Antipodean albatross spatial distribution and fisheries overlap 2019

Samhita Bose and Igor Debski

August 2020

Department of Conservation

Abstract

Bycatch in fisheries has been identified as the greatest known threat to the endangered Antipodean albatross (*Diomedea antipodensis antipodensis*). We used data from 63 satellite transmitting devices deployed on Antipodean albatross in 2019 to describe the year-round distribution of these birds by cohort (in particular, adult females and juveniles). For each bird location obtained, the overlap with fishing effort, using individual vessel data derived by Global Fishing Watch from vessel monitoring systems, was estimated at a daily temporal scale. These methods allowed a quantitative assessment of overlap by geographic or jurisdictional area, season and fishing fleet. The greatest overlap was with pelagic longline fishing effort, and that overlap was primarily in the high seas areas of the Western Pacific, particularly in the mid-Tasman Sea and to the north-east of New Zealand. Juvenile birds foraged further north than adult birds, and overlapped with fishing effort north to approximately 25°S. A number of key fishing fleets were identified as having fishing effort that overlapped with Antipodean albatross, and the ports used by these vessels were also identified. Despite limitations with the tracking data set, and using fishing effort derived from vessel monitoring systems rather than data on actual hooks set, our results can be used to help focus efforts to reduce seabird bycatch in the fisheries that overlap most with Antipodean albatross. Further tracking of Antipodean albatross in 2020 and beyond will provide for an expanded dataset to further improve our understanding of the which fisheries may pose potential bycatch risk to this endangered species.

Introduction

Antipodean albatross (*Diomedea antipodensis antipodensis*) is classified as 'Nationally Critical' under the New Zealand Threat Classification Status (Robertson et al 2017), and at the species level (*D. antipodensis*) is listed as 'Endangered' on the IUCN Red List (Birdlife 2018). Antipodean albatross is essentially endemic to Antipodes Island in the New Zealand subantarctic region, and range across the South Pacific, from Chile to Australia. The Antipodean albatross population has more than halved since 2004 and continues to decline (Elliott & Walker 2020). Bycatch in fisheries, particularly those outside New Zealand's jurisdiction, has been identified as one of the largest known threats to Antipodean albatross. At the species level, Antipodean albatross (*D. antipodensis*) was listed on Appendix 1 of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) in February 2020 and the Antipodes Island population is recognised as a population of priority conservation concern by the Agreement on the Conservation of Albatrosses and Petrels (ACAP). The Concerted Action plan adopted by CMS (https://www.cms.int/en/document/proposal-concerted-action-antipodean-albatross-diomedea-antipodensis) focuses on the reduction of fisheries bycatch, supported by research including the deployment of tracking devices to better describe areas of fisheries overlap (Action 3.2).

Objectives

The objective of this work was to assess the first year of intensive satellite tracking of Antipodean albatross, in 2019, to describe areas of fisheries overlap. Specifically, we aimed to:

1. quantify the overlap of Antipodean albatrosses with fishing activity.
2. describe fisheries overlap by bird age class, sex and breeding state.
3. identify fishing fleets that overlap with Antipodean albatross and quantify the degree of overlap.
4. identify the ports most frequently used by vessels that overlapped with Antipodean albatross.

Our analyses did not attempt to extrapolate a distribution for the entire population of Antipodean albatross (c.f. Carneiro et al 2020, Abraham et al 2019) in order to provide a comprehensive and broadscale assessment of overlap with fishing effort. We sought to provide a summary of fine scale individual bird-vessel overlap of the sample of tracked birds over the course of one year. Despite this limitation, using the overlap of fishing effort with individual birds as a proxy for potential bycatch risk, the findings can be used to target seabird bycatch reduction outreach to certain fleets or vessels, and to identify which ports could be used to provide such outreach to vessels of interest. It is envisaged that the intensive tracking of Antipodean albatross will continue as part of a multi-year research programme, and applying these methods to the growing data set over time will enhance the representativeness of the results to the entire population.

Methods

We developed a two-stage method to assess overlap between satellite tracked seabirds and fishing effort data available from Global Fishing Watch (GFW; https://globalfishingwatch.org/). The first step was a rapid mapping process using fishing effort data generated by GFW at a 100 km x 100 km grid resolution, that produced maps of relative overlap at the same spatial scale. This allowed rapid identification of key areas of overlap with fisheries. We then developed a point-based quantitative overlap method to more precisely describe overlap by area and vessel variable (e.g. fishing method, flag state, fishing company).

Fishing effort data

Daily fishing effort data for the South Pacific in 2019 was obtained from GFW as csv files in two resolutions. The first dataset included fishing effort and vessel presence by flag state and gear type at 100th degree resolution. This gridded dataset was used for mapping fishing effort and overlap at 100 km x 100 km scale. The second dataset included fishing effort and vessel presence data at 10th degree resolution by Maritime Mobile Service Identity (MMSI) and was used for quantifying point-based overlap of Antipodean albatross with fishing effort. MMSI information in the dataset allowed for estimating number of vessels the birds overlapped with. It also allowed for quantifying the overlap with different fishing fleets based on attributes of the vessel, such as flag state. Data was also obtained from GFW on port visits by MMSI number for the year of 2019. This allowed for identification of ports frequently visited by vessels which had fishing effort that overlapped with Antipodean albatross.

Global Fishing Watch was chosen as our source of fisheries data because it is available for recent years, comprehensive, and is available at high temporal and spatial resolution at global scale. The GFW algorithm uses data from Automatic Identification Systems (AIS) and Vessel Monitoring

Systems (VMS) to derive fishing effort (Kroodsma et al. 2018). We used this GFW-derived measure of fishing effort and did not attempt to reanalyse raw position data ourselves. The coverage and estimate of fishing activity for high seas is relatively precise compared to the data available from the RFMOs which is typically made available at a coarse 5° x 5° spatial resolution, and, due to limitations and data availability issues, have been found to be biased low in some regions and times (Francis & Hoyle 2019).

After our initial rapid-assessment of overlap of all relevant fishing methods; pelagic longline (drifting longline in the GFW data), trawl, demersal longline (set longline in the GFW data) and jig, we focused our detailed assessment on the overlap with pelagic longline fishing effort.

Tracking data

Data on Antipodean albatross distribution were obtained from 63 satellite tracking devices deployed on Antipodean albatross in January-February 2019, as described by Elliott & Walker (2020). Full tracking data can be viewed and accessed through the web-based tracking app Albatross Tracker (https://www.doc.govt.nz/albatrosstracker). An overview of all tracks obtained from the 63 tracked birds is shown in Figure 1. The tags were deployed on adult females, adult males and juveniles. The sample sizes and type of device varied by cohort (Elliott & Walker 2020), resulting in varying sample sizes over time (most devices either failed, were lost, or the bird died before the end of the year) as shown in Figure 2. The most consistent sample was obtained for juveniles (20 reducing to seven by the end of the year), the largest sample being of adult females (up to 28 tags working at any single time) and the smallest sample being for adult males (from 14 down to only one from mid-June onwards). Because of the smaller sample size of the adult male cohort, it was excluded from detailed comparative cohort overlap analyses (which compared only adult females and juveniles).

The initial step in both the rapid-mapping and point-based overlap analyses was to clean and groom the bird location data and to estimate amount of time a bird spent at a location. Bird location data consisted of both GPS fixes and PTT locations derived using the Argos satellite system. Any PTT-derived location with Argos accuracy 0, A, B, and Z were first discarded from the data set (Douglas et al 2012). In addition, consecutive bird locations that were too far apart for the bird to have travelled (having required over 50m/s of sustained flight speed to cover the distance between the locations) were also discarded. The time difference (ΔT) between two clean consecutive locations for each bird were then calculated. If a GPS location was followed by an Argos location and had a time difference less than the interval of acquisition of GPS fixes of the tag (either every hour or every 6 hours, depending on tag type), then the Argos location was discarded to avoid introduction of noise in more accurate GPS data. Argos locations for GPS tags were only included when there were missing GPS fixes.

The time difference between the retained consecutive locations were then calculated. The time attributed to each bird location (hence forth birdhour) was derived as the sum of half the time of time difference between the preceding location and half the time difference with the successive location;

$$T_p = \frac{\Delta T_{(p-1)} + \Delta T_{(p+1)}}{2}$$

where, T_p is birdhour or time spent at p^{th} location, $\Delta T_{(p-1)}$ time difference of p^{th} location with preceding location and $\Delta T_{(p+1)}$ time difference of p^{th} location with successive location.

The derived birdhour (T_p) was weighted by the inverse of the number of individuals of the same cohort (i.e. all birds, adult male, adult female or juvenile) actively tracked (i.e. with working tags) on that day to correct for the difference in sample size (progressively smaller) over time;

$$Tw_{ip} = {}^{T_p}/_{n_p} \; for \; i \in C$$

in which Tw_{ip} is the weighted birdhour for the p^{th} location of the i^{th} individual and n_p is total number of birds tracked on that day in the cohort C. Whilst this accounted for potential bias in changing sample size over time, the data obtained later in the year was based on a smaller sample and hence should be viewed as less representative of the total cohort population.

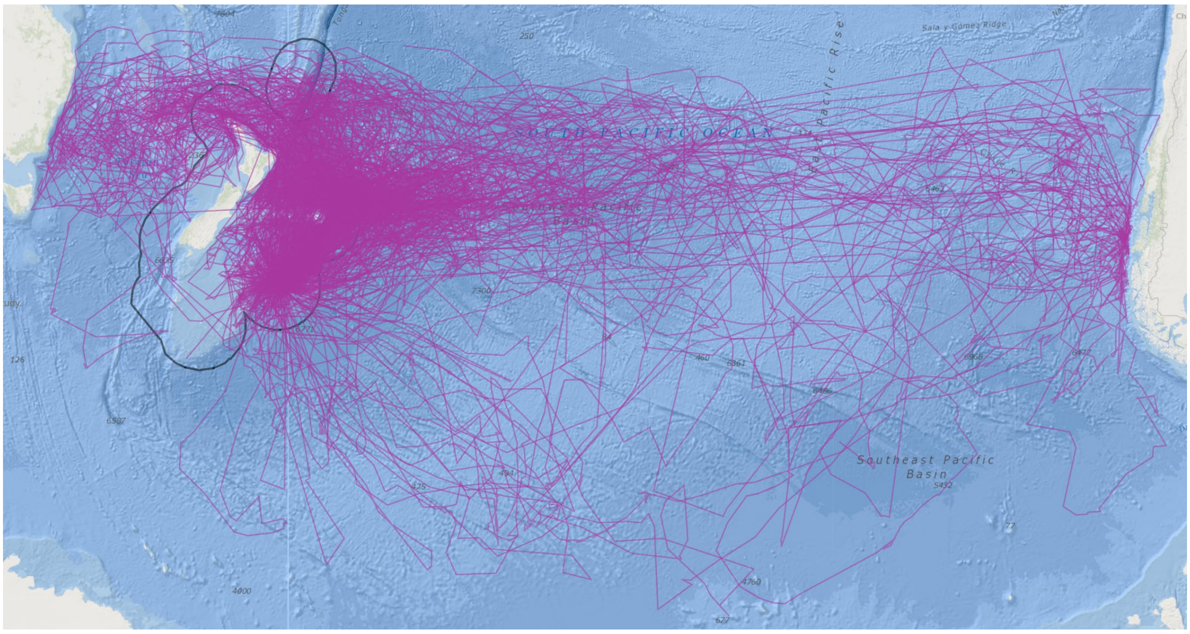

Figure 1. All tracks obtained from Antipodean albatross in 2019.

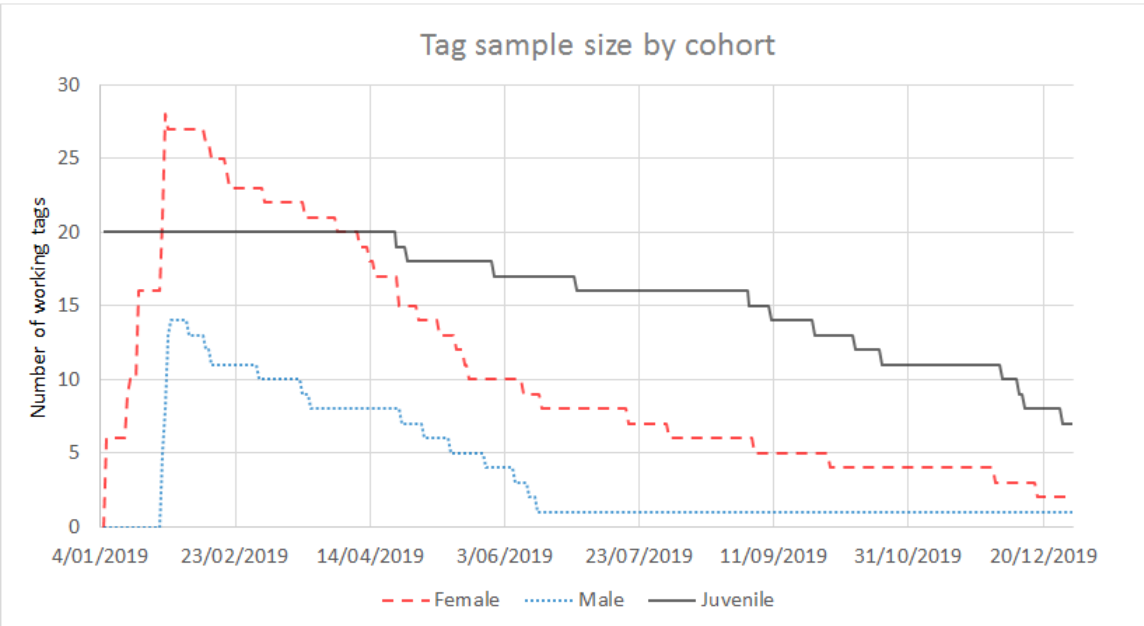

Figure 2. Sample size of working tags for female, male and juvenile Antipodean albatross over 2019.

Rapid-mapping of fishing effort overlap

Fishing hour data (fishing effort) for each day was acquired from GFW in csv format and were converted to a point shape file. A 100 km x 100 km fishnet grid was created and fishing hours for a day within a grid were summed to assign value (total fishing hours) to the grids. Daily grids were then converted to raster layers and used for the overlap analysis. The daily fishing hour raster layers were stacked and the fishing hours for each 100 km x 100 km cell was summed across all dates to obtain the cumulative fishing hours in each cell to highlight fishing hotspots. For pelagic longline fishing effort, comparison of the spatial distribution of GFW derived fishing effort with that obtained from RFMOs (as reported by Francis & Hoyle 2019) was limited by the coarse spatial resolution of the latter, though both data sets showed that in the Pacific south of 25°S there are higher levels of effort in the mid-Tasman and to the north and north-east of New Zealand. The bird location data (weighted birdhour) was added to the map as a spatial layer and was summed for each 100 km x 100 km grid cell to identify the amount of time spent by birds in a grid cell over the time period. The final bird location dataset was overlaid on daily fishing hour raster layers and value of the grid cell (hours of fishing in that cell for a day) was extracted for each bird location matched by the date. To correct for the period of bird occurrence in that cell on that day (weighted birdhour), the total fishing hour extracted against a location was divided by 24 then multiplied by the weighted birdhour for that cell on that day to give the estimate of overlap of the bird with fishing effort at that location on that day. The derived overlap value for each cell was then summed over the 100 km x 100 km grid to represent the cumulative overlap with fishing effort for that cell.

Point-based fishing effort overlap estimation

To quantify the overlap with fishing effort for each bird location, a radius of 100 km was used to sum the fishing effort for each location on that calendar day. Antipodean albatross may fly up to 100 km in an hour, so, given the frequency of bird positions obtained, a minimum appropriate radius of 100 km was used.

Fishing effort data at 10th degree resolution by MMSI acquired from GFW were converted to a point shape file. The final bird location dataset was overlaid on the fishing effort data. A spatial join was performed to identify all fishing effort within a radius of 100km of a bird location on that day. On review of vessel information found from other sources for the MMSIs that overlapped with Antipodean albatross, one vessel was excluded as likely not being a pelagic longline fishing vessel, and one vessel that had an unknown flag state in the GFW dataset was assigned China as flag state, based on a MMSI search in the Marine Traffic database (www.marinetraffic.com). All fishing effort on that day within 100 km distance of a bird location were then summed to assign total fishing effort against the location.

$$FE_{ip} = \sum_{j=0}^{n} f_j$$

where, FE_{ip} is the sum of fishing effort for the p^{th} location of the i^{th} individual and f_j is the fishing effort *j* of all n points within the radius of 100km of p^{th} location on that day.

The total fishing effort against a location was divided by 24 to provide an hourly fishing effort value (HFE_{ip}) for the location and then multiplied by the weighted birdhour for that location (Tw_{ip}) to give an estimate of overlap at that location (O).

$$O_{ip} = HFE_{ip} \times Tw_{ip}$$

We summed overlap by jurisdiction of fishing effort, we separated effort within EEZsand the non-EEZ portions of the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC). We included bird-fishing effort overlap in the area of geographic overlap between WCPFC and IAATC in the IATTC total only to avoid double reporting. The amount of bird-fishing effort overlap identified in the WCPFC and IATTC geographic overlap area was small compared to the remainder of the WCPFC area. We summed bird-fishing effort overlap for the western and eastern WCPFC separately, which was determined as areas to the west or east of the 180° longitude, respectively (this approximates to west or east of the New Zealand EEZ).

A slightly different approach was used to identify a list of vessels that overlapped tracked birds, and for which port use was investigated. For this purpose, we identified each vessel with fishing activity within 100 km and within 24 hours either side of each bird location. This method identified 16 additional vessels compared to the daily point-based overlap methods described above. Each vessel identified was matched to its history of port visits for 2019, as obtained from GFW, in order to assesses the ports most frequently used by this group of vessels. Eight port visits could not be assigned to a valid port or port state and were excluded from the analysis.

Results

Overview of rapid-mapping overlap with fishing effort

The year-round spatial distribution of the 63 tracked Antipodean albatross in 2019 is shown in Figure 3. The distribution extends from the east coast of Australia across the Pacific to the coast of Chile, from approximately 25°S to 60°S, with highest occurrence in the vicinity of Antipodes Island (the breeding site south-east of New Zealand), in an area to the east of New Zealand straddling the New Zealand EEZ, the mid-Tasman Sea, and an area off the southern Chile coast. This pattern broadly matches earlier tracking of this population (Walker & Elliott 2006; Elliott & Walker 2018).

Rapid-mapping of the overlap with pelagic longline, trawl, demersal longline and jig fishing effort is shown in Figures 4-7 (each figure provides a plot of total fishing effort for 2019, and overlap with the tracked birds). The greatest amount of overlap is clearly with pelagic longline fishing effort, and this was investigated in more detail using the point-based overlap method. The fishing method with the next largest amount of overlap was trawl. Most overlap with trawl fishing effort was within the New Zealand EEZ, with patchy overlap off the Chilean coast (within and beyond the Chile EEZ), and isolated overlap in the mid-Tasman Sea and Australia EEZ. Overlap with demersal longline fishing effort was restricted to only one 100 km by 100 km grid cell, in the New Zealand EEZ, and no overlap was found with jig fishing effort.

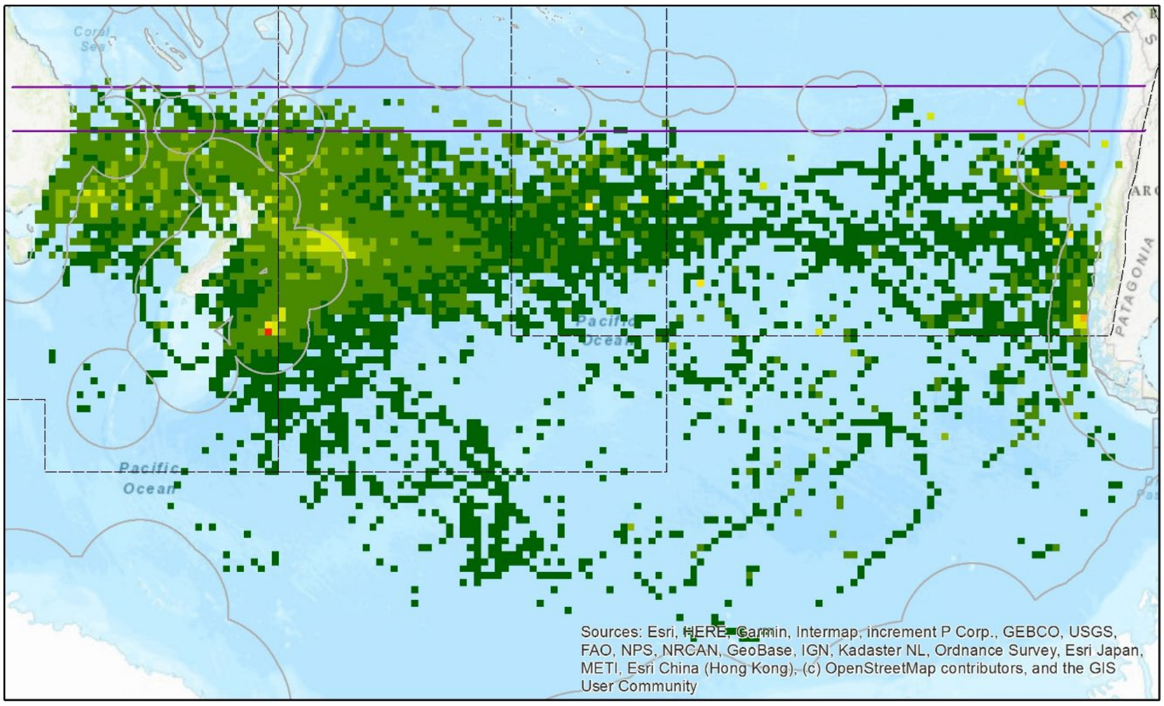

Figure 3. Spatial distribution of all tracked Antipodean albatross in 2019 (average number of bird hours per 100km x 100km grid cell). Red is highest occurrence, dark green lowest. Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude.

Rapid-mapping overlap with pelagic longline fishing effort

Rapid-mapping of overlap with pelagic longline fishing effort for adults and juveniles (Figure 8) showed that whilst adult distribution was more focussed within the New Zealand EEZ, the majority of overlap occurred in the high seas, primarily in the area to north-east of New Zealand and in the mid-Tasman Sea. These areas were also where juveniles had most overlap with pelagic longline fisheries. When adult males and females were compared (Figure 9), adult females reflected the core distribution for all adults and adult males had a broader and patchier distribution, the patchy nature being consistent with the much smaller sample size. Adult males had little overlap with pelagic longline fishing effort, but this finding must be treated with caution due to the low sample size (for half the year there was only one adult male with a working tag). Comparing juvenile males and females (Figure 10), they had very similar distribution and overlap patterns, primarily to the north-east of New Zealand and the mid-Tasman Sea, with very little occurrence in the eastern Pacific (late in the year 5 juveniles did travel towards the Chile coast and this may be a more important area for juveniles older than one year, which were not tracked). The comparative occurrence of adult male, adult female and juvenile birds by jurisdiction is shown in Figure 11 (note, a few locations were obtained within the New Caledonia and French Polynesia EEZs which have been included with areas south of WCPFC and IATTC for simplicity). Adult females and juveniles show a broadly similar distribution, although juveniles spend proportionately more time in the Australia EEZ, eastern WCPC and IATTC. Adult male occurrence was largely in the Chile EEZ, IATTC and in areas to the south of WCPFC and IATTC, but this must be considered with caution as due to the low sample size this reflects mostly the occurrence of a single bird (only one adult male had a working tag from mid-June onwards).

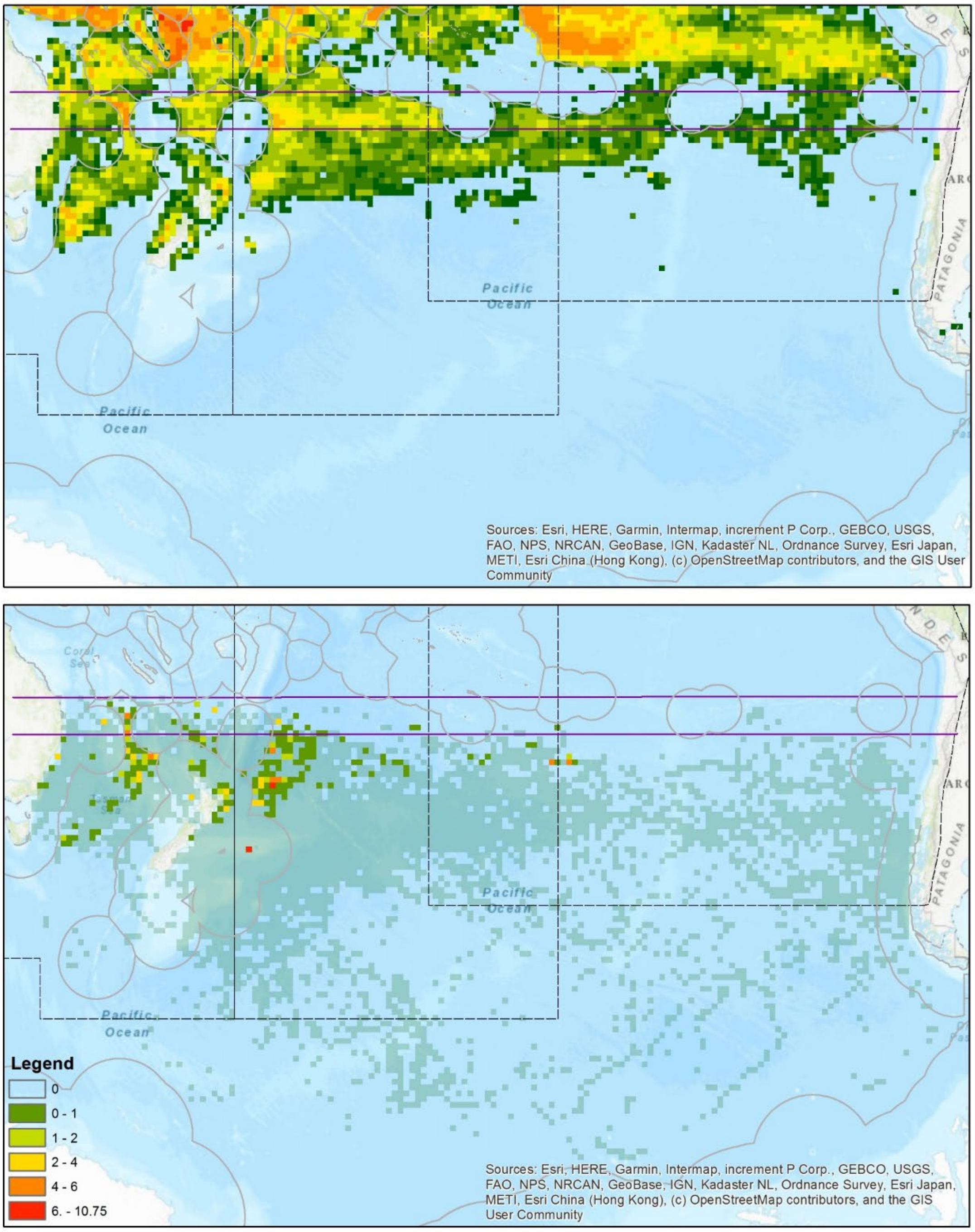

Figure 4. Pelagic longline fishing effort (top panel; total effort) and overlap with Antipodean albatross (bottom panel; cumulative daily overlap) at 100 km by 100 km grid scale for 2019. Red is highest effort/overlap, dark green is lowest overlap, and translucent green cells in the bottom panel represent bird distribution with no overlap. Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude.

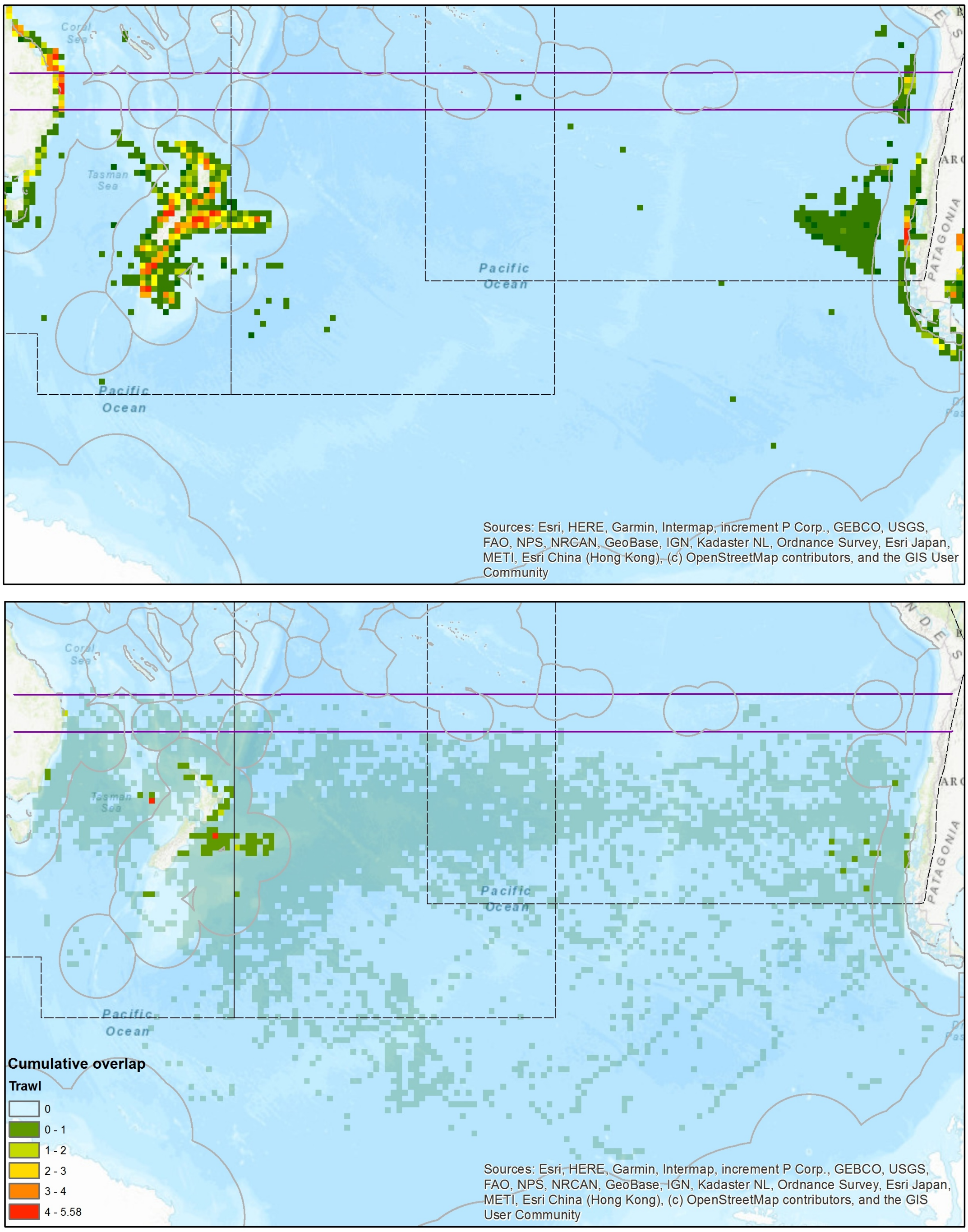

Figure 5. Trawl fishing effort (top panel; total effort) and overlap with Antipodean albatross (bottom panel; cumulative daily overlap) at 100 km by 100 km grid scale for 2019. Red is highest effort/overlap, dark green is lowest effort/overlap, and translucent green cells in the bottom panel represent bird distribution with no overlap. Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude.

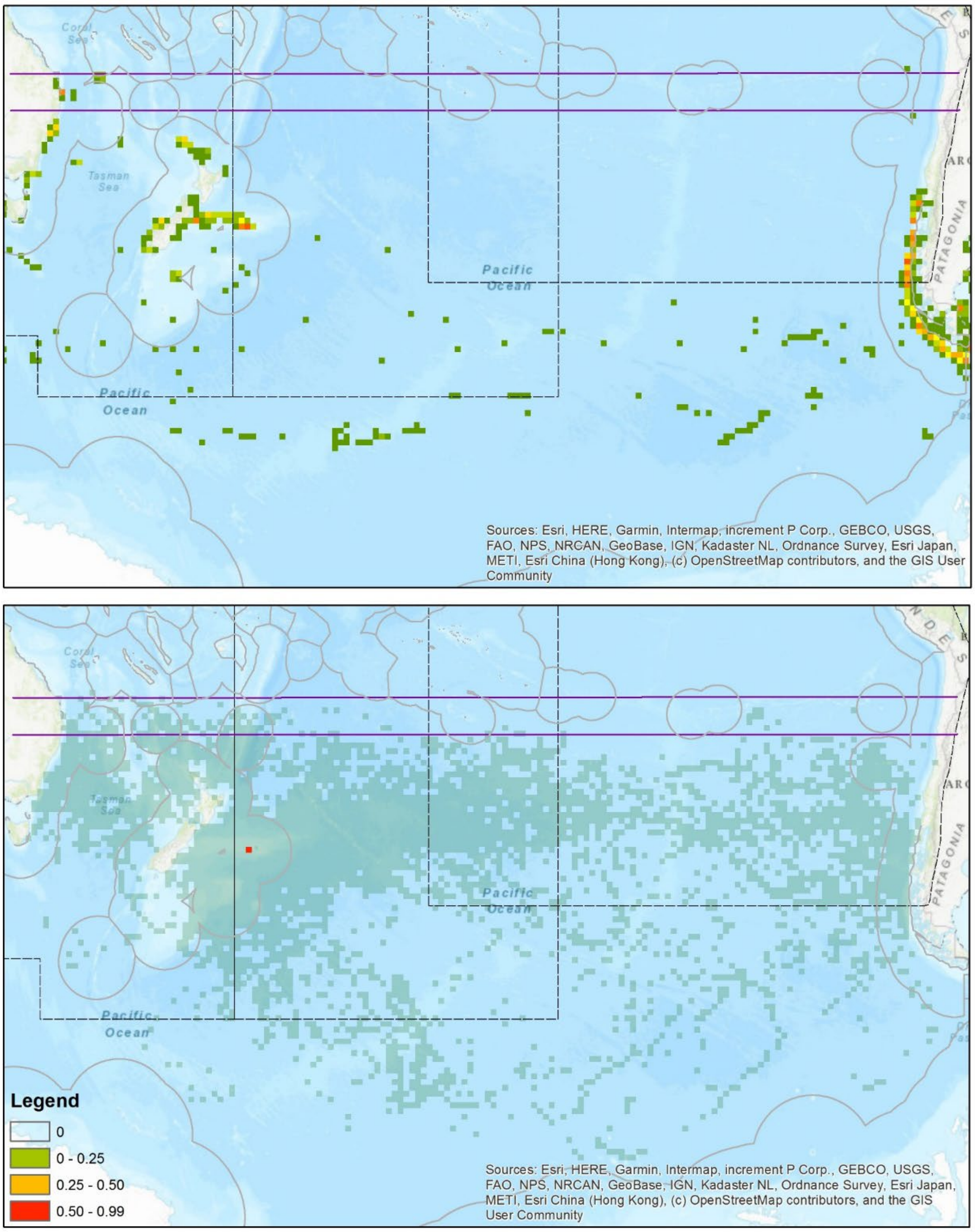

Figure 6. Demersal longline fishing effort (top panel; total effort) and overlap with Antipodean albatross (bottom panel; cumulative daily overlap) at 100 km by 100 km grid scale for 2019. Red is highest effort/overlap, dark green is lowest effort/overlap, and translucent green cells in the bottom panel represent bird distribution with no overlap. Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude.

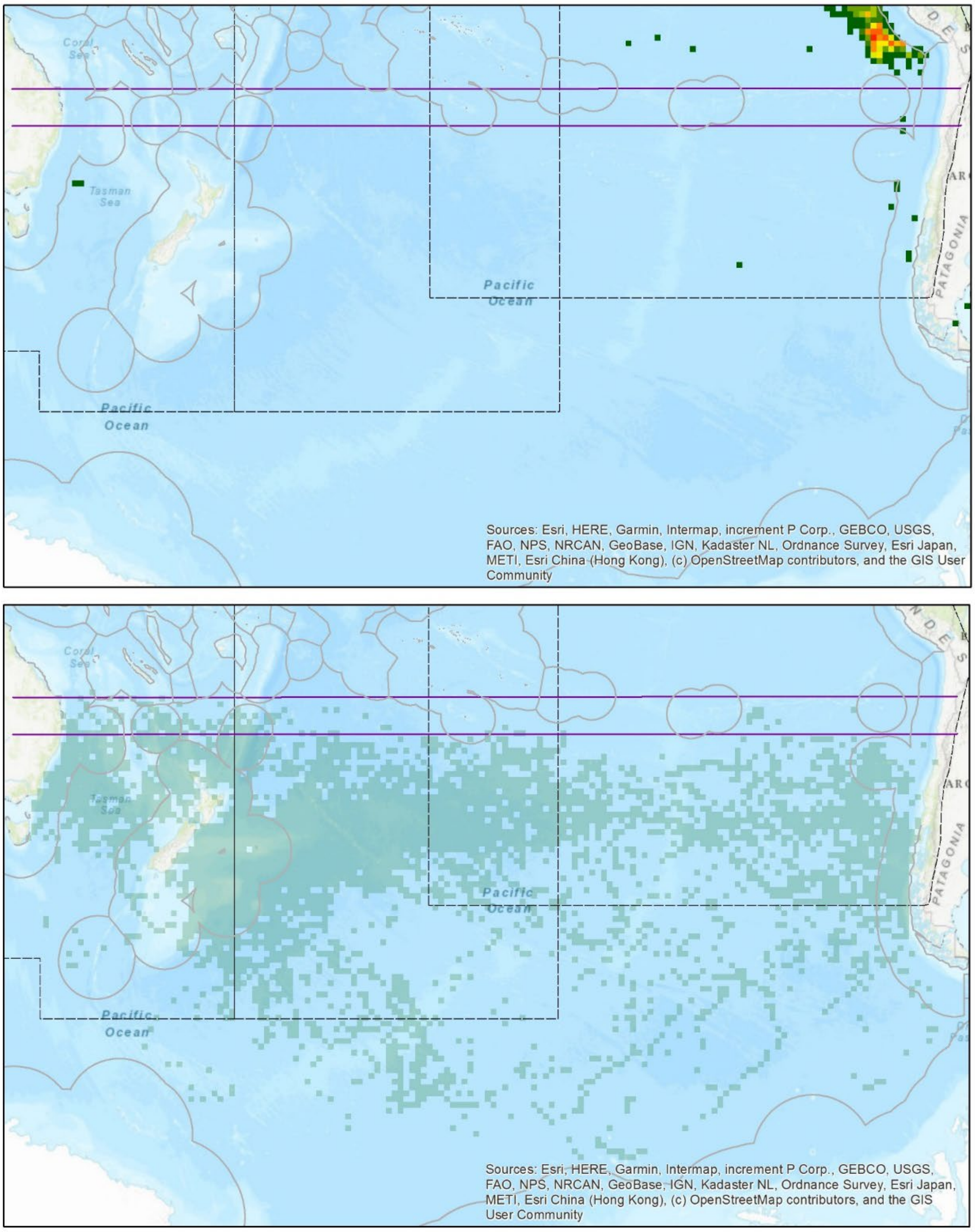

Figure 7. Jig fishing effort (top panel; total effort) and overlap with Antipodean albatross (bottom panel; no overlap identified) at 100 km by 100 km grid scale for 2019. Red is highest effort, dark green is lowest effort, and translucent green cells in the bottom panel represent bird distribution with no overlap. Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude.

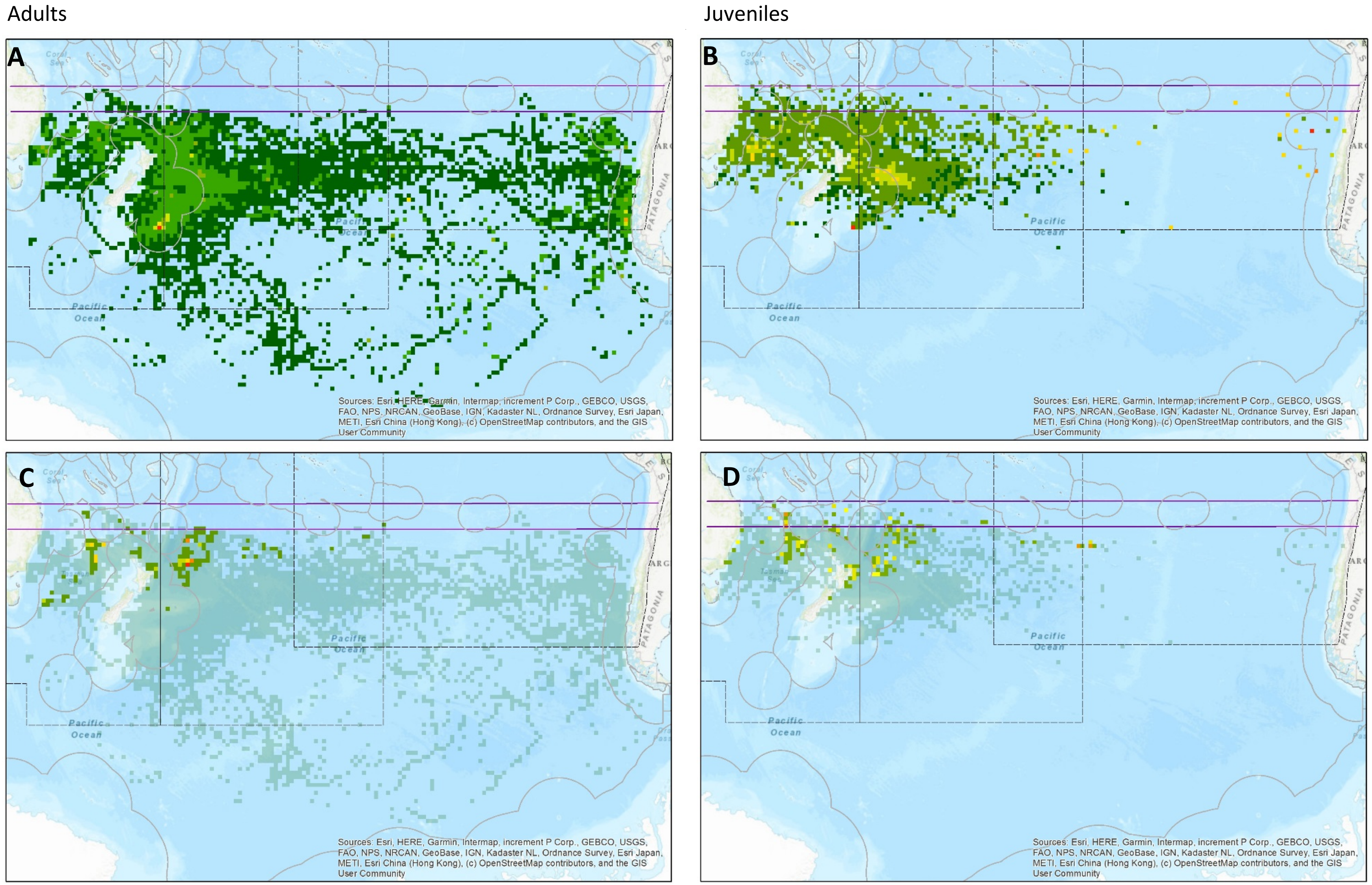

Figure 8. Year-round spatial distribution of all adult (A) and juvenile birds (B) in average number of bird hours per 100km x 100km grid cell and corresponding overlap with pelagic longline fishing effort (C, D). Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude. Note: overlap has not been corrected for sample size separately for each cohort at this stage.

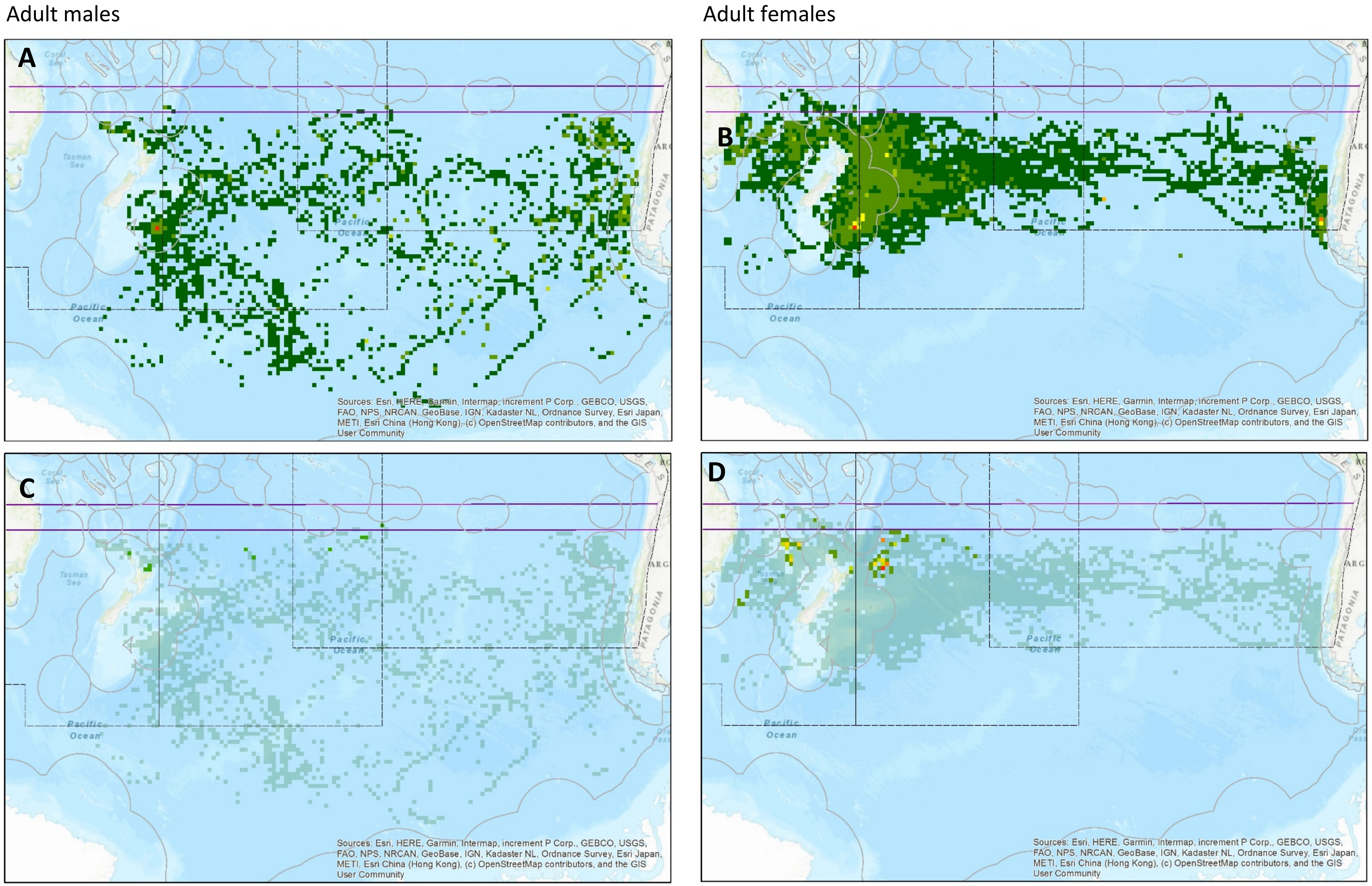

Figure 9. Year-round spatial distribution of adult male (A) and adult female birds (B) in average number of bird hours per 100km x 100km grid cell and corresponding overlap with pelagic longline fishing effort (C, D). Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude. Note: overlap has not been corrected for sample size separately for each cohort at this stage.

Juvenile females

Juvenile males

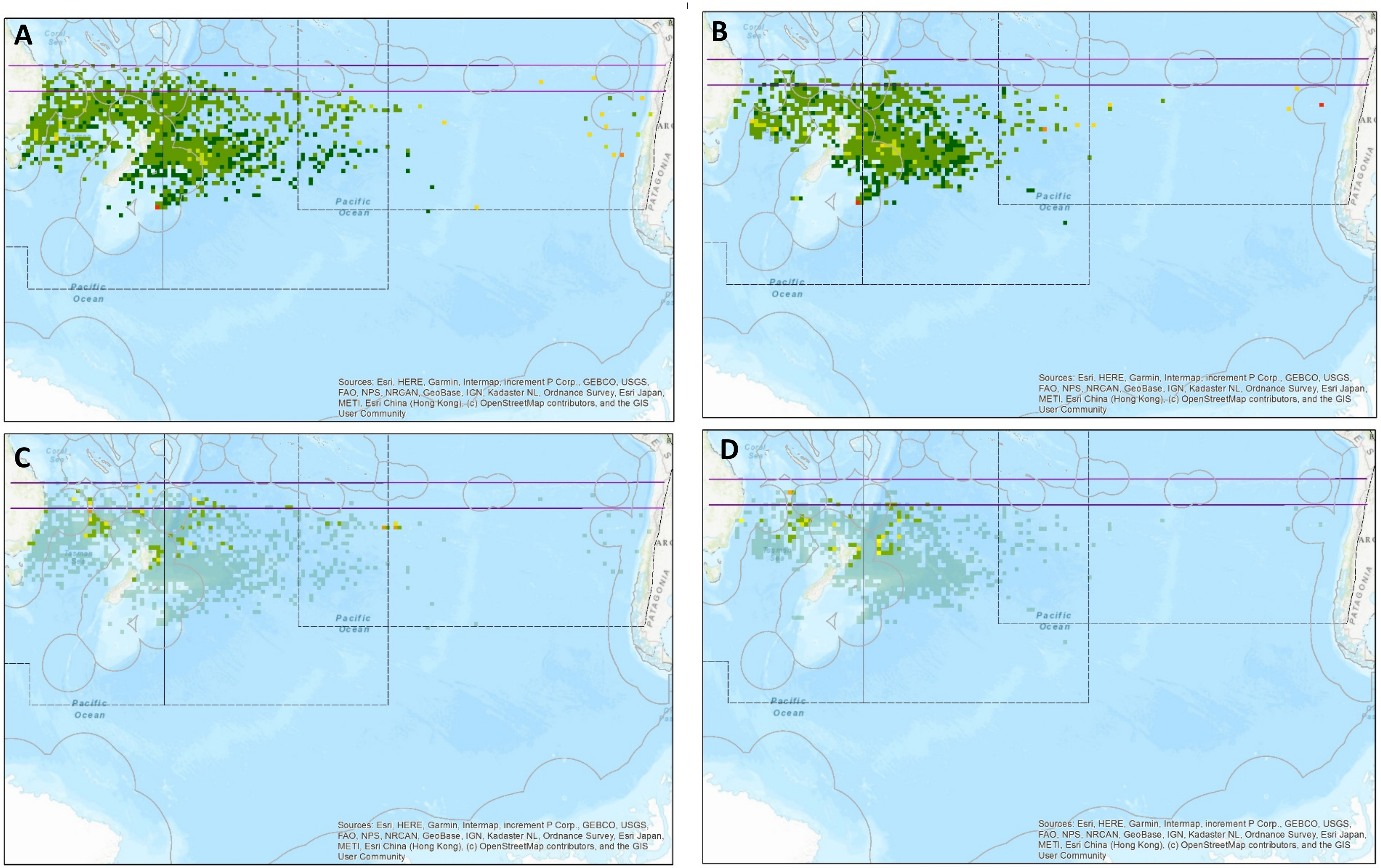

Figure 10. Year-round spatial distribution of juvenile females (A) and juvenile males (B) in average number of bird hours per 100km x 100km grid cell and corresponding overlap with pelagic longline fishing effort (C, D). Dashed lines indicate RFMO boundaries and purple lines represent 25°S and 30°S latitude. Note: overlap has not been corrected for sample size separately for each cohort at this stage.

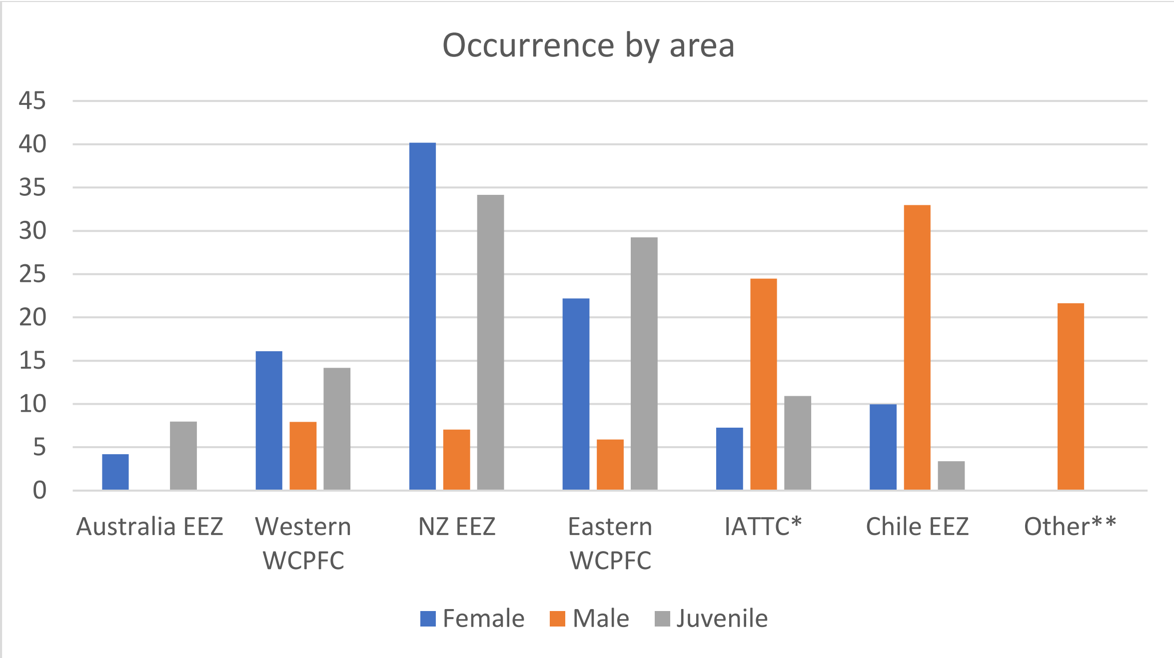

Figure 11. Distribution of bird occurrence (% total bird hours) by Jurisdiction, for adult females, adult males and juveniles. Note there was a small year-round sample size for males. RFMO areas are for high seas only. *Includes overlap area with WCPFC. **Primarily areas south of WCPFC and IATTC, also includes New Caledonia and French Polynesia EEZs.

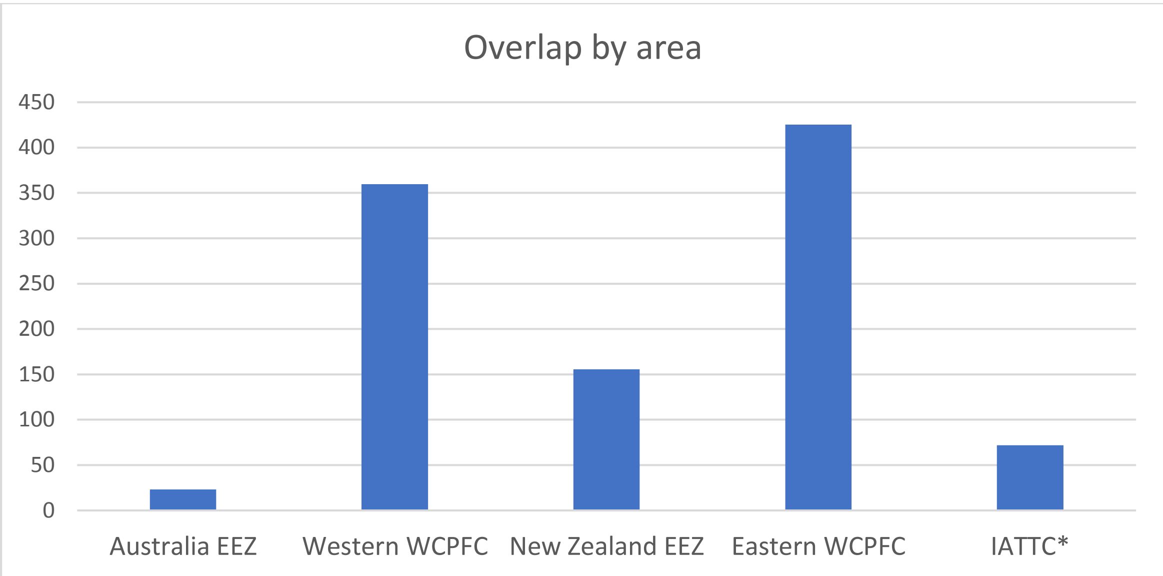

Figure 12. Distribution of pelagic longline fishing effort overlap (identified using the point-based method) by Jurisdiction. RFMO areas are for high seas only. *Includes overlap area with WCPFC. No overlap was identified in the areas south of WCPFC and IATTC or in the Chile EEZ.

Point-based overlap with pelagic longline fishing effort

The overlap with pelagic longline fishing effort of all tracked birds is shown by jurisdiction in Figure 12. The highest level of overlap was within the eastern WCPFC, closely followed by the western WCPFC, with overlap in New Zealand at only about one third the level in each of these two high seas areas. Overlap was also identified in the IATTC area and the Australian EEZ. No overlap was identified in the areas south of WCPFC and IATTC or in the Chile EEZ. A single incident of overlap with fishing effort in the New Caledonia EEZ was identified and was excluded from our figures for simplicity. Similar levels of overlap were found between adult female and juveniles (Figure 13). Note, we have excluded consideration of adult males in these analyses due to their small sample size. Comparing the overlap by jurisdiction for adult females and juveniles separately (Figure 14) showed adult females had a higher proportion of their overlap in the high seas areas of the WCPFC, particularly the western part, whilst juvenile overlap was more evenly spread across jurisdictions, though still primarily within the WCPFC high seas areas.

Overlap occurred mainly during the months of May through to September (Figure 15), with most overlap in May, followed by June. It is likely this is a consequence of particularly high relative fishing effort at this time of year in the areas to the north-east of New Zealand and in the mid-Tasman Sea, and to generally more northerly foraging by Antipodean albatross in the Austral winter months. The overlap in the eastern WCPFC occurred mostly in May and June, with overlap in the western WCPFC being more spread out from May through to September (Figure 16). Overlap in the New Zealand EEZ occurred year-round and there was a peak of overlap in the IATTC in September (Figure 16).

When overlap was summed by flag state, vessels flagged to Chinese Taipei accounted for the greatest amount of overlap, followed by Vanuatu, New Zealand, Spain, China and Japan (Figure 17). We understand most of the vessels flagged to Vanuatu are operated by companies in Chinese Taipei or China, and none of these vessels were found to visit Vanuatu during 2019 (Table 1). Vessels flagged to Australia and Fiji had lower levels of overlap, and single incidents of overlap were identified with vessels flagged to Ecuador and New Caledonia, but these were excluded from the figures for simplicity. Similar patterns of overlap with vessels by flag state were found for adult female and juveniles (Figure 18), although most overlap with Australian flagged vessels was with juveniles, reflecting the relatively higher occurrence of juveniles in the Tasman Sea (Figure 8B)

Port visits

In our analysis of overlap for the purpose of identifying ports used by vessels overlapping with Antipodean albatross we identified 132 vessels flagged to 11 flag states (Table 1). Note, the slightly larger sample size was due to the difference in methodology in that fishing effort within 24 h of a bird location was considered, rather than only that effort on the same calendar day used for the point-based overlap method. For these vessels, the GFW data set identified ports used in 24 port states (Table 1), mostly in the western Pacific. We report findings using the number of unique port visits (i.e. a unique combination between vessel and port, which excludes repeat visits to the same port by the same vessel). New Zealand, Australia, Japan, Fiji, Chinese Taipei, China, New Caledonia, Papua New Guinea and French Polynesia were the port states with the highest number of unique port visits. Unique visits to individual ports in the western Pacific have been shown in Figure 19.

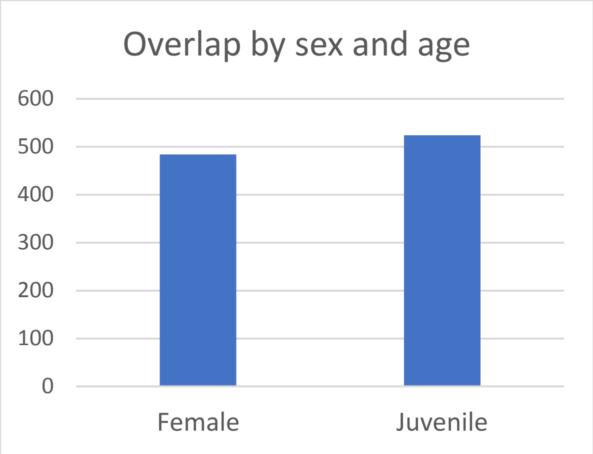

Figure 13. Distribution of pelagic longline fishing effort overlap (identified using the point-based method) for adult females and juveniles.

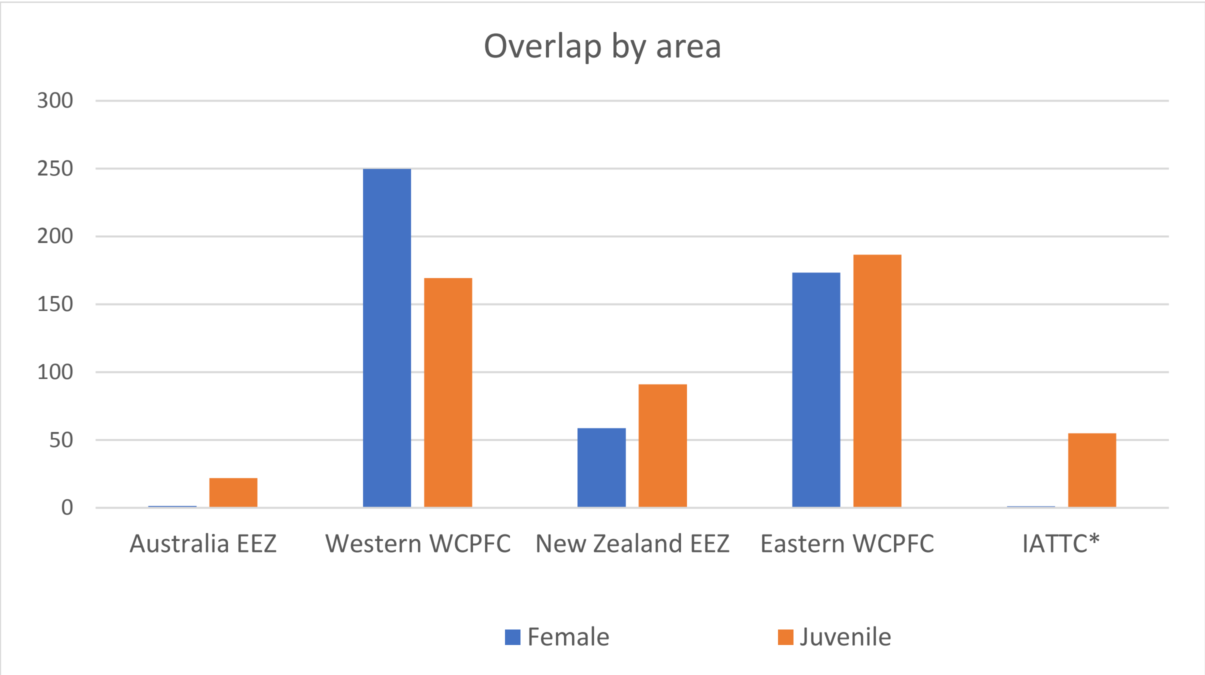

Figure 14. Distribution of pelagic longline fishing effort overlap (identified using the point-based method) by Jurisdiction, for adult females and juveniles. RFMO areas are for high seas only. *Includes overlap area with WCPFC. No overlap was identified in the areas south of WCPFC and IATTC or in the Chile EEZ.

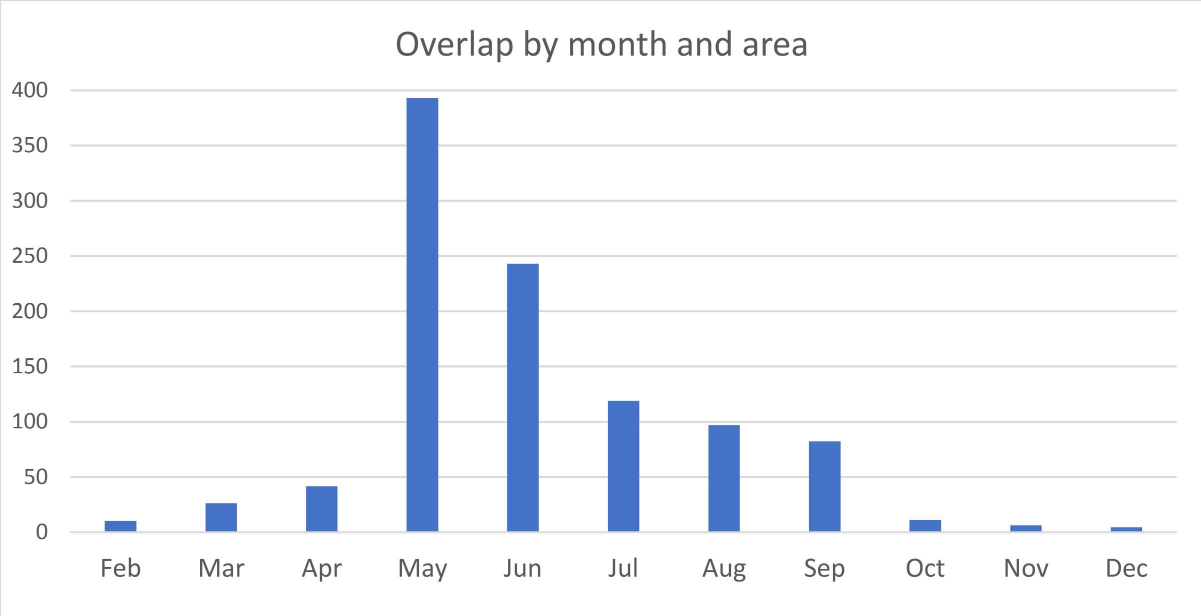

Figure 15. Monthly pelagic longline fishing effort overlap (identified using the point-based method). January is not shown as tags were not fully deployed until early February.

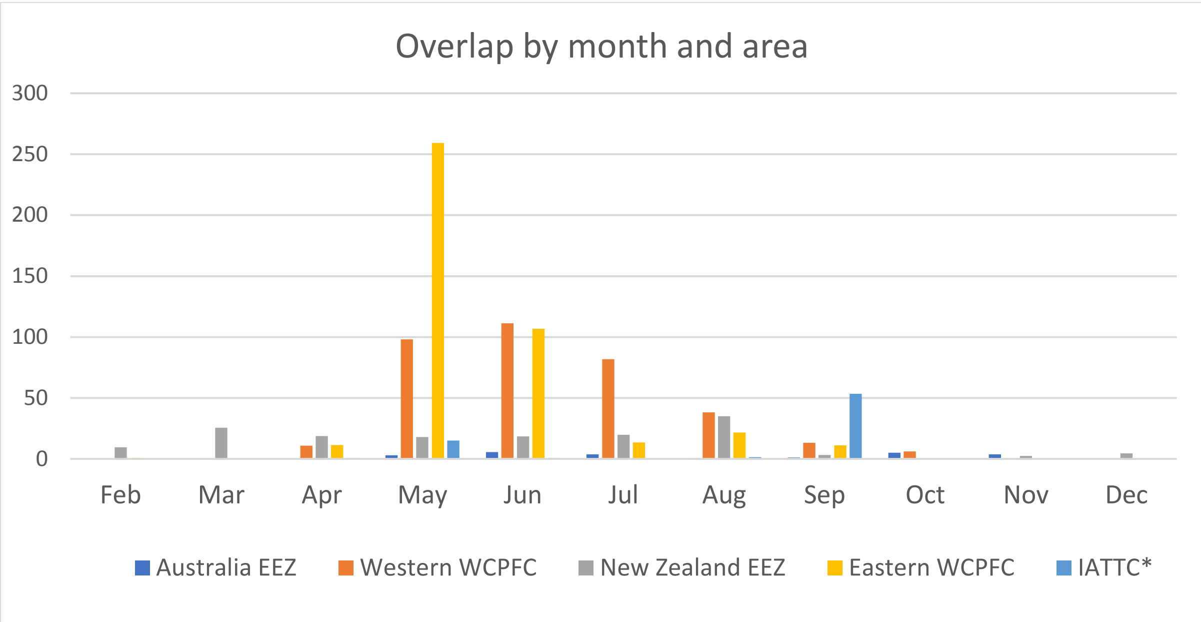

Figure 16. Monthly pelagic longline fishing effort overlap (identified using the point-based method). January is not shown as tags were not fully deployed until early February. RFMO areas are for high seas only. *Includes overlap area with WCPFC. No overlap was identified in the areas south of WCPFC and IATTC or in the Chile EEZ.

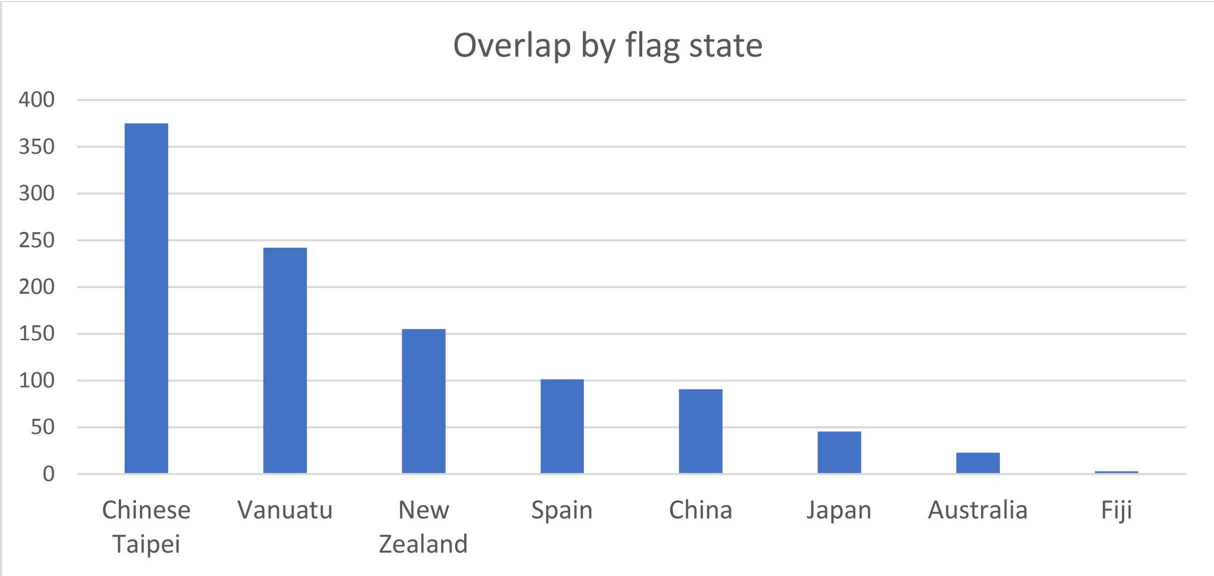

Figure 17. Pelagic longline fishing effort overlap (identified using the point-based method) by flag state. Flag states with only a single incident of overlap are excluded.

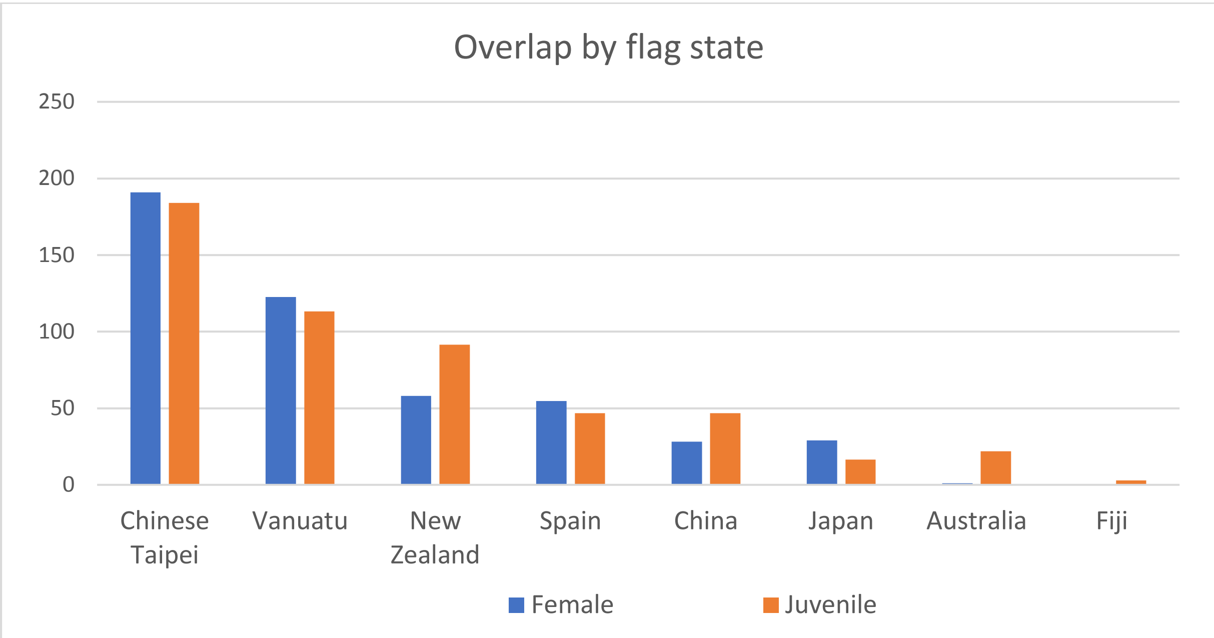

Figure 18. Pelagic longline fishing effort overlap (identified using the point-based method) by flag state, for adult females and juveniles. Flag states with only a single incident of overlap are excluded.

Figure 19. Western Pacific ports used by vessels that had fishing effort overlap (using the point-based method) with Antipodean albatross in 2019. The size of the circle is proportional to the number of unique vessel visits to these ports in 2019.

Table 1. Number of vessels that had fishing effort overlap (within 100 km and within 24 h of a bird location) with Antipodean albatross in 2019 and the ports used (number of unique vessel visits) in 2019, by flag state and port state. FSM = Federated States of Micronesia

Number of vessels/ Port state	Flag state											Total
	Australia	China	Cook Islands	Ecuador	Spain	Fiji	Japan	Korea	New Zealand	Chinese Taipei	Vanuatu	
Number of vessels	10	20	2	2	4	1	27	1	11	32	22	132
American Samoa										2		2
Australia	48						3					51
China		5								11	1	17
Cook Islands					1							1
Ecuador			1	2								3
Fiji		15	1			1	1			9	11	38
FSM							7					7
Guam							1					1
Indonesia							1					1
Japan							44					44
Korea		2									3	5
Marshal Islands							2					2
Mauritius								1				1
Namibia					1							1
New Caledonia							16					16
New Zealand					2		13		55			70
Peru		1	1									2
Papua New Guinea							12					12
French Polynesia		3			1		1				6	11
Solomon Islands										1		1
Chinese Taipei										21	14	35
Uruguay					1							1
Western Samoa		1								2	1	4
South Africa							1	1				2

Conclusion

Like many quantitative fisheries overlap studies, we faced a number of limitations with our data inputs. One of the major limitations of this study was the variable sample sizes of the cohorts of tracked birds over time. However, the bird occurrence we estimated from the tracking data (Figure 3) corresponded well with historic tracking data (Elliott and Walker 2018) so the results are likely to be representative of longer-term foraging patterns. As the tracking programme is extended into 2020 and beyond, the application of the methods we have developed here will provide much more enriched results and allows us to examine year to year variation. Another key uncertainty in our fishing effort overlap assessment is that we had to rely on fishing effort data derived by GFW from AIS and VMS data sources. Our preference would have been to describe fishing effort using data on the number of hooks set at each location by each vessel. However such data is not publicly available, and the effort data that is available is at such coarse spatial resolution, and subject to various availability limitations (Francis & Hoyle 2019) that we would have been unable to estimate overlap at a scale corresponding to the resolution of our tracking data.

Despite the data limitations from this first year of intensive satellite tracking Antipodean albatross, the year round results of bird occurrence and overlap with fishing effort have provided some useful insights as to where and when these birds overlap with identified fishing vessels and fleets. Amongst fishing methods, the greatest overlap was with pelagic longline fishing effort, and that overlap was primarily in the high seas. A great advantage of using the GFW derived fishing effort data was that not only were we able to estimate overlap at fine spatial and temporal resolutions, we could also identify individual vessels, and were able to investigate overlap at a vessel and fleet level. Further, we were able to identify where these vessels visited ports. This level of detail in our results is of great importance in helping to inform where seabird bycatch reduction efforts should be focussed to ensure this threat to Antipodean albatross is minimised or avoided.

Acknowledgements

Field research to deploy tracking devices was funded by DOC and undertaken by Kath Walker and Graeme Elliott using methods approved by the DOC Animal Ethics Committee (AEC 338). Satellite tracking tags were jointly funded by DOC and Fisheries New Zealand, and we particularly acknowledge William Gibson for development of the tracking app. We are also very grateful to the support provided by Global Fishing Watch in facilitating access to relevant fishing activity data.

References

Abraham, E., Richard, Y., Walker, N., Gibson, W., Ochi, D., Tsuji, S., Kerwath, S., Winker, H., Parsa, M., Small, C. and Waugh, S., 2019, May. Assessment of the risk of surface longline fisheries in the Southern Hemisphere to albatrosses and petrels, for 2016. In Report prepared for the 13th Meeting of the Ecologically Related Species Working Group (ERSWG13) of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT-ERS/1905/17).

BirdLife International. 2018. Diomedea antipodensis. The IUCN Red List of Threatened Species 2018: e.T22728318A132656045. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22728318A132656045.en

Carneiro, A.P., Pearmain, E.J., Oppel, S., Clay, T.A., Phillips, R.A., Bonnet-Lebrun, A.S., Wanless, R.M., Abraham, E., Richard, Y., Rice, J. and Handley, J., 2020. A framework for mapping the distribution of seabirds by integrating tracking, demography and phenology. Journal of Applied Ecology, 57(3), pp.514-525.

Douglas, D.C., Weinzierl, R., C. Davidson, S., Kays, R., Wikelski, M. and Bohrer, G. 2012. Moderating Argos location errors in animal tracking data. Methods in Ecology and Evolution, 3(6), pp.999-1007.

Elliott, G., Walker, K. 2018. Antipodean wandering albatross census and population study 2018. Research Report prepared by Albatross Research for the Department of Conservation.

Elliott, G., Walker, K. 2020. Antipodean wandering albatross: satellite tracking and population study Antipodes Island 2020. Department of Conservation Research Report.

Francis, M. and Hoyle, S.D., 2019. Estimation of fishing effort in the Southern Hemisphere. New Zealand Aquatic Environment and Biodiversity Report No. 213. Ministry for Primary Industries, Wellington, New Zealand.

Kroodsma, D.A., Mayorga, J., Hochberg, T., Miller, N.A., Boerder, K., Ferretti, F., Wilson, A., Bergman, B., White, T.D., Block, B.A. and Woods, P., 2018. Tracking the global footprint of fisheries. Science, 359(6378), pp.904-908.

Robertson, H.A.; Baird, K.; Dowding, J.E.; Elliott, G.P.; Hitchmough, R.A.; Miskelly, C.M.; McArthur, N.; O'Donnell, C.F.J.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A. 2017: Conservation status of New Zealand birds, 2016. New Zealand Threat Classification Series 19. Department of Conservation, Wellington. 23 p.

Walker, K.; Elliott, G. 2006. At-sea distribution of Gibson's and Antipodean wandering albatrosses, and relationships with long-line fisheries. *Notornis* 53 (3): 265-290.