et al.* 2019, Edwards *et al.* 2023a,b, Richard *et al.* 2024a). The challenge of these analyses is usually the scarcity of data that is particularly prevalent in the high seas where observer coverage for longline vessels is rarely above 5% and where the identity of bycaught seabirds is rarely established to species-level (e.g., Peatman *et al.* 2019).

Regardless of these challenges, several analyses, including those employing fisheries observer collected bycatch data alongside fishing effort and seabird distribution and demographic data in sophisticated spatially explicit fisheries risk assessments (SEFRA), have been conducted (Abraham *et al.* 2019, BirdLife International 2019, Edwards *et al.* 2023a,b, Richard *et al.* 2024). All iterations of SEFRA (e.g., using different data sources or covering different geographical areas) have provided recurring and consistent evidence that a range of seabird taxa succumb to bycatch in commercial fisheries to such extents that bycatch is the most likely driver of population declines (e.g., Abraham *et al.* 2019, Edwards *et al.* 2023a,b, Richard *et al.* 2024a).

Different fisheries impact different seabird taxa in different ways, but all analyses to date have highlighted the particularly high susceptibility of the most *k*-selected seabird taxa (e.g., *Diomedea* albatross taxa) to pelagic longline fishing, including in the WCPO (Abraham *et al.* 2019, BirdLife International 2019, Peatman *et al.* 2019, Edwards *et al.* 2023a,b, Richard *et al.* 2024a). Our trend analyses align with these more sophisticated analyses as they indicate that the most rapidly declining taxa are the most *k*-selected taxa (e.g., those most vulnerable to decreases in adult survival, and thus the most vulnerable to bycatch): Antipodean Albatross, Gibson's Albatross, royal albatrosses, and biennial and semi-biennial *Thalassarche* albatrosses. Bycatch of these seabirds in New Zealand waters does occur, but not to such an extent as to drive population declines even if there were no impacts from other fisheries outside of the New Zealand EEZ (apart from, potentially, Southern Buller's Albatross; Edwards *et al.* 2023a). Consequently, the most likely cause of the declines observed in this New Zealand seabird community is bycatch in a range of commercial fisheries, in which international pelagic longline fisheries account for much of the risk, which causes unsustainable levels of adult mortality, as has been illustrated by Richard *et al.* (2024a) for the Antipodean Albatross.

Non-fisheries threats for the studied New Zealand seabird taxa do not explain the observed declines. Invasive predators are not a driver of the observed population declines in New Zealand. Of the nine sites where these 11 taxa are monitored, six (67%) never had any invasive species occur and two (22%) have been cleared of all invasive species in major conservation successes (including what once was the world's largest predator eradication; Towns & Broome 2003, Horne *et al.* 2019, ACAP 2024). The only site where invasive predators still occur is the Black Petrel colony on Aotea and here, invasive predators are managed to such an extent that the Black Petrel population counts have been increasing.

There is no compelling evidence that the studied New Zealand seabirds are impacted by climate change yet. A sophisticated analysis of the most data-rich species, the Antipodean Albatross,



highlighted the absence of climate change impacts (so far) on the population trend of this taxon (Richard *et al.* 2024a,b). The studied New Zealand seabirds are also among the most highly mobile species on the planet (i.e., adults can forage off Chile while breeding in New Zealand) and are well adapted to forage widely and follow shifting prey.

Exposure to plastic pollution to seabirds in the Southern Ocean around New Zealand is limited and thus an unlikely driver of the observed declines. A global analysis highlighted that New Zealand seabirds are among the least exposed species and that their risk only increases once they cross the equator to the Northern Hemisphere where pollution is more prevalent (Clark *et al.* 2023). Few New Zealand seabirds conduct such migrations, including only one of the analysed taxa (Flesh-footed Shearwater), and thus the overall risk from plastic pollution to this community appears limited. Records of plastic ingestion at New Zealand colonies when compared to the well-known impacted colonies on the Hawaiian Islands (Rapp *et al.* 2017) and Lord Howe Island (Lavers *et al.* 2018) further support the notion of limited exposure.

Finally, the novel risk of highly pathogenic avian influenza (HPAI) is not a driver of the documented declines of the studied New Zealand taxa. To this date, not a single case of HPAI has been detected in New Zealand despite nation-wide screening involving 1000s of tests on all study sites. Outside New Zealand, only Grey-headed Albatross of the studied taxa has been infected with HPAI, which occurred in the South Atlantic (ACAP 2024).

In summary, bycatch in commercial fisheries, including pelagic longline fisheries, across the distribution of these seabird taxa is the most likely driver of the observed population declines. No other threat compares to the threat that bycatch poses to this seabird community, both in magnitude and in evidence. Fortunately, bycatch in commercial fisheries, including pelagic longline fisheries, is also the most manageable threat as proven effective bycatch mitigation methods exist (Pierre 2023, Fischer *et al.* 2024). Should climate change or other threats, more challenging to mitigate, also start to put pressure on these taxa in future, such pressures will act to exacerbate the impacts of bycatch in commercial fisheries.

### **Year-round distributions**

The distribution maps we generated provide simple and accessible overviews of the annual ranges of these taxa and the seabird communities they form. Tracking data is inherently complex and is subject to spatiotemporal and technical biases and specifications (e.g., Carneiro *et al.* 2020) and thus providing easy and accessible insights for non-technical, but key audiences (e.g., industry, fisheries managers) has been challenging. The approach we used here provides an answer to this challenge, as the maps provided in Supplementary Material 1 and 2, and Fig. 4, provide easily interpretable single-pane figures of the annual distribution of each taxon, the Southern and Northern Hemisphere seabird communities, and the WCPO seabird community in general, respectively. In addition, our approach is relatively straightforward and thus readily repeatable.

We note that this approach, in common with many other approaches, is subject to sample size issues, which is illustrated by the patchy distribution maps of the two Royal Albatross species (Supplementary Material 1). We also acknowledge that there are other approaches to generating year-round insights into the distributions of seabirds, including more complex approaches (e.g., Richard *et al.* 2024b), but such approaches require extensive datasets and technical knowledge, and are thus not suitable for many taxa or multi-taxa analyses as ours here, or regular updating. Alternatively, simply plotting tracks (e.g., Fig. 5) could also present an alternative, but this approach does not account for the various shortcomings, typical of tracking data (e.g., differing

tag types, different colony sizes, and spatiotemporally varying sample sizes). Consequently, our approach here provides a middle ground of various analysis and visualisation approaches suited for the complexity of tracking data, while retaining accessibility and interpretability, crucial for key audiences.

Our distribution mapping approach highlighted key areas of importance for these seabird taxa in which the application of effective bycatch mitigation methods will be crucial to address the population collapse revealed by our trend analyses. We chose to identify the key areas for the application of effective seabird bycatch mitigation methods using seabird distribution data alone, as seabird distributions appear more static and predictable than fisheries distributions, and thus also the overlap between the two (Richard *et al.* 2024b).

For the southern WCPO, key areas are the waters around New Zealand, Tasman Sea including waters surrounding Tasmania and off eastern Australia, and the high seas areas north-west, north, and north-east of New Zealand, up to at least 25°S and potentially extending further north to 20°S (Fig. 4-6). These key areas align with a wide range of previous analyses, including those that highlighted key areas of overlap and bycatch estimates (e.g., Abraham *et al.* 2019, Peatman *et al.* 2019, Edwards *et al.* 2023a,b).

Key areas in the northern WCPO that may require additional seabird bycatch mitigation focus revealed by our mapping approach align with previous analyses (Orben *et al.* 2021) and match more with the current spatial delimitations in CMM 2018-03 (e.g., >23°N; WCPFC 2018), although it should be noted that some core areas in the northern WCPO extend slightly further south to approx. 20°N. Additionally, it should be noted that in the northern WCPO, seabird bycatch mitigation methods are still being applied that are largely considered ineffective (e.g., Chaloupka *et al.* 2021, Gilman *et al.* 2021, ACAP 2023, Fischer *et al.* 2024). Finally, our mapping exercise also highlighted that some core areas of use are present between 25°S and 23°N, where currently no bycatch mitigation methods are required.

### **Fine scale overlap with pelagic longline fisheries**

For both the Antipodean and Gibson's albatross, the area north of 30° South forms a relatively small portion of their overall distribution. Yet, despite this, we have found an inverse relationship between overlap and latitude for these taxa where, as latitude decreases, the rate of bird-vessel overlap, and thus bycatch risk, increases. This is particularly evident in the area between 25° and 30° S within the WCPFC Convention Area, yet only one Southern Hemisphere mitigation method is required to be used in this area under CMM 2018-03 (WCPFC 2018). These results highlight a significant bycatch risk for Antipodean and Gibson's albatross due to high levels of fishing effort with limited mitigation methods increasing the likelihood of baited hooks being accessible to birds. To emphasise this risk, a tracked Antipodean albatross was reported bycaught in 2019, and another bird was reported bycaught in 2021 by fishing operations in the waters between 25° and 30° South (Walker & Elliott 2022).

We acknowledge that the interpolation of our albatross tracks may introduce uncertainty of our overlap assessments. However, recent, sophisticated work employing time geography has highlighted that our approach mirrors the medians of time-geography-based estimates and is therefore a valid approach for large-scale analyses like the work we present here (Rutter *et al.*, 2024).

Both the individual-level analyses we present here, and the sophisticated species-level analyses presented by Richard *et al.* (2024a), provide clear evidence for the elevated bycatch risk from

pelagic longline fisheries in the high seas which are the most likely driver of the population decline of this seabird. When considering the above results, we must acknowledge that the relationship between overlap and bycatch is neither simple nor linear. This is particularly evident with point-based overlap as it can only indicate *potential* bycatch risk and when mitigation management is implemented correctly this *potential* risk can, and often is, significantly reduced (Fischer *et al.*, 2024).

It is widely accepted that fishing effort inferred from AIS data does not represent all fishing effort. This disparity, between complete effort and that recorded, occurs for a multitude of reasons (including poor satellite coverage, signal interference, alongside human behaviour driven by safety and/or the desire of obscuring locations of high-quality fishing grounds). Consequently, overlap estimates based on AIS data represent an underestimation of true overlap and recent work in the North Pacific has shown that AIS-based overlap may underestimate true overlap by ~30% (Welch *et al.* 2024). While the degree of underrepresentation, including in our study, is yet to be fully explored, we should interpret the documented significant overlap rate for these two taxa as an ‘overlap minimum’.

In general, the degree of overlap between Antipodean and Gibson’s albatross and pelagic longline fishing vessels in the high seas within the Convention Area of WCPFC is of great concern, unless effective seabird bycatch mitigation methods are in place. We tracked 236 Antipodean and Gibson’s albatross of which 180 individuals had at least one instance of vessel overlap during a relatively short tracking period (for a strongly *k*-selected species with a life span of multiple decades; Bird *et al.* 2021). Previous work on a subset of this data has reported that a single tracked Antipodean albatross in 2020 overlapped with as many as 88 individual vessels (Bose & Debski 2021).

## CONCLUSION

The trend estimates, distribution maps, and overlap assessments we presented here highlighted the dire state of New Zealand albatrosses and large petrels, their dependency on the high seas, and thus the importance of international cooperation for reversing the current and ongoing declines. Of the studied New Zealand taxa, 73% of the studied taxa are declining and rates of decline have not improved over the decades, including during the time period during which WCPFC has required the use of various seabird bycatch mitigation measures in some areas. All evidence points levels of bycatch on the high seas as the most likely driver of these declines. Many taxa occur in areas with reduced, not mandated and/or ineffective bycatch mitigation requirements, particularly in the Southern Hemisphere in waters between 25° and 30° South, where most (~80%) vulnerable seabirds readily overlap on an individual level with pelagic longline fishing effort. Whilst decades of bycatch mitigation development has resulted in the ready availability of highly effective tools (e.g., Fischer *et al.* 2024), these have generally not resulted in improvements in population trends (for many taxa, not even stabilisation). Therefore, further, concerted, and improved efforts to ensure effective seabird bycatch mitigation methods are in place where these taxa occur (i.e., Fig. 6) are crucial to preserve seabird communities.

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**Table 1.** Sample size and characteristics of analysed population count and tracking data per taxon. Northern Hemisphere taxa were only included in the spatial analyses, not the trend analyses.

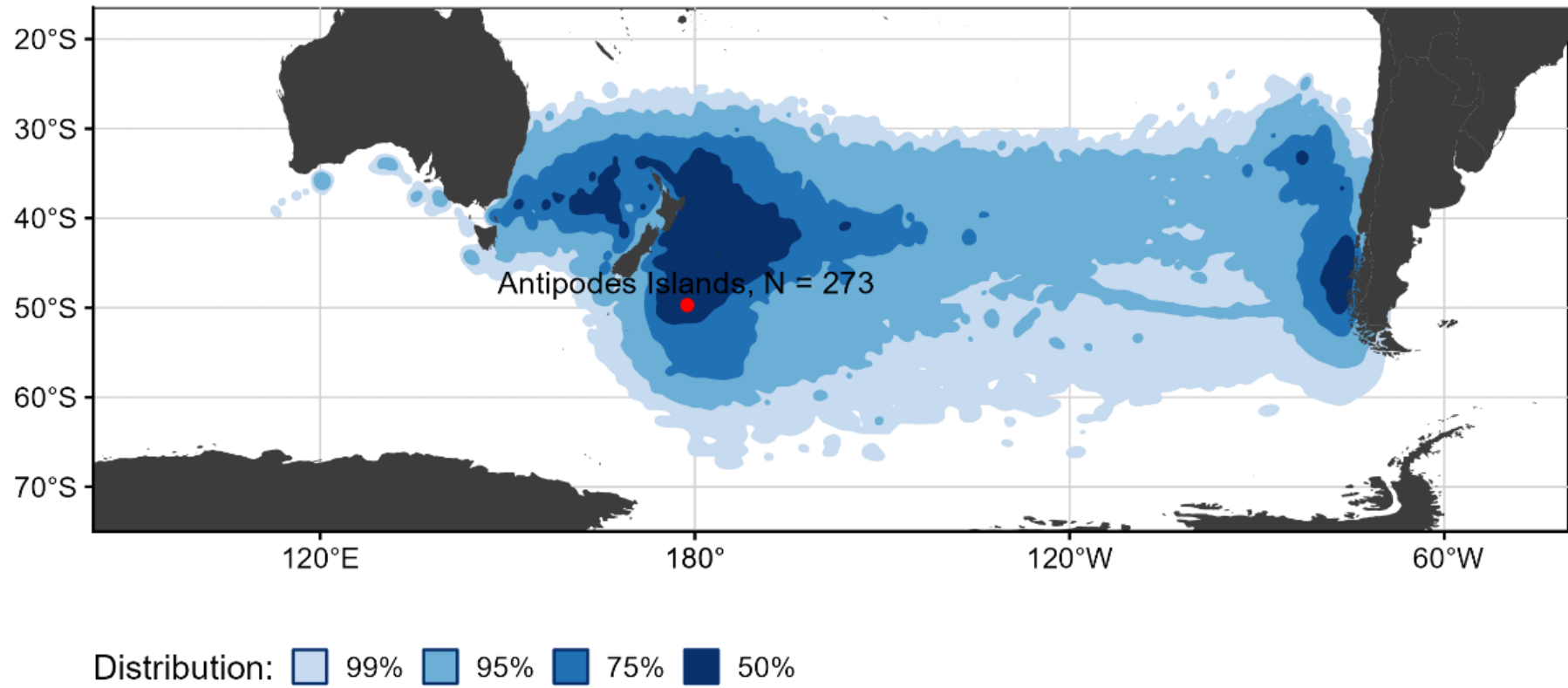
Taxon		NZ endemic	IUCN status	N tracks (N GPS/PPT; N GLS)	Tracked colonies	Tracking period	N counts	Count period (N years)	Count frequency (year <sup>-1</sup> )	Counted colonies	Count method
Antipodean Albatross	<i>Diomedea antipodensis antipodensis</i>	✓	EN <sup>2</sup>	273 (223; 50)	Antipodes Is.	1996-2023	30	1994-2024 (31)	0.97	Antipodes Is.	Study/index site counts
Gibson's Albatross	<i>Diomedea antipodensis gibsoni</i>	✓	EN <sup>2</sup>	190 (116; 74)	Adams Is.	1994-2024	27	1997-2024 (28)	0.96	Adams Is.	Study/index site counts
Southern Royal Albatross	<i>Diomedea epomorphora</i>	✓	VU	39 (36; 3)	Campbell Is.	2024	7	1997-2024 (26)	0.27	Campbell Is.	Study/index site counts
Northern Royal Albatross	<i>Diomedea sanfordi</i>	✓	EN	81 (76; 5)	Motuhara & Pukekura	1993-2021	20	1972-2024 (30)	0.66	Motuhara	Whole island counts
Grey-headed Albatross	<i>Thalassarche chrysostoma</i>		EN	69 (17; 52)	Campbell Is.	1997-2013	12	1945-2024 (80)	0.15	Campbell Is.	Whole island counts
Campbell Albatross	<i>Thalassarche impavida</i>	✓	VU	78 (10; 68)	Campbell Is.	1997-2011	12	1945-2024 (80)	0.15	Campbell Is.	Whole island counts
Salvin's Albatross	<i>Thalassarche salvini</i>	✓ <sup>1</sup>	VU	82 (29; 53)	Proclamation Is., Western Chain	2008-20	7	1978-2020 (43)	0.16	Proclamation Is.	Whole island counts
White-capped Albatross	<i>Thalassarche steadi</i>	✓ <sup>1</sup>	NT	34 (13; 21)	Disappoint. Is.	2005-10	12	2002-18 (17)	0.71	Disappoint. Is.	Study/index site counts
Southern Buller's Albatross	<i>Thalassarche bulleri bulleri</i>	✓	NT <sup>2</sup>	176 (118; 58)	Solander Is., Snares Is.	1994-2024	31	1969-2024 (56)	0.55	Snares Is.	Study/index site counts
Black Petrel	<i>Procellaria parkinsoni</i>	✓	VU	93 (21; 72)	Aotea, Hauturu	2007-20	23	2001-23 (23)	1.00	Aotea	Study/index site counts
Flesh-footed Shearwater	<i>Ardenna carneiceps</i>		NT	36 (30; 6)	Lady Alice Is., Ohinau Is.	2006-23	3	2009-24 (16)	0.19	Lady Alice Is.	Whole island counts
Laysan Albatross	<i>Phoebastria immutabilis</i>		NT	346 (236; 110)	Midway Atoll, French Frigate Shoals, Isla Guadelupe	1998-2014	-	-	-	-	-
Black-footed Albatross	<i>Phoebastria nigripes</i>		NT	206 (121; 85)	Midway Atoll, French Frigate Shoals	1998-2012	-	-	-	-	-
Short-tailed Albatross	<i>Phoebastria albatrus</i>		VU	31 (31; 0)	Izu Shoto	2002-08	-	-	-	-	-

<sup>1</sup> A small number of breeding pairs breed outside of Aoteaora New Zealand but given the vast majority of the population breeds in New Zealand, these taxa are considered endemic.

<sup>2</sup> IUCN threat status is assigned at species level and reported here at taxa level.

Supplementary Material 1. Taxon-specific, year-round distribution maps for selected focal taxa.

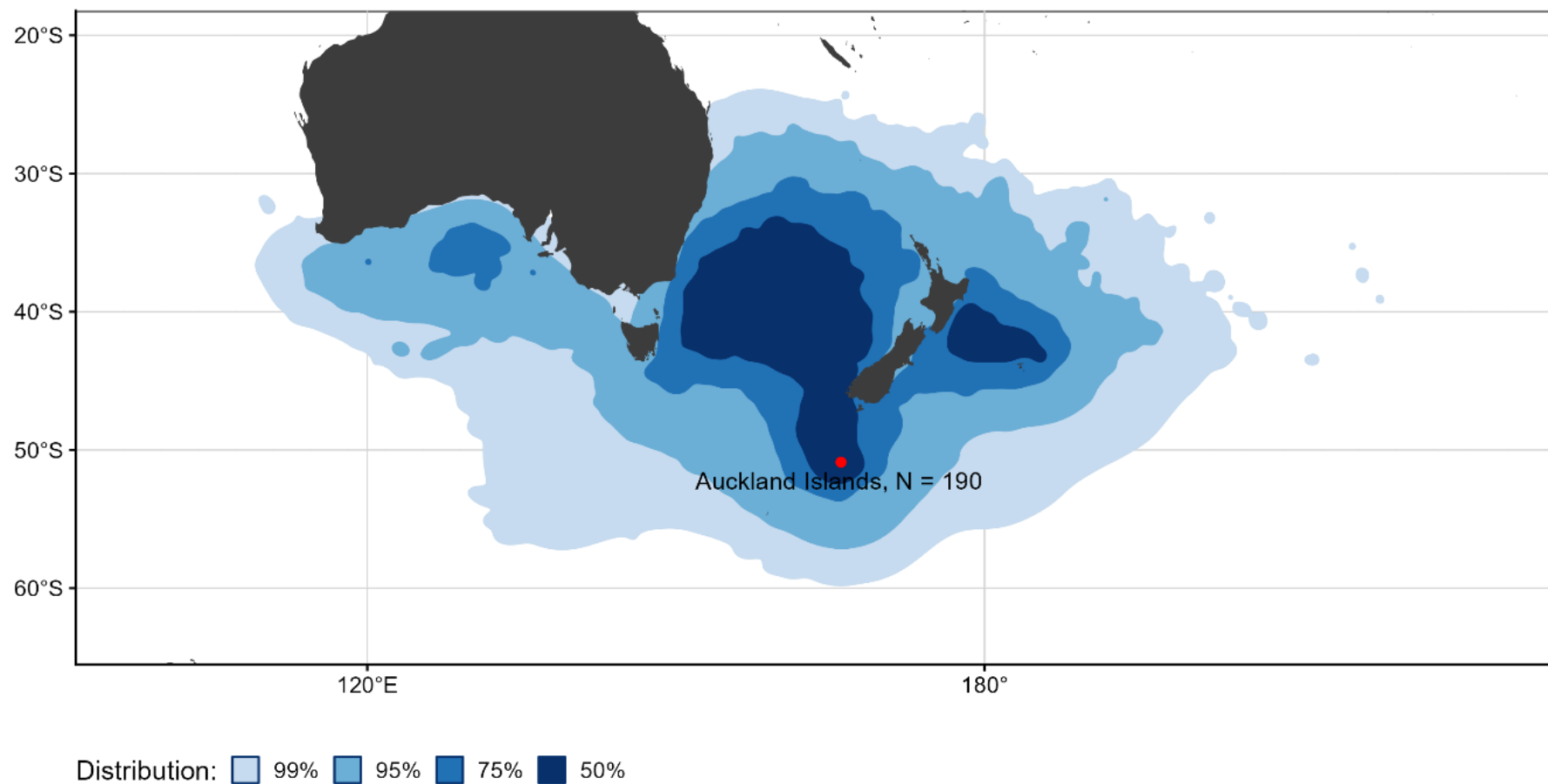
### Antipodean Albatross



Sup. Fig. 1. Year-round distribution of Antipodean Albatross.

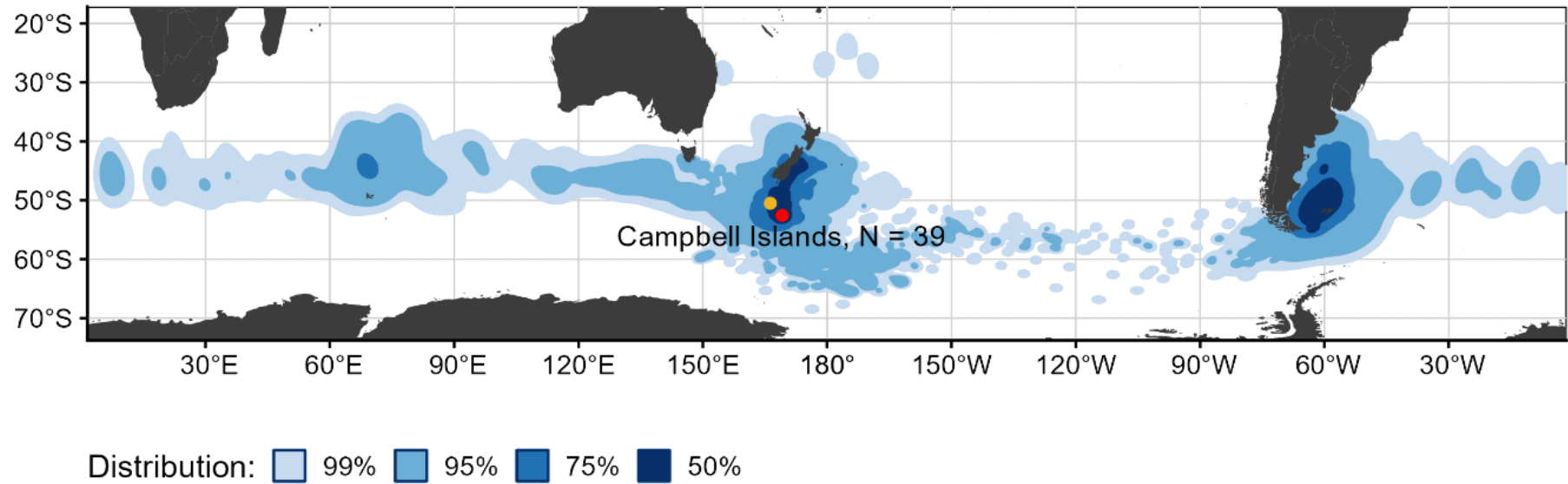


### Gibson's Albatross

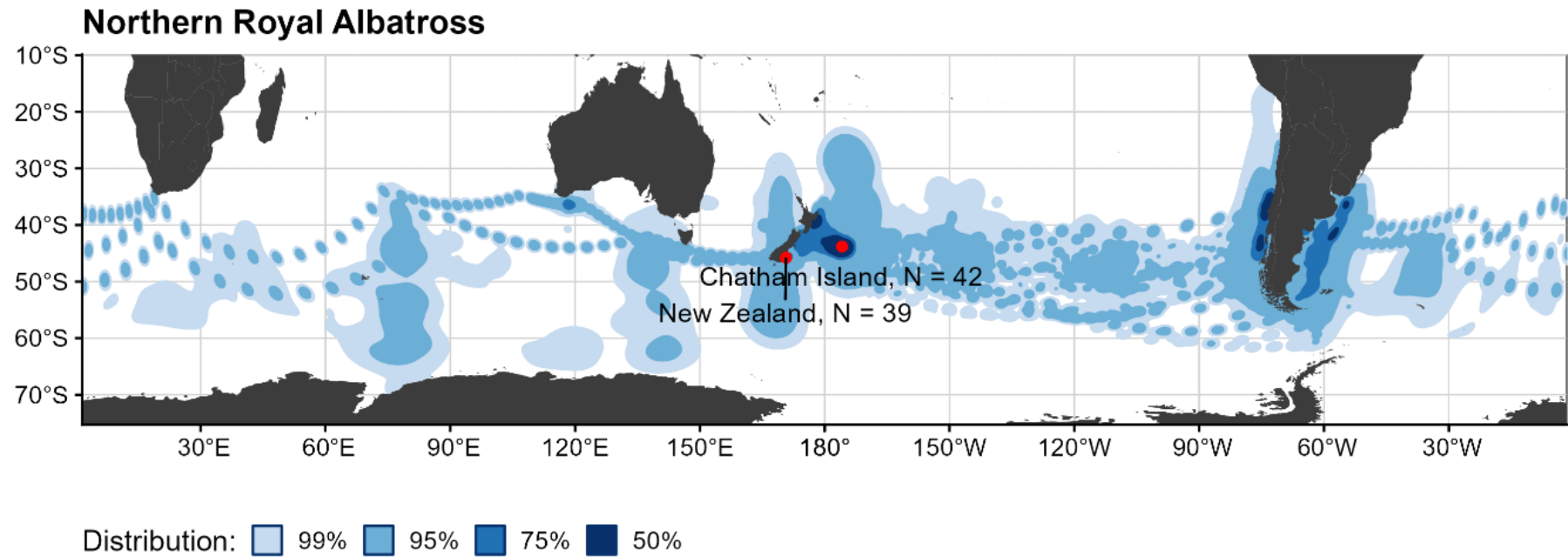


Sup. Fig. 2. Year-round distribution of Gibson's Albatross.

### Southern Royal Albatross

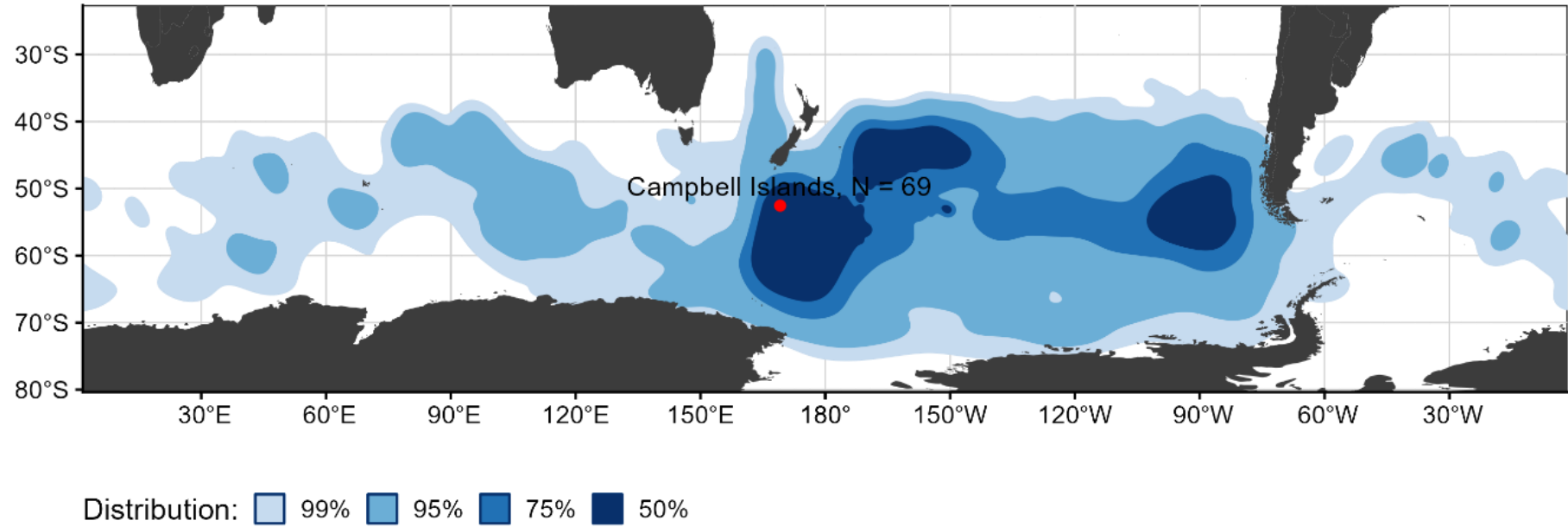


**Sup. Fig. 3.** Year-round distribution of Southern Royal Albatross. Yellow symbol represents the untracked Enderby Island colony (<1% of the total population).



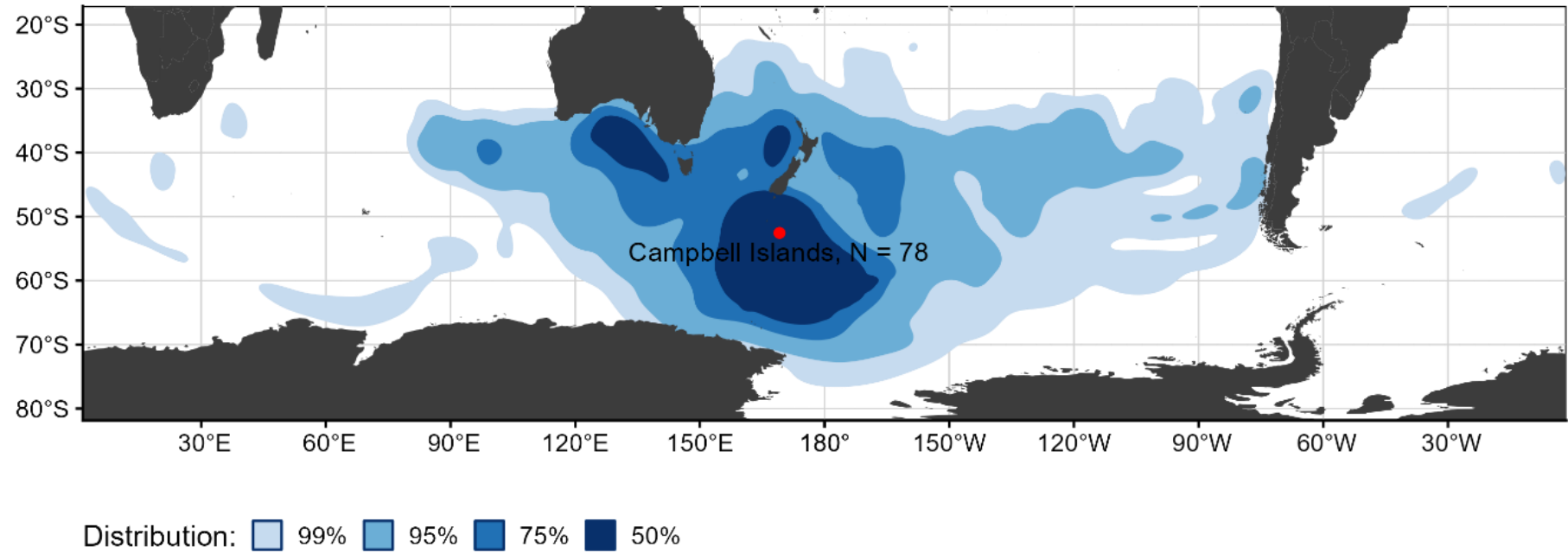
**Sup. Fig. 4.** Year-round distribution of Northern Royal Albatross.

## Grey-headed Albatross



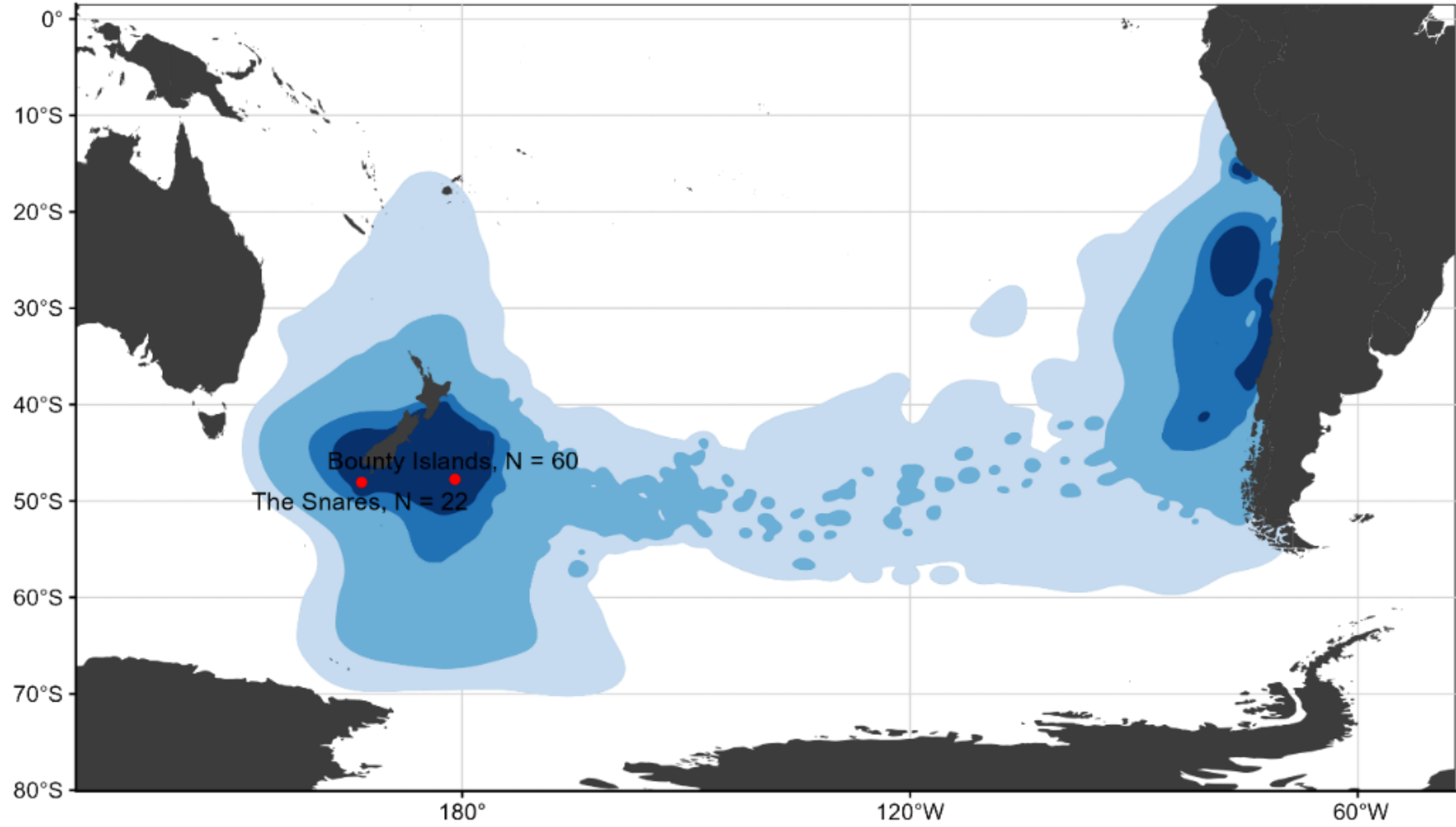
Sup. Fig. 5. Year-round distribution of Grey-headed Albatross.

## Campbell Albatross



**Sup. Fig. 6.** Year-round distribution of Campbell Albatross.

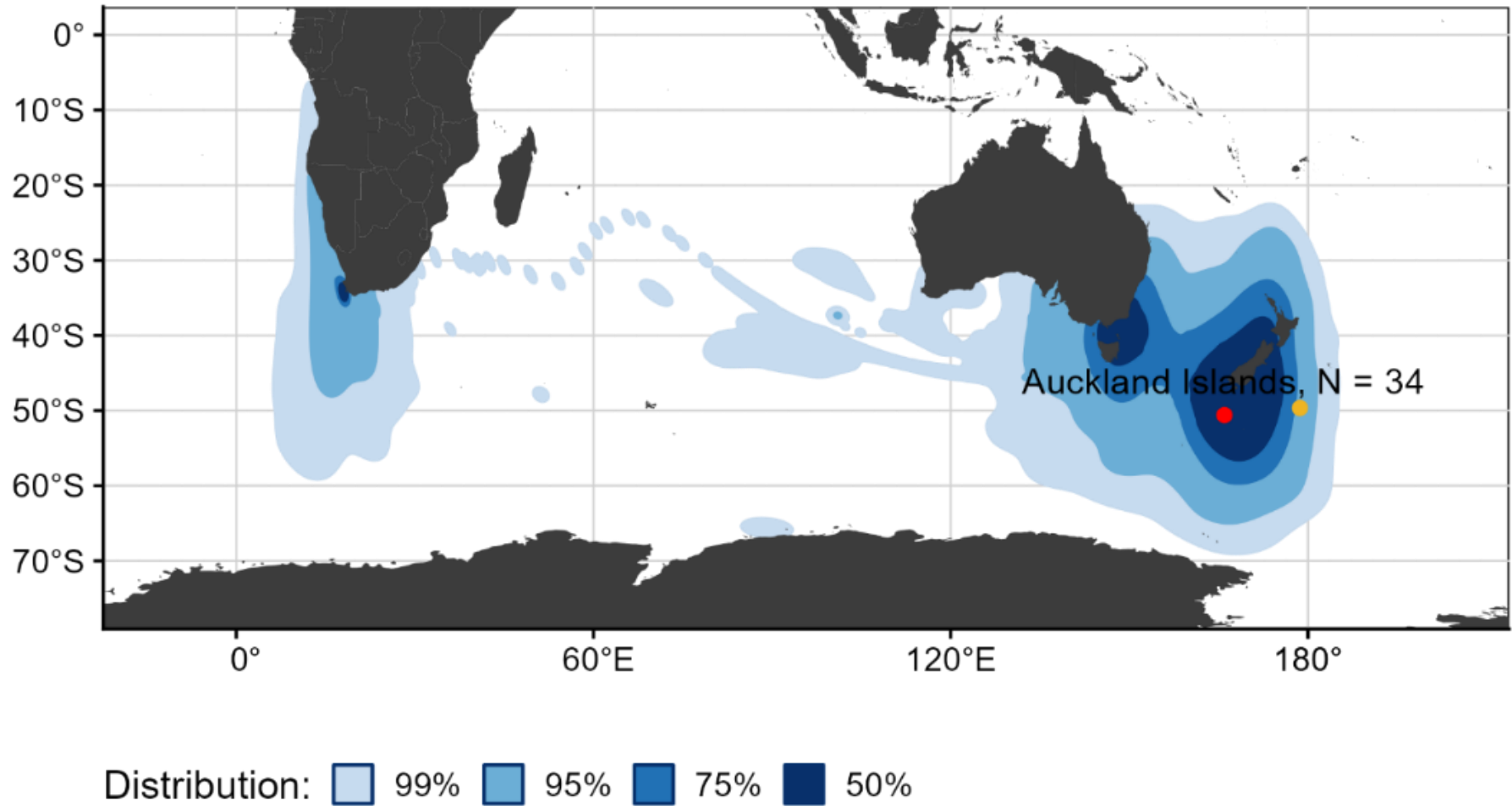
### Salvin's Albatross



Distribution: 99% 95% 75% 50%

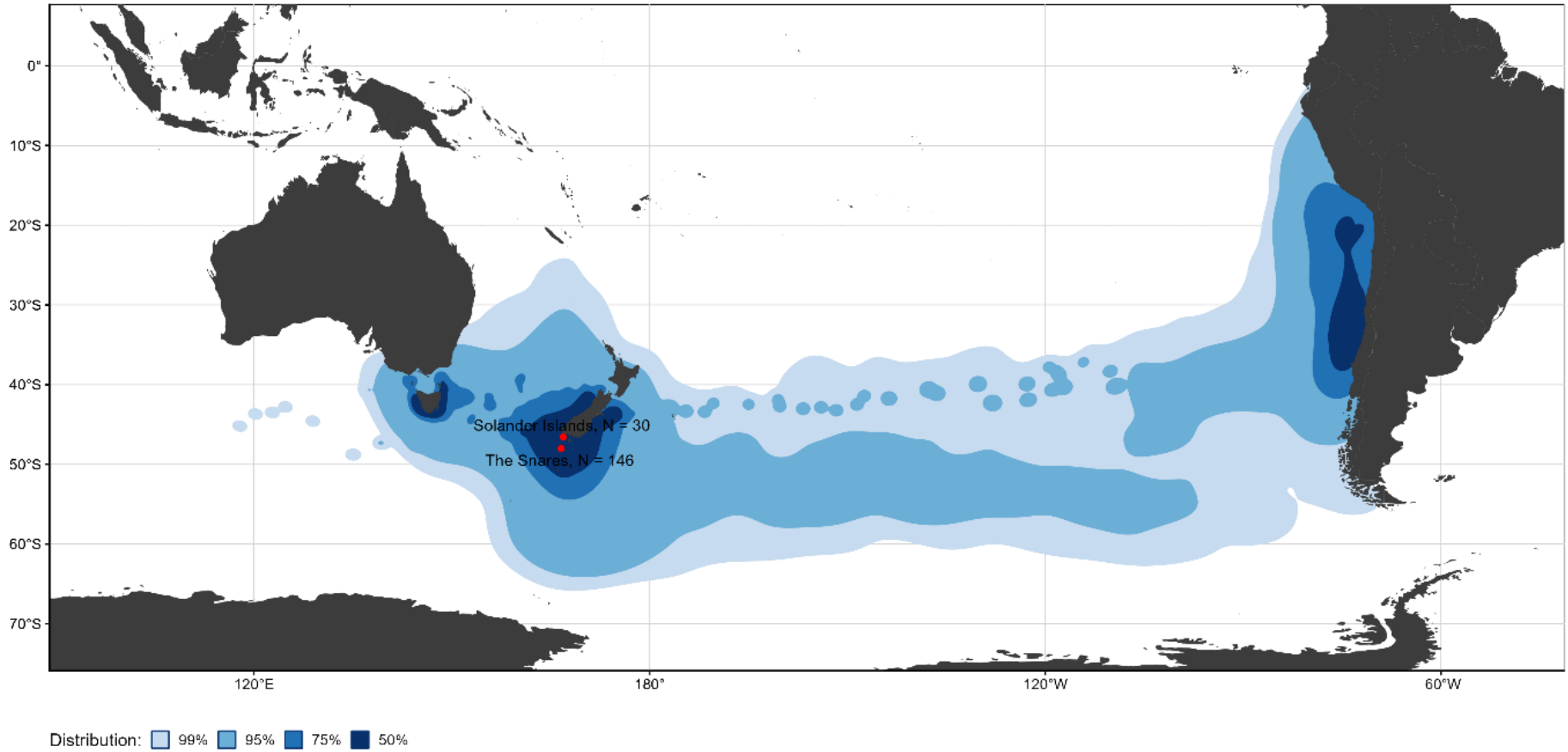
Sup. Fig. 7. Year-round distribution of Salvin's Albatross.

## White-capped Albatross



**Sup. Fig. 8.** Year-round distribution of White-capped Albatross. Yellow symbol represents the untracked Bollon's Island colony (<1% of the total population).

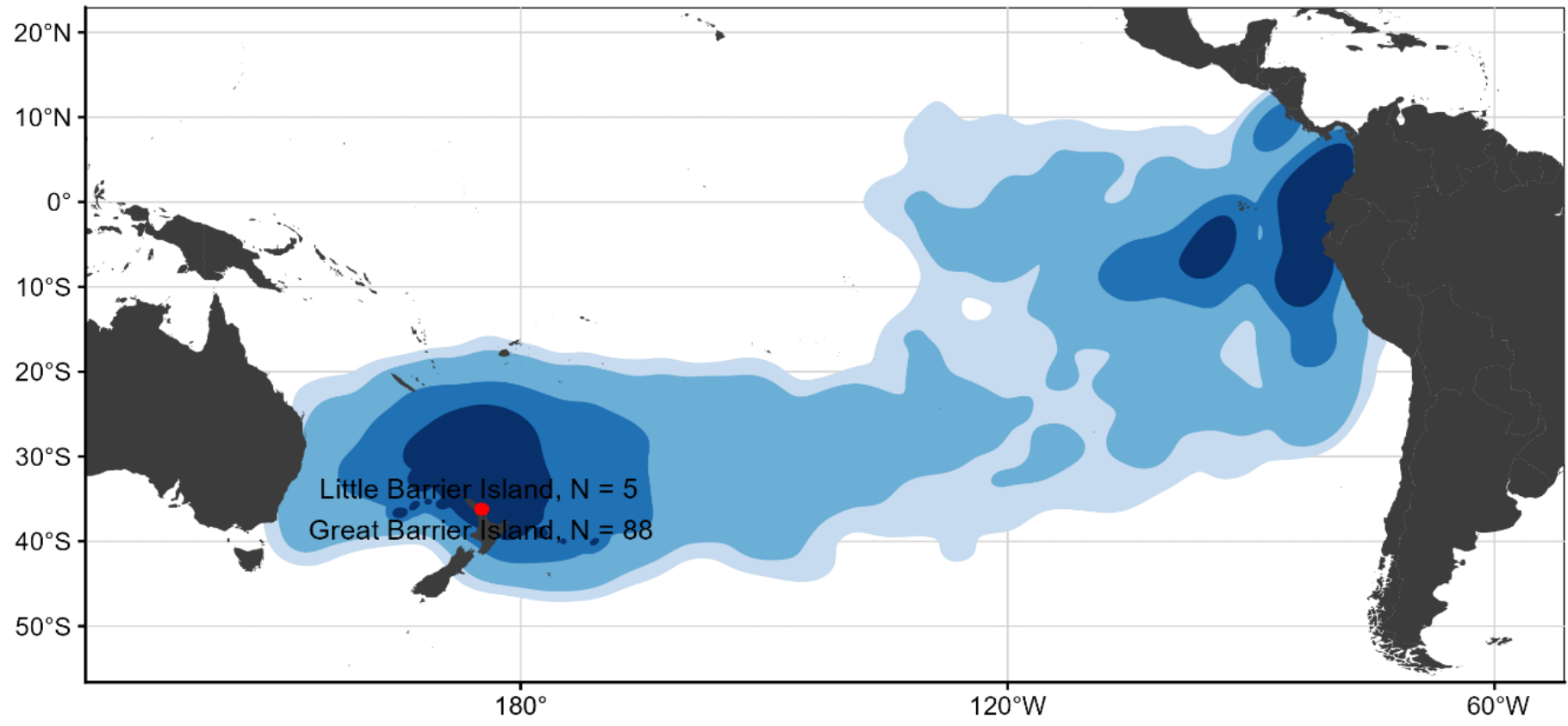
Southern Buller's Albatross



Sup. Fig. 9. Year-round distribution of Southern Buller's Albatross.

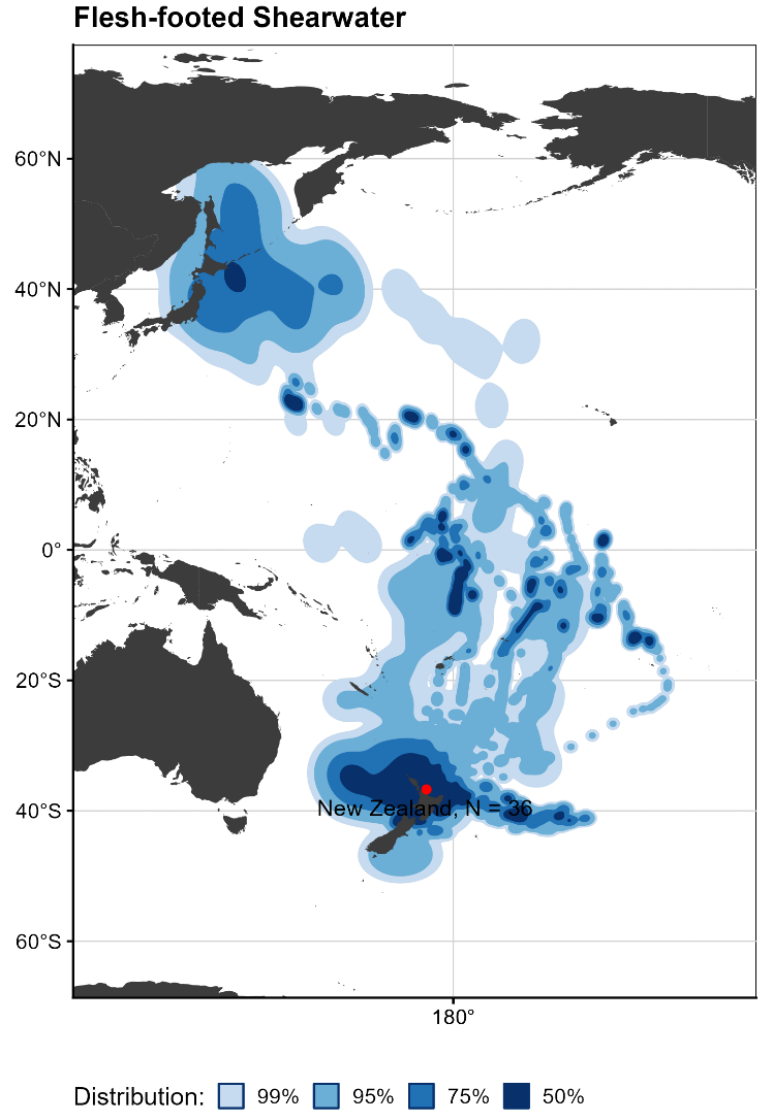


# Black Petrel



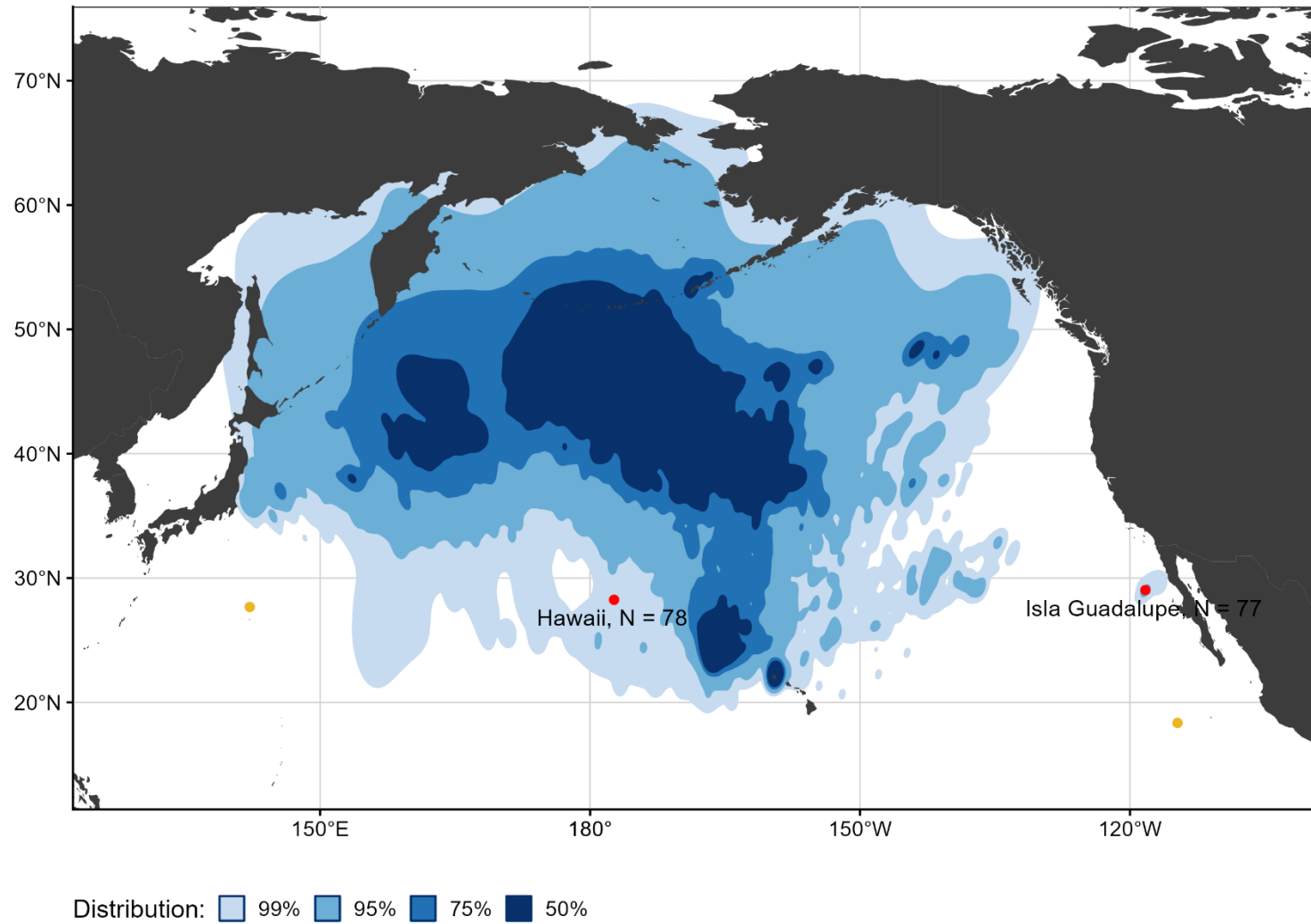
Distribution: 99% 95% 75% 50%

Sup. Fig. 10. Year-round distribution of Black Petrel.

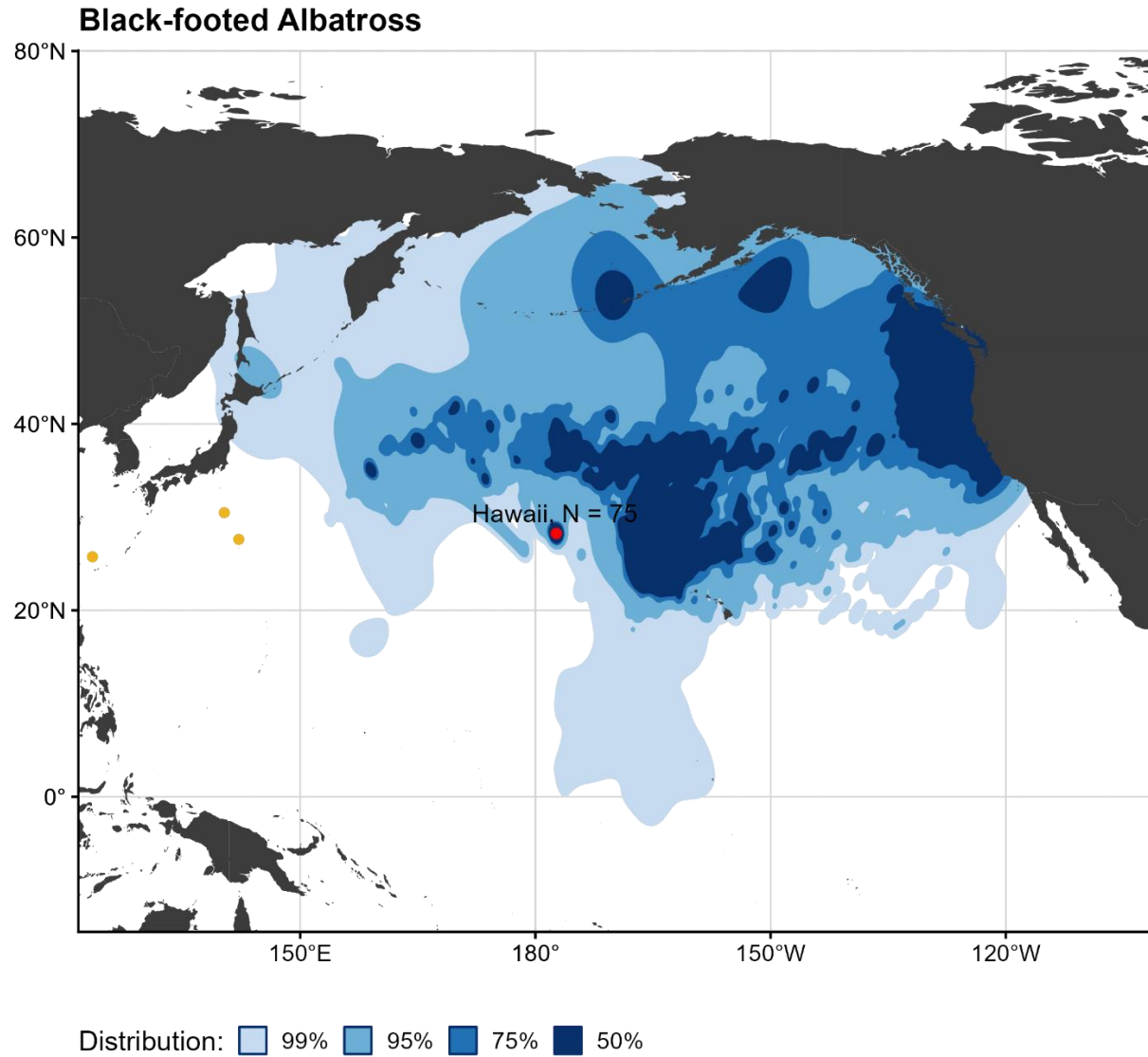


**Sup. Fig. 11.** Year-round distribution of Flesh-footed Shearwater tracked from New Zealand (Lady Alice Island and Ohinau Island, jointly encompassing ~5% of the total population).

# Laysan Albatross

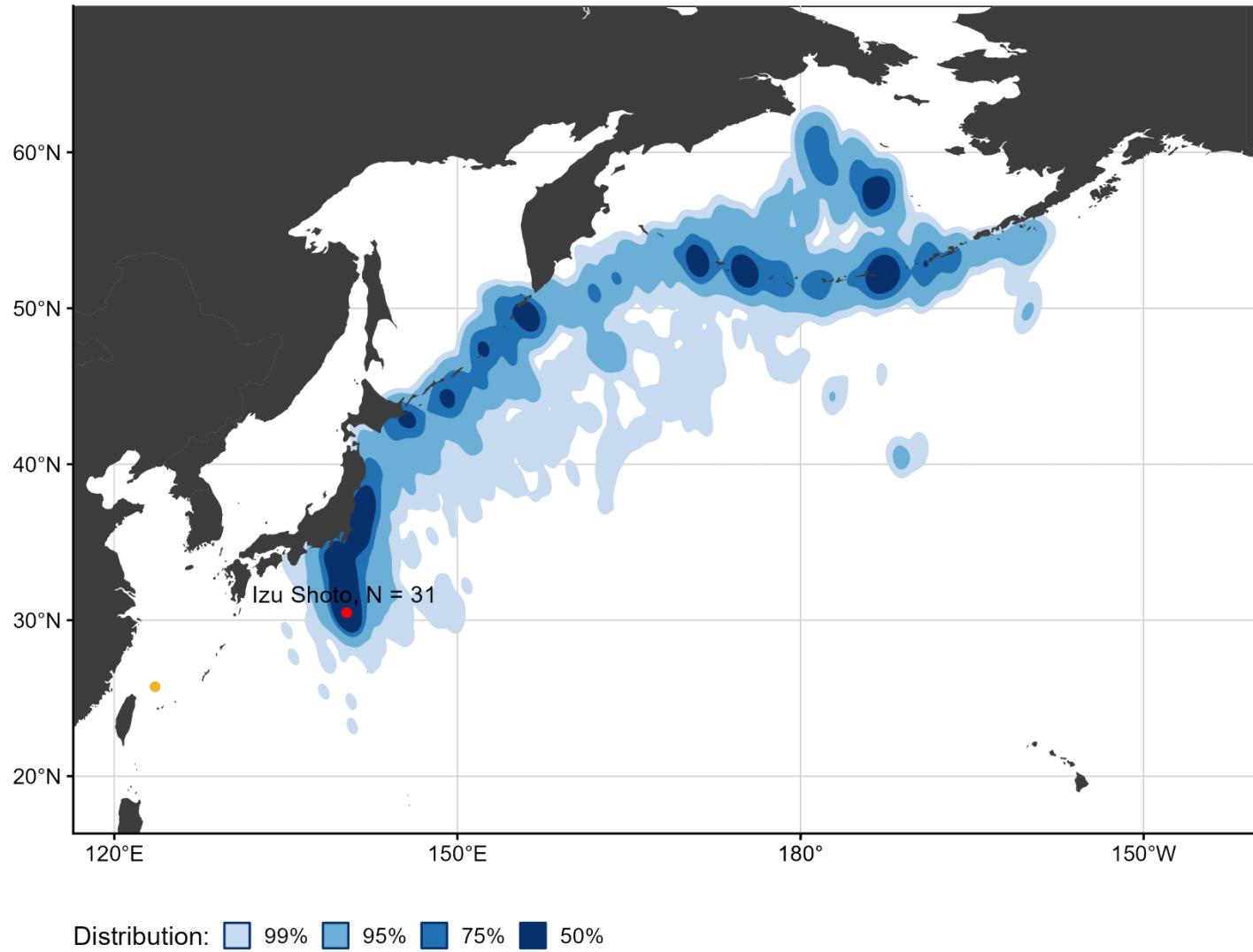


Sup. Fig. 12. Year-round distribution of Laysan Albatross.



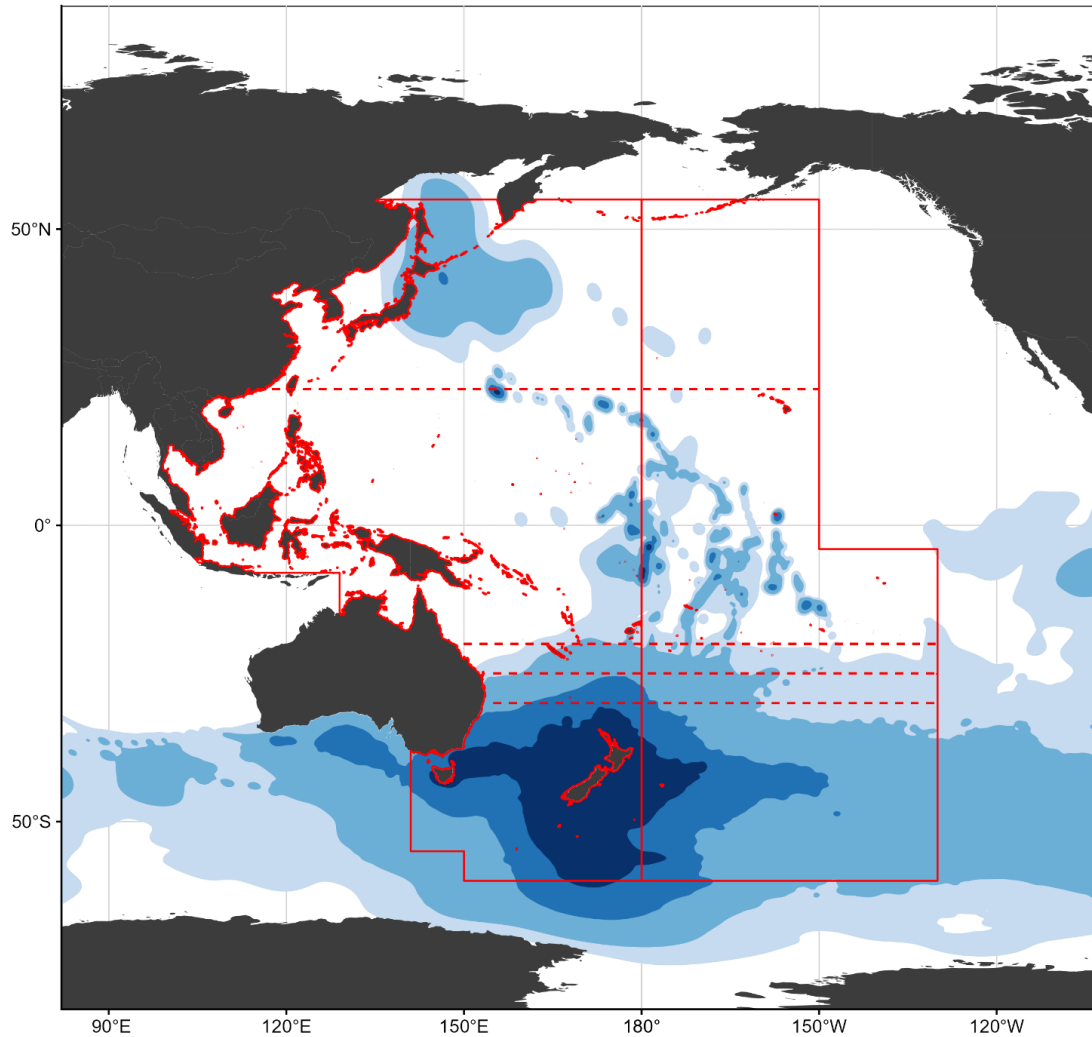
**Sup. Fig. 13.** Year-round distribution of Black-footed Albatross.

### Short-tailed Albatross

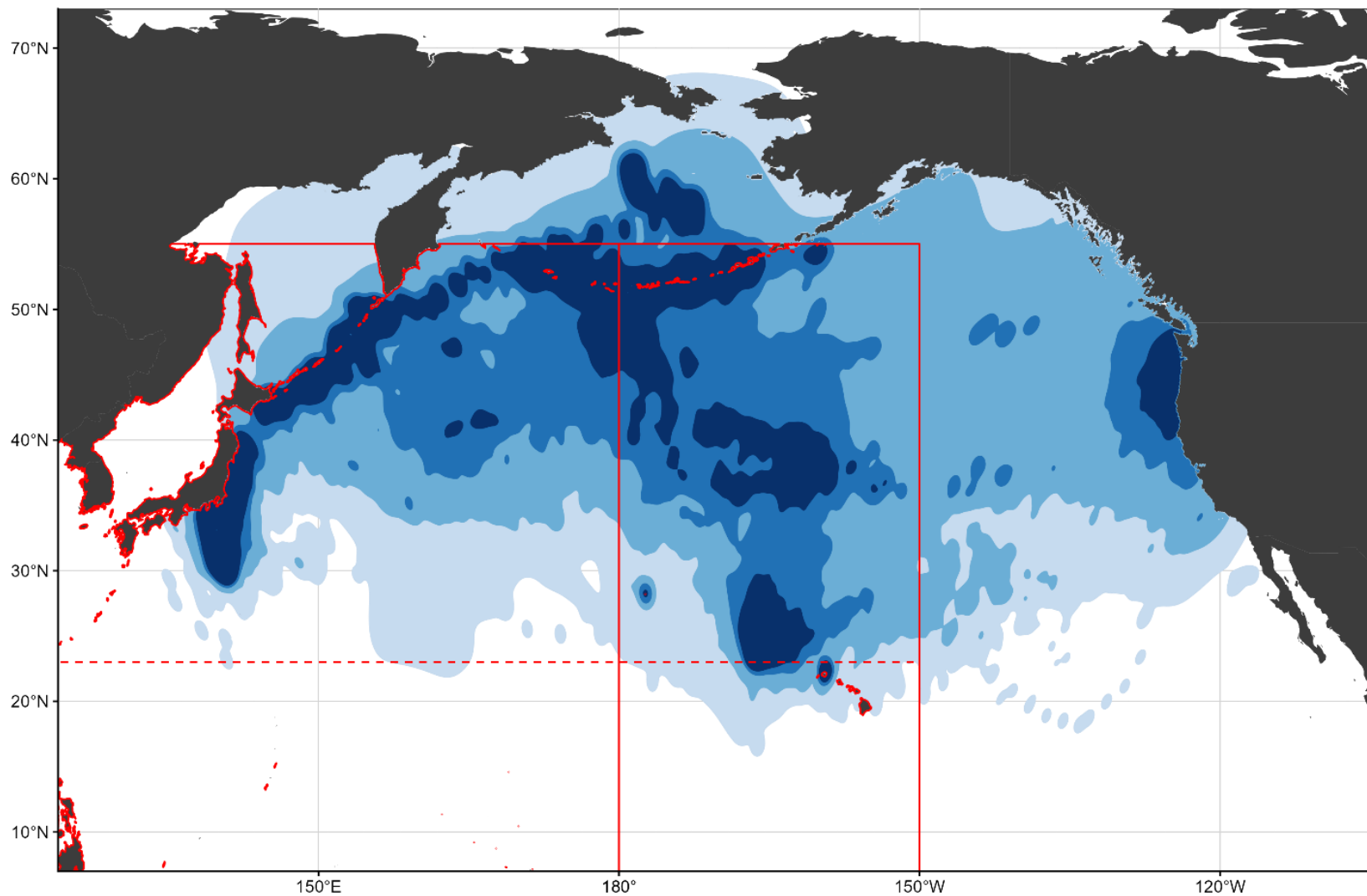


Sup. Fig. 14. Year-round distribution of Short-tailed Albatross.

**Supplementary Material 2. Combined, year-round distribution maps for each Hemisphere.**

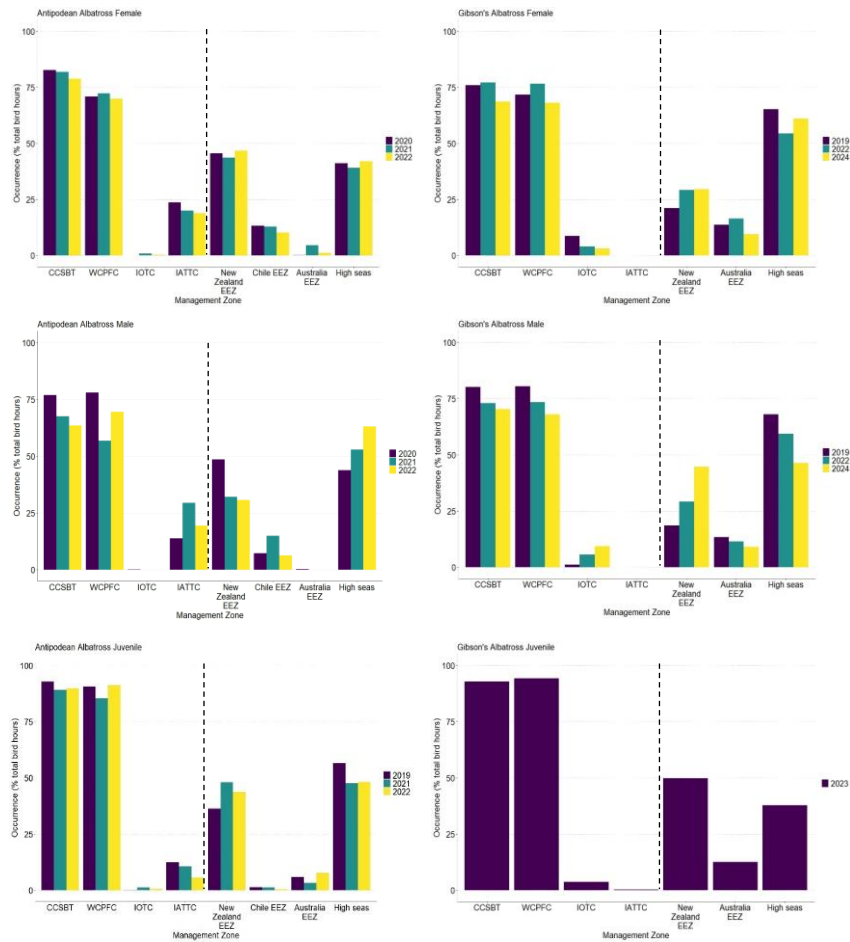


**Sup Fig 15.** Distribution of all 11 New Zealand focal taxa combined, based on 1,151 tracks, in relation to the WCPFC Convention Area and the 23°N, 20°S, 25°S, and 30°S parallels. Shades of blue represent 99, 95, 75 and 50% UD (from light to dark).



**Sup. Fig 16.** Distribution of all three Northern Hemisphere albatross species, based on 583 tracks, in relation to the WCPFC Convention Area and the 23°N parallel. Shades of blue represent 99, 95, 75 and 50% UD's (from light to dark).

### Supplementary Material 3. Additional Antipodean and Gibson's Albatross overlap statistics.



**Sup. Fig. 17.** Antipodean and Gibson's albatross proportional occurrence by management zone (RFMO & EEZ). Total bird hours (percent occurrence) by regional fisheries management organisation (RFMO) and exclusive economic zone (EEZ). Zones are denoted as - EEZs and the High Seas, as well as RFMOs (including EEZs), including the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), the Western and Central Pacific Fisheries Commission (WCPFC), the Inter-American Tropical Tuna Commission (IATTC), and the Indian Ocean Tuna Commission (IOTC). As some RFMOs overlap, the total sum of the relative occurrence exceeded 100%.