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ALBATROSS AND PETREL DISTRIBUTION IN THE ATLANTIC OCEAN AND OVERLAP WITH ICCAT LONGLINE EFFORT

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SUMMARY

This paper presents an analysis of tracking data for 9 species (10 populations) of albatross and petrel species and calculates the degree of overlap with pelagic longline fisheries in the Atlantic Ocean. The analysis confirms the importance of the ICCAT area for a suite of globally significant albatross species. The Critically Endangered Tristan albatross and Endangered Atlantic yellow-nosed albatross have the highest degree of overlap with longline fishing and, along with the Vulnerable white-chinned petrel, have the highest exposure to longline hooks of the species analysed. Adjacent to the southern African coast the same two albatross species - plus black-browed albatross migrating from South Georgia – range as far north as 10°S where the ICCAT Recommendation 11-09 to reduce incidental seabird bycatch does not currently apply. Estimates of the number of pelagic longline hooks set south of 25°S suggest that pelagic longline effort in areas of high seabird abundance has decreased since 2000-2005.

RÉSUMÉ

Le présent document fournit une analyse des données de suivi de 9 espèces (10 populations) d'albatros et de pétrels et calcule le niveau de chevauchement de ces espèces avec les pêcheries palangrières pélagiques dans l'océan Atlantique. L'analyse confirme l'importance que revêt la zone de l'ICCAT pour un ensemble d'espèces d'albatros mondialement importantes. L'albatros de Tristan en danger critique d'extinction et l'albatros à nez jaune de l'Atlantique en danger d'extinction présentent le niveau de chevauchement le plus élevé avec l'effort de pêche palangrier, ainsi que le puffin à menton blanc vulnérable, sont les espèces analysées les plus exposées aux hameçons des palangriers. La zone adjacente à la côte méridionale africaine, où sont présentes ces deux mêmes espèces d'albatros ainsi que l'albatros à sourcils noirs, migrant depuis la Géorgie du Sud, jusqu'au Nord de 10ºS, n'est pas concernée par la Recommandation 11-09 de l'ICCAT visant à réduire les prises accessoires d'oiseaux de mer. Les estimations du nombre d'hameçons mouillés par des palangriers pélagiques au Sud de 25ºS donnent à penser que l'effort palangrier pélagique exercé dans des zones présentant une abondance élevée d'oiseaux de mer a diminué depuis 2000-2005.

RESUMEN

Este documento presenta un análisis de los datos de seguimiento de nueve especies (10 poblaciones) de albatros y petreles y calcula el grado de solapamiento con las pesquerías de palangre pelágico en el océano Atlántico. El análisis confirma la importancia de la zona de ICCAT para un grupo de especies de albatros importante a nivel mundial. De las especies analizadas, el albatros de Tristán, en peligro crítico, y el albatros de pico fino del Atlántico, en peligro, tienen el mayor grado de solapamiento con la pesca con palangre y, junto con el petrel barba blanca, vulnerable, son las que tienen un mayor nivel de exposición a los anzuelos del palangre de las especies analizadas. Junto a la costa africana meridional, las dos mismas especies de albatros, además del albatros ceja negra que migra desde Georgia del sur, se distribuyen muy al norte, hasta 10ºS, donde la Recomendación 11-09 de ICCAT para reducir la captura incidental de aves marinas no se aplica actualmente. Las estimaciones del número de anzuelos de palangre pelágico calados al sur de 25ºS sugieren que el esfuerzo del palangre pelágico en zonas de gran abundancia de aves marinas ha descendido desde 2000-2005.

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KEYWORDS

Seabird, pelagic longline, by catch, fishery regulations, international waters

1. Introduction

Incidental capture in fisheries (bycatch) is recognised as the primary threat to seabirds at sea, particularly impacting albatrosses and petrels (Robertson & Gales, 1998; Croxall *et al*., 2012). Fifteen of the world's 22 albatross species are Globally Threatened (IUCN 2016), and declines of albatross and petrel populations have been particularly severe in the South Atlantic (Robertson & Gales, 1998).

When ICCAT undertook its first seabird assessment (2006-2009), two of the six stages were to identify spatial and temporal overlap between albatross and petrel distribution and pelagic longline fishing effort, in order to identify species, areas and seasons of highest bycatch risk (ICCAT 2007; ACAP 2010). This paper updates the 2010 overlap analysis, incorporating newly available seabird tracking data and new estimates of ICCAT pelagic longline fishing effort (Beare *et al*., 2015), and also uses the new fishing effort data to examine whether the degree of overlap has changed across the 2000-2005, 2005-2010 and 2010-2014 periods.

2. Methods

2.1 Seabird tracking data, cleaning and standardisation

The Global Seabird Tracking Database (www.seabirdtracking.org) holds data on all 7 species of albatross that breed in the Atlantic Ocean, as well as both species of giant petrel, and spectacled and white-chinned petrel. Data were made available for this analysis through the agreement of data owners, listed in the Acknowledgements. Since the 2010 analysis (ACAP, 2010), additional tracking data have become available for some albatross and petrel species (**Appendix 3**). In particular, the number of tracks of breeding black-browed albatross from the Falkland Islands (Islas Malvinas) has increased from 78 to 1024 tracks; and there are increases in the number of tracks of non-breeding grey-headed albatross, breeding and non-breeding wandering albatross, and breeding black-browed albatross from South Georgia (Georgias del Sur). Despite the increases for some species, for two species (light-mantled albatross and spectacled petrel), the situation remains as it was in 2010, i.e. data gaps mean that these species must be excluded from the analysis. White-chinned petrel tracking data were only available for the South Georgia (Georgias del Sur) population, and breeding populations in the Indian Ocean are missing. In addition, as in the 2010 analysis, care must also be taken when interpreting 'kernel distributions' where data are missing from some colonies and where sampled sizes are small and ideally, analysis would be based on at least 10-15 tracks for each breeding stage before results would be considered to approach optimal reliability (BirdLife International, 2004).

All the data were formatted using standardised procedures (BirdLife International, 2004)[4]. The tracks include data collected by a variety of devices, including Platform Terminal Transmitters (PTT), Global Positioning System devices (GPS), and geolocators or Global Location Sensing (GLS) loggers. These devices have different performances, with trade-offs between temporal resolution, deployment duration, device mass and cost (Wakefield *et al*., 2009). PTTs can provide multiple locations per day with accuracy typically of <15 km (Burger & Shaffer 2008; Phillips *et al*., 2008). These devices have, to an extent, been displaced in the last decade by GPS loggers which have a much better spatial accuracy (within 10 m) and temporal resolution (up to 1 Hz) (Guilford *et al*., 2008; Phillips *et al*., 2008; Kotzerka *et al*., 2010). However, the usefulness of miniaturised GPS loggers is still limited by their short lifespan. The use of GLS loggers avoids some of these problems as these devices have low power requirements, and are small enough to be attached to a tarsus ring (Wilson *et al*., 2002; Phillips *et al*., 2004; Shaffer *et al*., 2005), but GLS loggers will provide only two locations per day with an average accuracy of 186 ± 114 km, and latitude is impossible to estimate from light for 3 to 4 weeks around the equinoxes (Phillips *et al*., 2004; Shaffer *et al*., 2005). GLS technology is therefore unsuitable for fine-scale analysis, but valuable for monitoring large-scale movements during the non-breeding season or over extended periods.

[4] Details for data formatting available at www.seabirdtracking.org

The PTT data were cleaned using a speed filter based on McConnell et al. (1992), and GLS data were cleaned by removing locations for 2 to 4 weeks around the equinoxes, when latitudes were unreliable and by removing obviously erroneous positions after visual inspections (Phillips *et al*., 2004). PTT and GPS data were interpolated at hourly intervals to obtain regular positions. Re-sampling was not conducted for GLS data since the locations of tracked birds collected using this type of devices are available at regular (approximately 12-hour) intervals.

2.2 Data analysis

Seabird tracking data were analysed using the same approach as the 2010 analysis (ACAP 2010).

After standardisation, seabird tracking data were split into a unique combination of species-colony- breeding stage-device type. Seabird density distributions (or 'utilization distributions', UDs) were created for each of those combinations using kernel analysis in the *adehabitatHR* package (Calenge 2006). For PTT and GPS data, the kernel analysis had a fixed smoothing parameter (*h*) of 55 km, while an *h* value of 200 km was used for GLS data. Utilization distribution maps derived from PTT, GPS, and GLS data were then combined using the overlay function in the raster package. When seabirds were tracked from different colonies, but from the same population, density maps were combined by weighing the percentage of the population involved. For example, the black-browed albatross population from the Falklands (Islas Malvinas) was tracked during the brood-guard stage from New Island and Steeple Jason, which represent 7.3 and 92.7% of the Falkland/Malvinas population, respectively.

Because both seabird distribution and ICCAT longline fisheries vary seasonally, this variation was taken into account by analysing data separately by quarters (Quarter 1 (Q1): Jan-March, Quarter 2 (Q2): April-June, Quarter 3 (Q3): July-Sept, Quarter 4 (Q4): Oct-Dec). Quarterly spatial distribution maps were based on the length of each breeding stage (start and end dates rounded up to 0.5 months) associated with the respective quarter (**Appendix 1**), and on the proportion of breeders and non-breeders in the population (**Appendix 2**). If no tracking data were available for a particular stage then the distribution was estimated based on the assumptions in **Appendix 3**. Details of the equations used to create the quarterly spatial distribution maps for each of the populations considered in this paper are given in **Appendix 4**. Density distributions are represented on maps by the 25, 50, 75 and 95% UDs, indicating the areas where 25, 50, 75 and 95% of the population's time is spent during that quarter.

Although there may also be variations in seabird distribution between years (e.g. Dias *et al.*, 2011), the general trend appears to be for high regional site fidelity among seabirds (Croxall *et al*., 2005; Phillips *et al*., 2005, 2006; Thiebot *et al.*, 2011; Guilford *et al.*, 2011; Yamamoto *et al.*, 2014). Therefore, seabird distribution data were combined for different years. Statistical analyses were done in the R software environment (R Core Team, 2015) and final maps were produced in ArcGIS 10.3.

2.3 Overlap of seabird distributions with ICCAT longline fishing effort

Longline fishing effort data were obtained from the ICCAT Secretariat in the form of a database referred to as EFFDIS (ref) and the unit of interest being 'numbers of hooks set' . ICCAT maintains two relevant databases known as 'Task I' and 'Task II'. Task I is the total annual landings (usually by weight) recorded by a country/fleet. Task 2 are in theory the same landings data but available at a more detailed spatial and temporal resolution (ie. 5x5 degree square grid, by month and year). In practice, however, the Task II data are often incomplete and hence the Task II data are 'raised' by the Task I totals. Various methodologies have been used by the ICCAT Secretariat to do this. Most recently (Beare *et al*., 2015) the data are first modeled as smooth functions of space and time and then these are 'raised' by the Task I data using the same method as described by de Bruyn *et al*. (2014).

Here 'fishing effort' (number of hooks set) was calculated using the method of Beare *et al*. (2015) as the average number of (estimated) hooks set per grid square per year quarter for three different periods: 2000-2005, 2005-2010, and 2010-2014. To facilitate comparison with the ACAP (2010) report, we split the effort periods in to six years, with the exception of the last (2010-2014), which was of five years. Fishing effort data from 2005 and 2010 therefore overlaps between the periods. This was a measure taken in order to reduce the shorter interval for 2010-2014. The following overlap calculations were then made for each seabird population:

- OVERLAP SCORE 1: percent seabird distribution (represented by the 95% UD) within the area of the ICCAT longline effort, by year quarter;

- OVERLAP SCORE 2: percent seabird distribution per 5x5° grid square multiplied by the average longline hooks set within each 5x5°, per year quarter;
- OVERLAP SCORE 3: percent ICCAT longline effort occurring within the range of each seabird population (represented by the 95% UD), by year quarter.

3. Results

3.1 Seabird distribution and longline overlap

Sufficient tracking data were available to allow the calculation of seasonal distribution and overlap with fishing effort for 6 of the 7 species of albatross that breed in the Atlantic, and 3 of the 4 species of petrels which breed in the Atlantic and are known to be at risk of bycatch in pelagic longline fisheries. Of these 9 species, 6 are Globally Threatened (Vulnerable, Endangered or Critically Endangered according to the IUCN Red List of Threatened Species). Overlap scores are presented separately for the different year periods (**Tables 1-3**). Seabird distribution maps are overlapped to the most recent fishing effort estimates (2010-2014; **Figures 1-10**).

Across all three time periods, results are broadly consistent with those presented in ACAP (2010). Atlantic yellow-nosed albatross and Tristan albatross have high year-round overlap with longline fishing effort (Overlap Scores 1 and 2 in **Tables 1-3, Figures 1 and 8**), with our results indicating a slight decrease in overlap in the Austral Spring (Q4), when longline effort shifts northwards. Sooty albatross also overlaps with estimated fishing effort throughout the year, albeit at a slightly lower level, which reflects its central south Atlantic distribution, rather than near the coast where there is higher fishing effort (**Figure 6**). Black-browed albatross from South Georgia (Georgias del Sur) and the Falkland Islands (Islas Malvinas) and white-chinned petrels have a high overlap with the numbers of hooks set during the non-breeding season (Q2 and Q3), when birds shift northwards (**Figures 2, 3 and 10**). Black-browed albatross from South Georgia (Georgias del Sur) reach as far north as 10°S along the coast of Angola, as do the Atlantic yellow-nosed albatross. White-chinned petrel displayed notably high Overlap 2 Scores in the 2000-2005 period (e.g. in Q3, **Table 1**) because of particularly high fishing effort when compared with the other time periods in areas that overlapped with their distribution along the South American coast.

Wandering albatross have a relatively low Overlap 2 Score, but they do overlap with ICCAT fishing effort, particularly in Q2 where relatively high longline effort occurs off the coast of Uruguay and the south eastern Atlantic (**Figure 9**). As expected, given a tendency to forage at higher latitudes, grey-headed albatross and both giant petrels all have low overlap with ICCAT fishing effort, the only exception being northern giant petrel in Q2.

3.2 Pelagic longline effort

Fishing effort maps for the different periods are presented in **Figures 11-13** for comparison. In general the highest longline effort in the ICCAT area is distributed across tropical and sub-tropical waters, with extensions in the south towards higher latitudes along the coast of southern Africa (off Angola, Namibia and South Africa) and South America (primarily off Uruguay and Brazil), with effort extending as far south as 50-55°S on each side of the Atlantic. There is a southerly shift in effort during Q2 and Q3 and the proportion of ICCAT hooks deployed in the South Atlantic in the area of implementation of Recommendation 11-09 is higher in the Austral winter. For example, for the time period 2010-2014, total estimated pelagic longline hooks per year quarter (averaged over the 5 year period) south of 25°S are as follows: Q1 10,000,000; Q2 16,000,000; Q3 11,000,000; Q4 6,000,000 (rounded to nearest million hooks). In the same period the proportion of all ICCAT longline hooks deployed south of 25°S is approximately 20% in Q2 and Q3 compared to 10% in Q1 and Q4.

Total estimated hooks in the ICCAT area have declined over time. South of 25°S this change has been most abrupt between effort estimates for 2000-2005 (average 59,000,000 hooks per year) and 2005-2010, which has the same approximate total as the 2010-2014 period (44,000,000 hooks per year).

Overlap Score 3 indicates that in general less than 10% of ICCAT longline fishing effort overlaps with the 95% UD for the 9 species analysed. For Tristan albatross and Atlantic yellow-nosed this rises above 20% in Q2 and Q3 (**Table 3**), while for species (and populations) with southerly distributions (e.g. white-chinned petrel and northern giant petrel from South Georgia/Georgias del Sur, black-browed albatross from the Falkland Islands/Islas Malvinas), the percentage overlap of effort with their ranges is consistently low per quarter throughout the year (<5%).

4. Discussion

4.1 The importance of the ICCAT area for seabirds

The analysis confirms the importance of the South Atlantic for albatross and petrel species of conservation concern, and confirms the findings from the previous analysis, that highest overlaps with estimated fishing effort occur for the three species of albatross breeding at Tristan da Cunha (Tristan, Atlantic yellow-nosed and sooty), together with the non-breeding distributions of black-browed albatross and white-chinned petrels (ACAP, 2010). Wandering albatross distribution is focused south of 30°S but the South Georgia population comes into increased contact with ICCAT longline effort in the areas offshore from Uruguay, as identified by Jiménez *et al.* (2014).

Tristan and Atlantic yellow-nosed albatrosses breed exclusively on the Tristan da Cunha archipelago (approximately 37-40°S). Tristan albatross is Critically Endangered and in decline due to low adult survival and low breeding success (Wanless *et al*., 2009; IUCN, 2016), and the previous ICCAT seabird assessment found that the Tristan albatross was one of the species most at risk from longline fishing within the ICCAT area of jurisdiction (Philips & Small, 2007; Tuck *et al*., 2011).

The remote tracking data indicate that two albatross species in this study – Atlantic yellow-nosed and Black-browed from South Georgia– forage along the Benguela Current as far north as 10°S. Tristan albatross is also recorded to approximately 15°S (Reid *et al*. 2013). In this area the species overlap with ICCAT longline fishing effort which currently fall outside of the area of application of the ICCAT seabird Recommendations requiring vessels to use seabird bycatch mitigation measures (Rec. 07-07, Rec. 11-09).

It is important to also note that this analysis only included white-chinned petrel from the South Georgia population, whereas one quarter of the global population of this species breeds in the Indian Ocean, but has a non-breeding distribution which extends into the south east Atlantic along the Benguela current. White-chinned petrels have been recorded as bycatch in this area in both in pelagic longline fisheries (Inoue *et al*., 2012) and demersal longline fisheries in this area. In relation to the latter, the Namibian hake longline fishery was estimated to kill 20,500 birds in 2010 (Paterson *et al*., in prep.) and a large proportion of bycatch in Namibia is projected to be of white-chinned petrels (Peterson *et al*., 2009; Ryan *et al*., 2012). In 2015 the Namibian government passed regulations (government gazette No. 5877) requiring demersal longline vessels to use seabird bycatch mitigation measures.

Although indicative of the possible encounter rate, overlap indices such as those applied here do not consider susceptibility to capture (Tuck *et al*., 2011), and the probability of bycatch for a given species depends on their behavioural traits (Inoue *et al*., 2012) and other factors determining susceptibility to capture.

4.2 Pelagic longline effort in the ICCAT area

Since the late 1990s, ICCAT pelagic longline fishing effort deployed south of 20°S and reported to ICCAT has been declining (Tuck *et al*., 2011). Updated EFFDIS estimates south of 25°S suggest a drop in total number of longline hooks deployed between 2000-2005 and 2005-2010, and we see a concomitant drop in Overlap 2 Scores suggesting that the likelihood of seabirds encountering hooks has decreased to some degree in the area. For wandering albatross, for example, the overlap score halves between 2000-2005 and 2010-2014. We have not reviewed in detail here the implications for specific species of temporal changes in effort, and this would merit further review. The EFFDIS pelagic longline estimates go back as far as the 1950s, and a paper providing an overview of the spatial and temporal changes that have occurred in Atlantic Ocean fishing effort would be useful to inform this type of analysis for non-target species.

Overlap Score 3 represents the proportion of the ICCAT fleet that could be affected by management decisions to mitigate bycatch in areas of albatross and petrel distribution. In general albatross and petrel species are distributed in the South Atlantic, and based on the data available for the analysis, albatross and petrel populations impact mostly <10% of ICCAT longline fishing area. Worth noting that this is based on the 95% utilisation distribution of seabirds, and therefore reflects a conservative estimate, in line with the finding for a broadly similar suite of species and populations analysed in ACAP (2010).

4.3 Data gaps and limitations

This analysis updates the ACAP (2010) paper, with increases in the number of tracks made available by data holders for the analysis, notably for breeding black-browed albatrosses (from the Falklands/Islas Malvinas), breeding grey-headed albatross and breeding and non-breeding wandering albatross. Species were selected on the basis of available data and known risk of incidental mortality. No Mediterranean species were included in this analysis, although seabird bycatch is known to occur there (Yesou *et al*., 2016); this is therefore a gap which needs addressing. As noted above, another key gap in this analysis is distribution data from white-chinned petrels breeding in the Indian Ocean.

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Southern giant petrel (South Georgia)
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Tristan albatross (Gough Islands)
Alex Bond, Ross Wanless

Wandering albatross (South Georgia)
Richard Phillips

White-chinned petrel (South Georgia)
Richard Phillips

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Table 1. Summary of overlap scores of seabird distribution and ICCAT fishing effort during 2000-2005. Overlap Score 1: % seabird distribution within the ICCAT area; Overlap Score 2: % seabird distribution multiplied by the average fishing effort per 5x5° grid square. Overlap Score 3: % longline fishing effort within each species' range. Year quarters: Q1 (Jan-March), Q2 (April-June), Q3 (July-Sept), Q4 (Oct-Dec). UD=Utilisation Distribution.

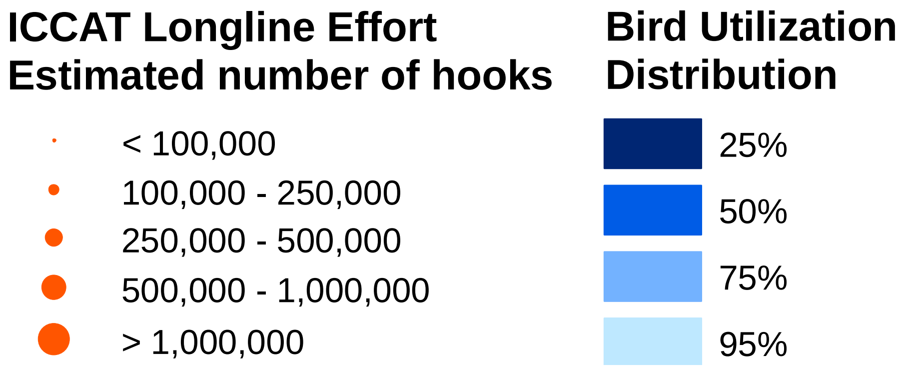
Species	Population	Overlap Score 1 (%)				Overlap Score 2 (No Unit)				Overlap Score 3 (95% UD)			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Atlantic yellow-nosed albatross	Gough Island	84.5	90.9	85.1	64.3	3384	4776	3847	2496	14.6	25.4	22.4	12.1
Black-browed albatross	Falkland Islands (Islas Malvinas)	0.0	7.5	4.8	0.0	0	4834	3440	0	0.0	2.3	1.8	0.0
Black-browed albatross	South Georgia	36.0	49.5	50.1	22.1	1156	3210	4976	1815	7.6	19.0	15.8	6.1
Grey-headed albatross	South Georgia	17.1	22.0	14.3	6.4	252	411	198	32	2.8	9.7	9.6	0.6
Northern giant petrel	South Georgia	12.3	21.0	10.0	4.0	746	4202	2708	1641	2.4	7.4	4.8	1.5
Sooty albatross	Gough Island	44.4	50.4	39.6	28.8	1216	1813	1021	830	9.4	14.9	9.1	6.4
Southern giant petrel	South Georgia	18.0	23.6	14.3	8.0	234	361	293	197	8.2	15.4	7.4	5.8
Tristan albatross	Gough Island	57.6	65.9	58.6	43.7	2269	3416	2336	1186	14.5	25.0	22.5	12.1
Wandering albatross	South Georgia	17.4	21.2	17.2	11.4	694	2150	1542	1193	12.0	22.4	16.4	8.9
White-chinned petrel	South Georgia	29.7	22.2	15.7	23.8	669	12004	24913	651	4.0	7.6	6.2	2.7

Table 2. Summary of overlap scores of seabird distribution and ICCAT fishing effort during 2005-2010. Overlap Score 1: % seabird distribution within the ICCAT area; Overlap Score 2: % seabird distribution multiplied by the average fishing effort per 5x5° grid square. Overlap Score 3: % longline fishing effort within each species' range. Year quarters: Q1 (Jan-March), Q2 (April-June), Q3 (July-Sept), Q4 (Oct-Dec). UD=Utilisation Distribution.

Species	Population	Overlap Score 1 (%)				Overlap Score 2 (No Unit)				Overlap Score 3 (95% UD)			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Atlantic yellow-nosed albatross	Gough Island	81.4	88.2	76.6	77.2	3242	3846	3364	2343	13.5	19.6	18.5	11.5
Black-browed albatross	Falkland Islands (Islas Malvinas)	0.0	6.3	4.8	0.0	0	3159	1205	0	0.0	1.1	0.7	0.0
Black-browed albatross	South Georgia	34.9	46.5	41.1	28.5	793	2130	3659	817	6.3	15.4	13.7	5.1
Grey-headed albatross	South Georgia	14.3	19.0	12.9	9.0	252	255	152	249	2.9	8.2	6.3	1.1
Northern giant petrel	South Georgia	12.3	17.2	9.0	5.2	516	2188	1077	729	1.6	4.2	2.4	0.6
Sooty albatross	Gough Island	43.0	47.3	32.6	37.9	1176	1619	1044	987	8.2	12.8	8.4	7.1
Southern giant petrel	South Georgia	17.0	21.6	12.5	11.7	178	236	194	102	7.8	11.7	5.6	5.0
Tristan albatross	Gough Island	56.2	63.5	54.1	52.4	2210	2697	1792	1312	12.9	19.6	18.8	11.4
Wandering albatross	South Georgia	16.9	19.9	15.7	15.0	502	1267	813	588	11.1	17.2	12.2	7.8
White-chinned petrel	South Georgia	29.7	18.7	16.3	26.5	391	5638	8899	356	3.2	4.7	3.3	2.3

Table 3. Summary of overlap scores of seabird distribution and ICCAT fishing effort during 2010-2014. Overlap Score 1: % seabird distribution within the ICCAT area; Overlap Score 2: % seabird distribution multiplied by the average fishing effort per 5x5° grid square. Overlap Score 3: % longline fishing effort within each species' range. Year quarters: Q1 (Jan-March), Q2 (April-June), Q3 (July-Sept), Q4 (Oct-Dec). UD=Utilisation Distribution.

Species	Population	Overlap Score 1 (%)				Overlap Score 2 (No Unit)				Overlap Score 3 (95% UD)			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Atlantic yellow-nosed albatross	Gough Island	82.4	89.2	71.8	69.5	3505	3230	2795	2104	14.6	21.6	20.3	11.1
Black-browed albatross	Falkland Islands (Islas Malvinas)	21.2	23.0	4.8	0.0	999	3073	747	0	0.2	1.4	0.5	0.0
Black-browed albatross	South Georgia	38.7	50.6	39.6	29.2	487	1499	3654	515	8.1	17.5	16.4	5.7
Grey-headed albatross	South Georgia	19.1	25.1	11.2	7.9	269	158	163	53	3.7	9.4	5.9	0.5
Northern giant petrel	South Georgia	26.2	29.9	10.2	11.9	531	2084	623	278	2.2	4.0	1.5	0.3
Sooty albatross	Gough Island	43.0	51.4	30.2	31.8	1429	1928	1482	1436	10.1	14.9	11.4	8.6
Southern giant petrel	South Georgia	21.7	27.4	12.9	12.5	201	191	193	57	7.7	12.9	6.4	3.3
Tristan albatross	Gough Island	55.9	66.2	50.7	46.4	2573	2573	1834	1248	13.6	21.8	20.6	11.2
Wandering albatross	South Georgia	18.5	22.4	14.1	13.4	534	1136	532	321	12.7	19.1	12.6	7.6
White-chinned petrel	South Georgia	44.0	30.2	16.2	20.8	502	4874	5675	261	4.3	5.1	2.4	1.8



Map Legend for **Figures 1-13.**

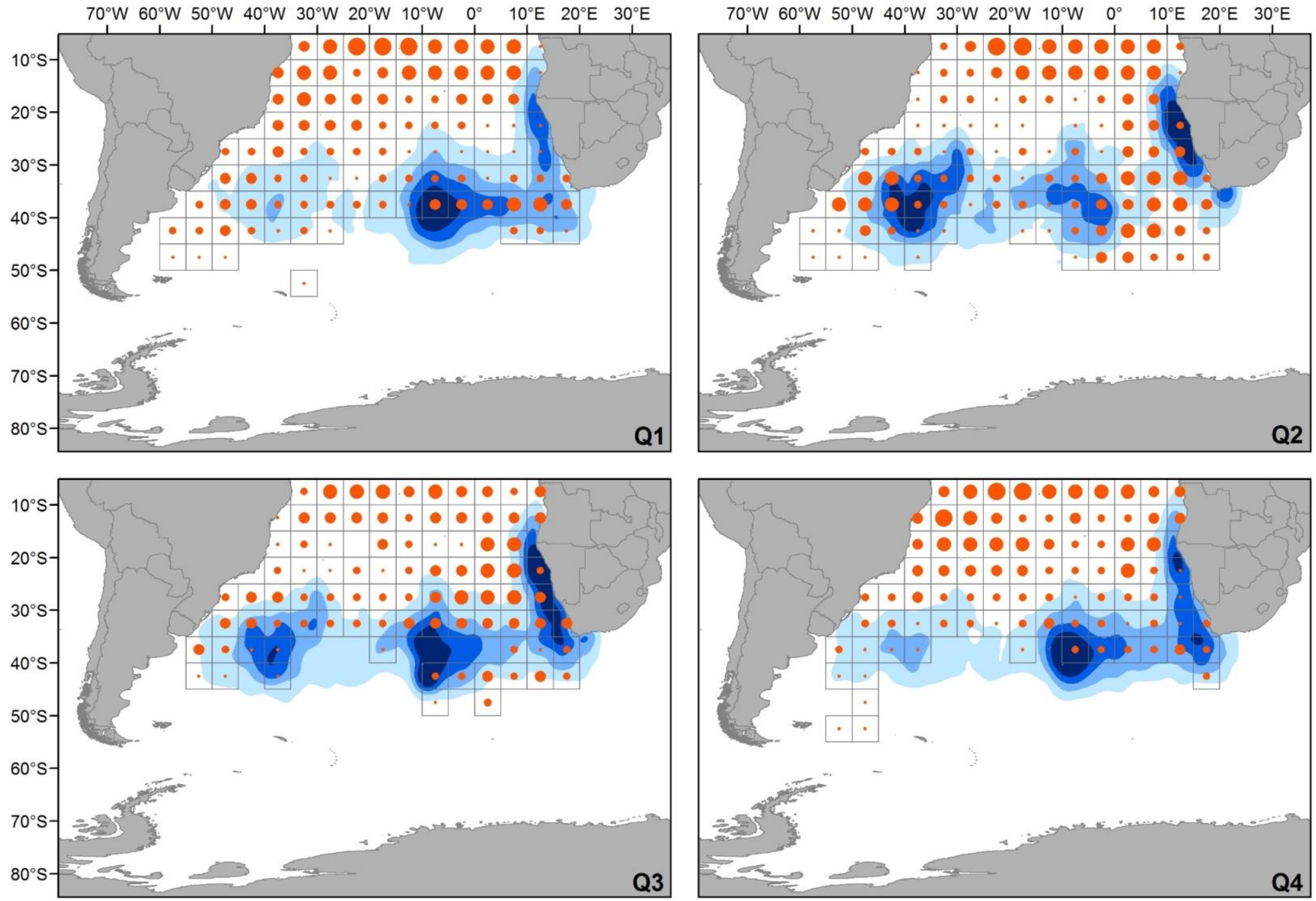


Figure 1. Atlantic yellow-nosed albatross (Gough Islands population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

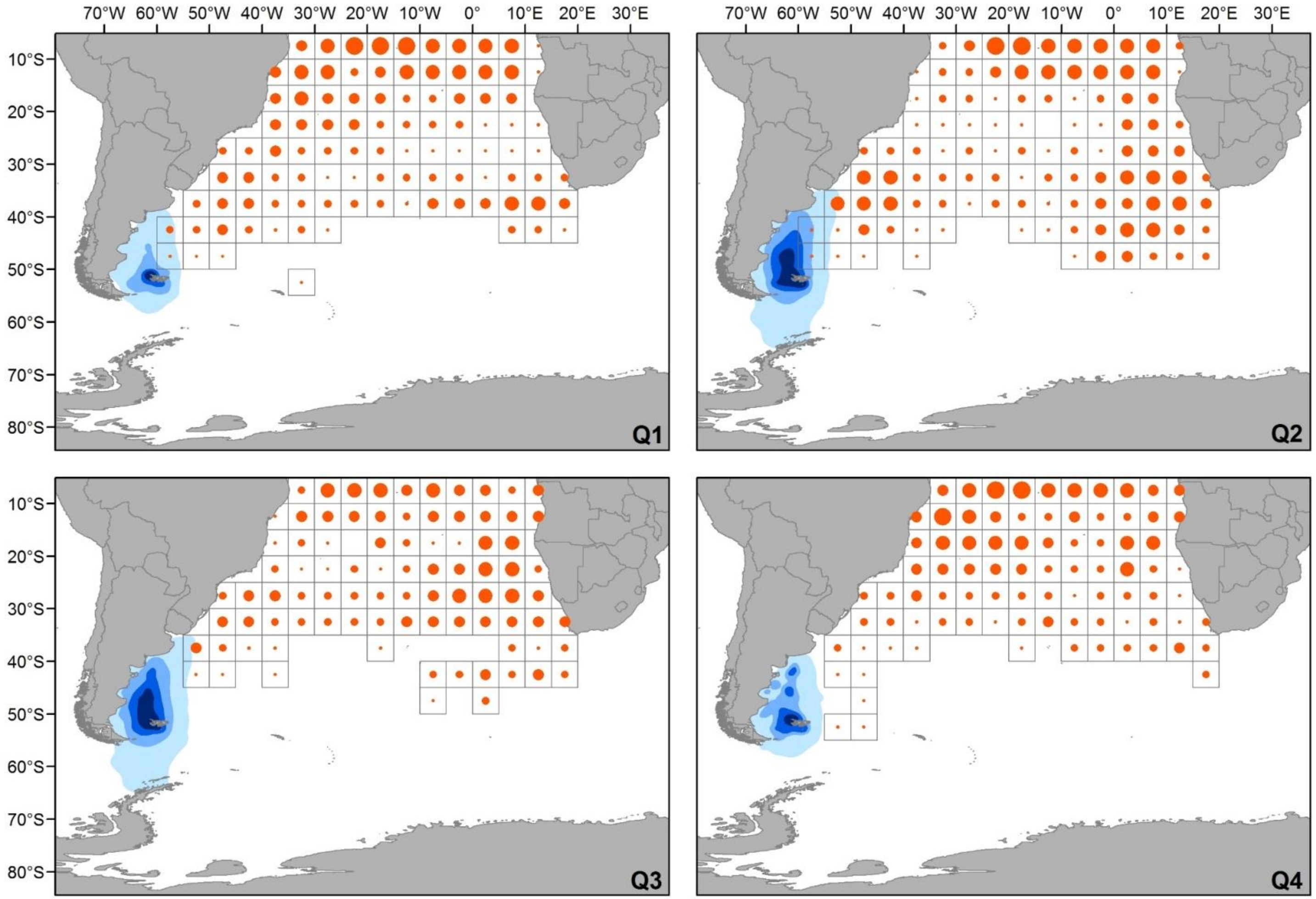


Figure 2. Black-browed albatross (Falkland/Malvinas population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. Colonies (Beauchene Island, New Island, Saunders Island, Steeple Jason) are weighted by population size.

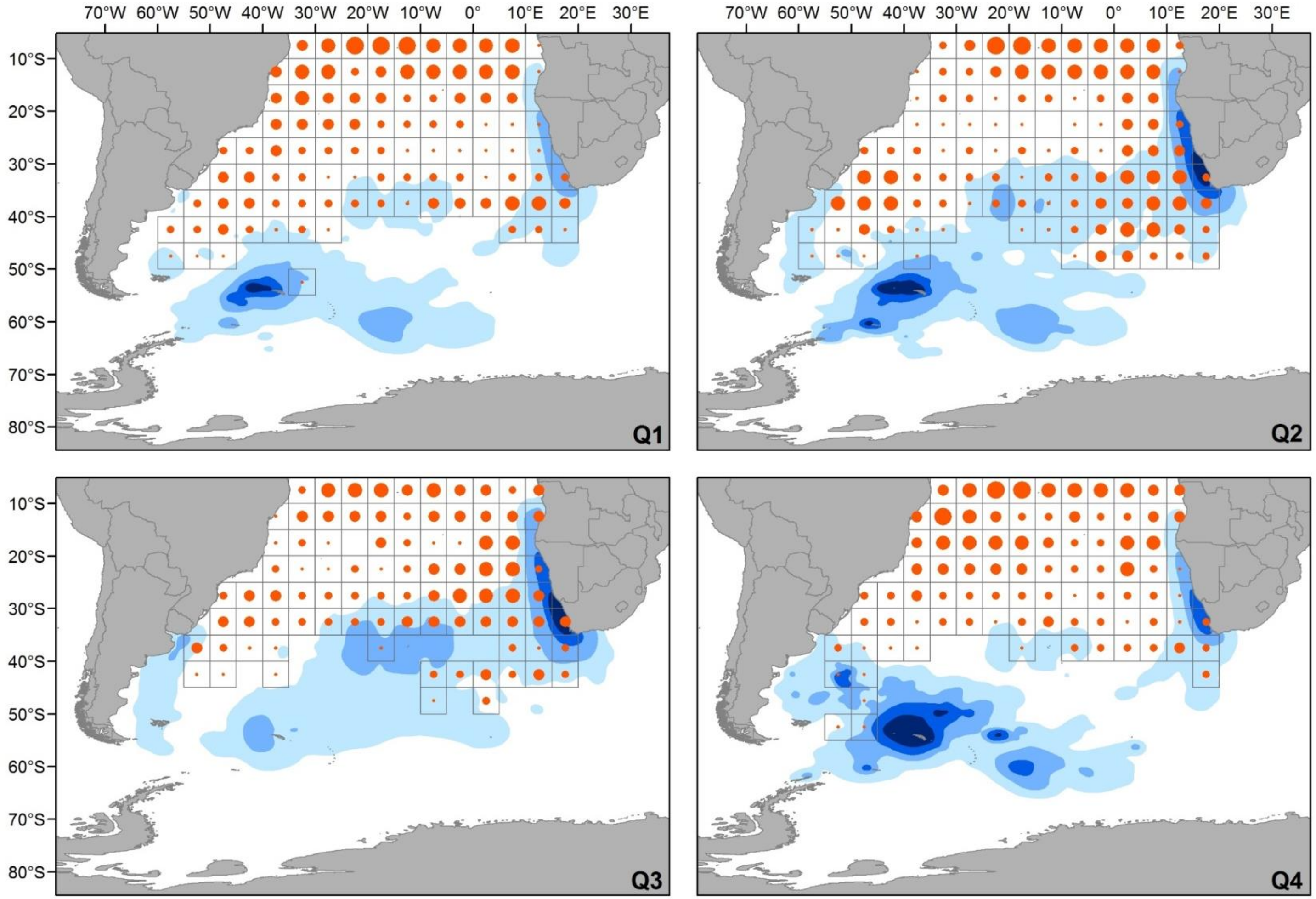


Figure 3. Black-browed albatross (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

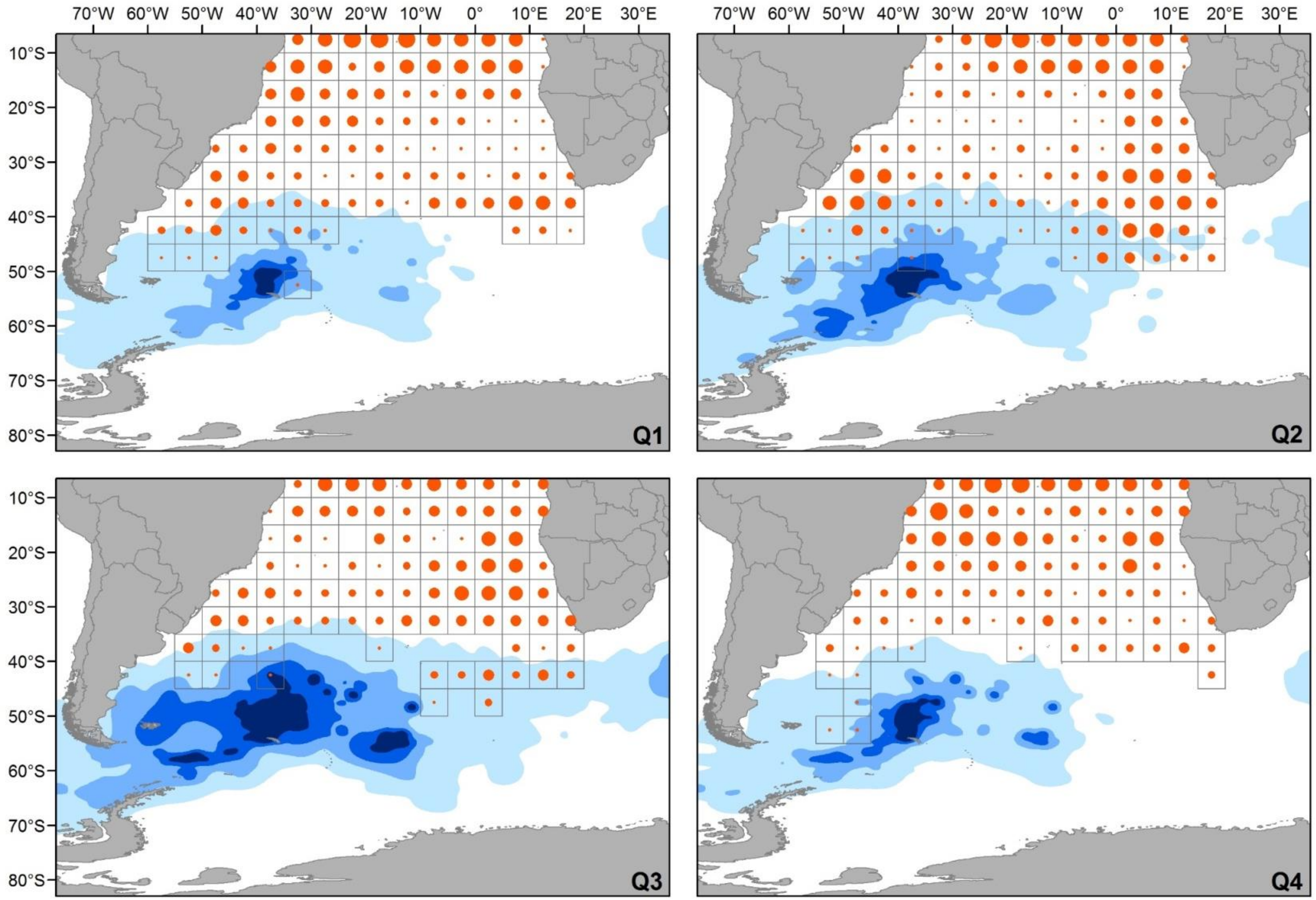


Figure 4. Grey-headed albatross (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

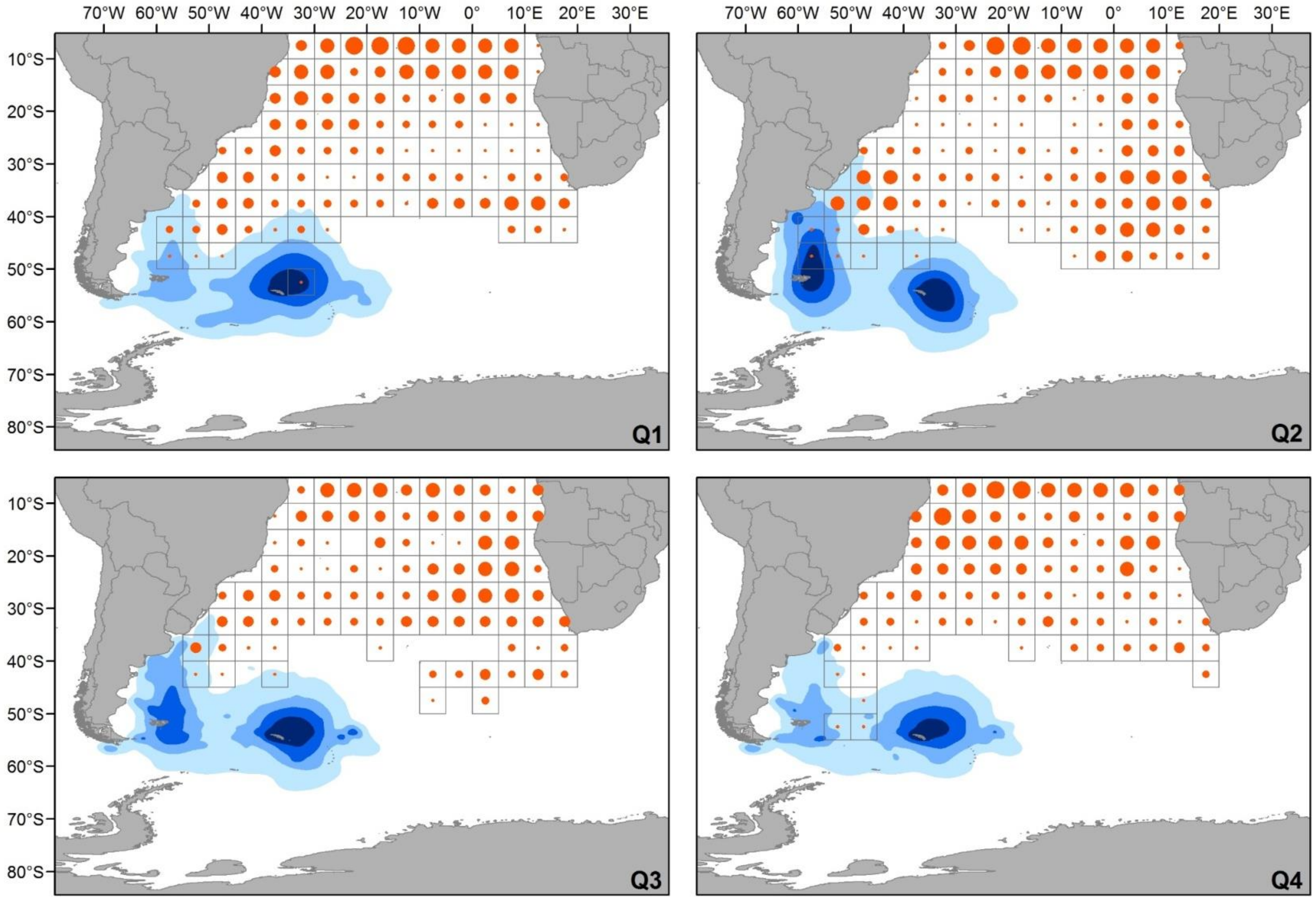


Figure 5. Northern giant petrel (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

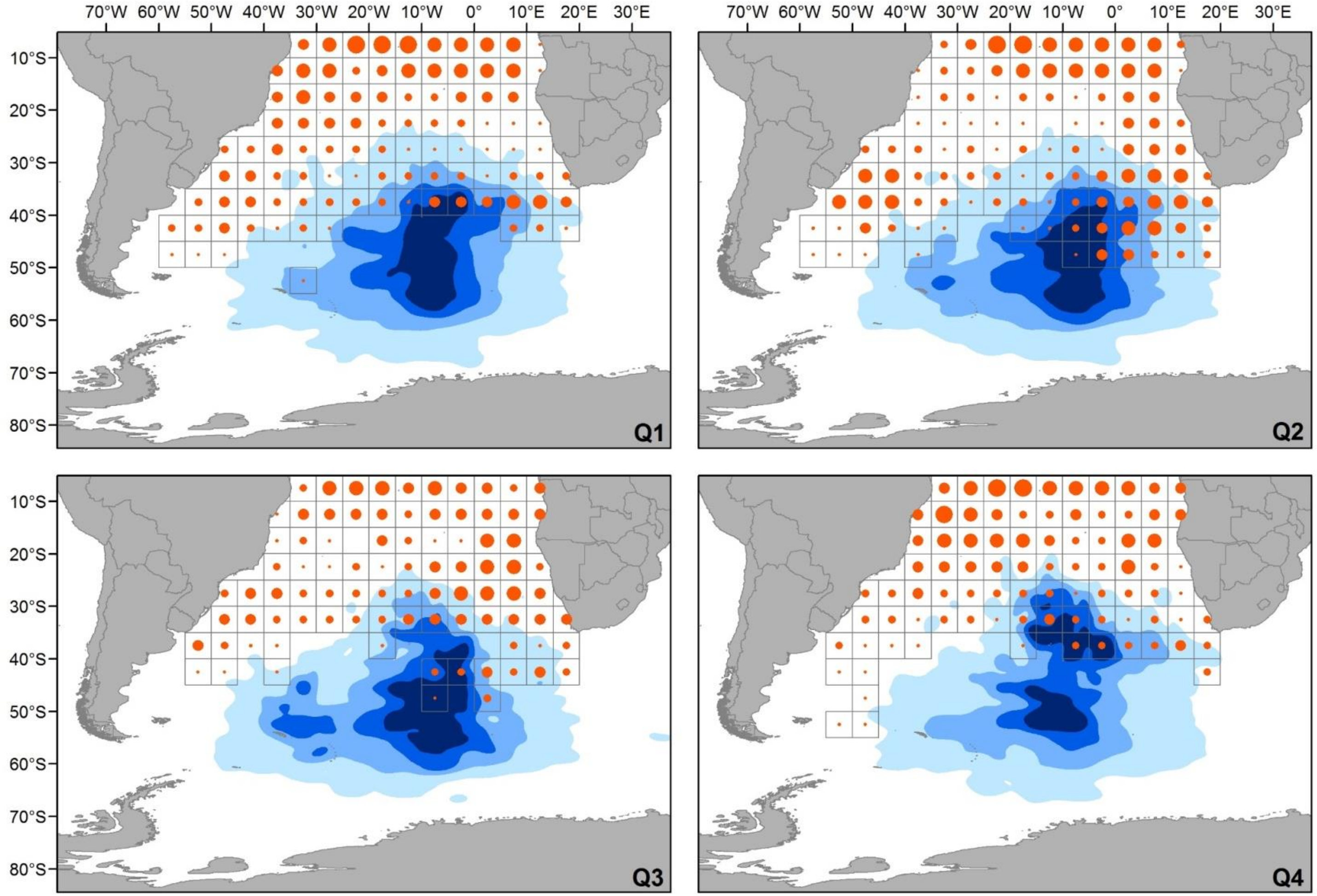


Figure 6. Sooty albatross (Gough Islands population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

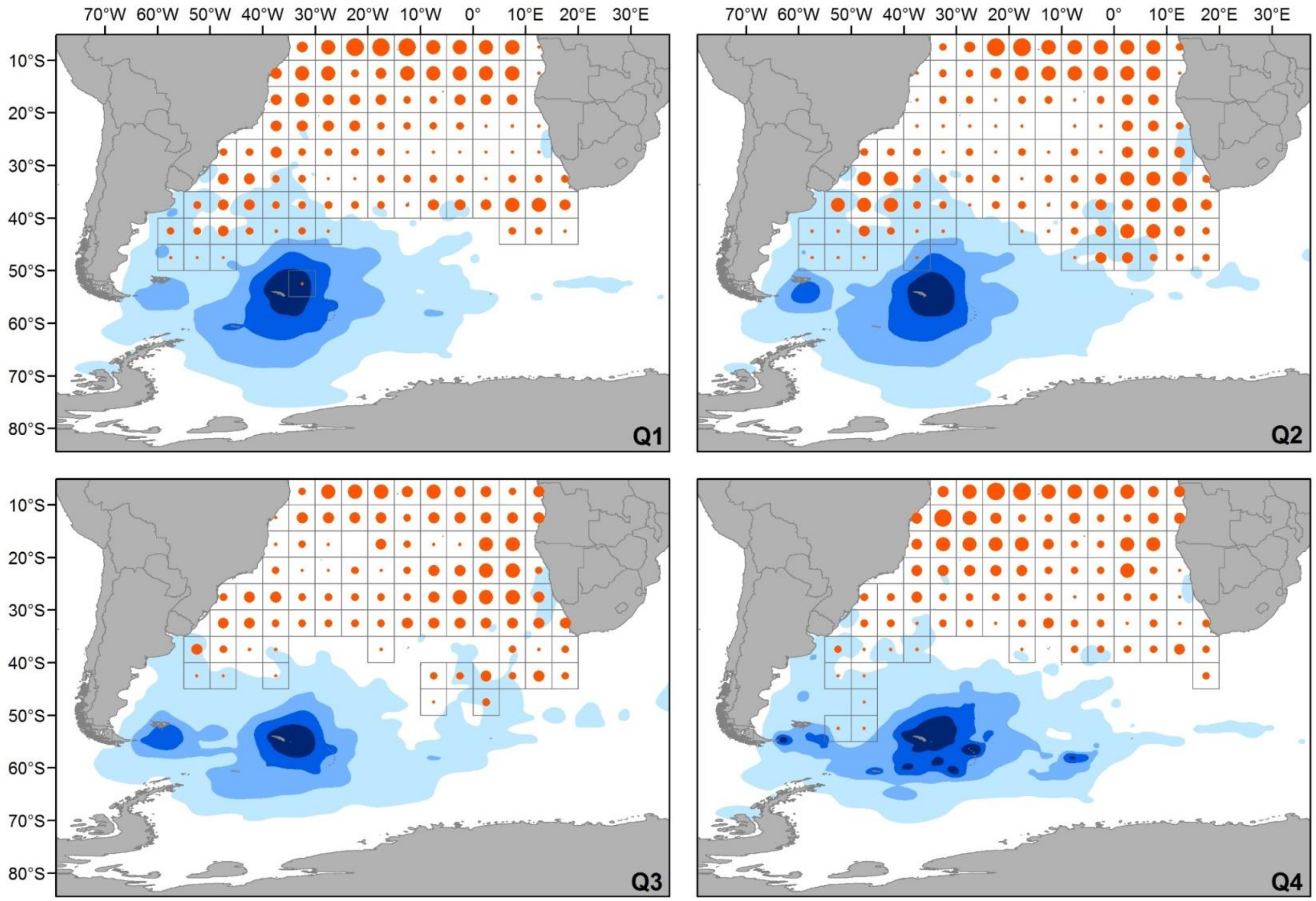


Figure 7. Southern giant petrel (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

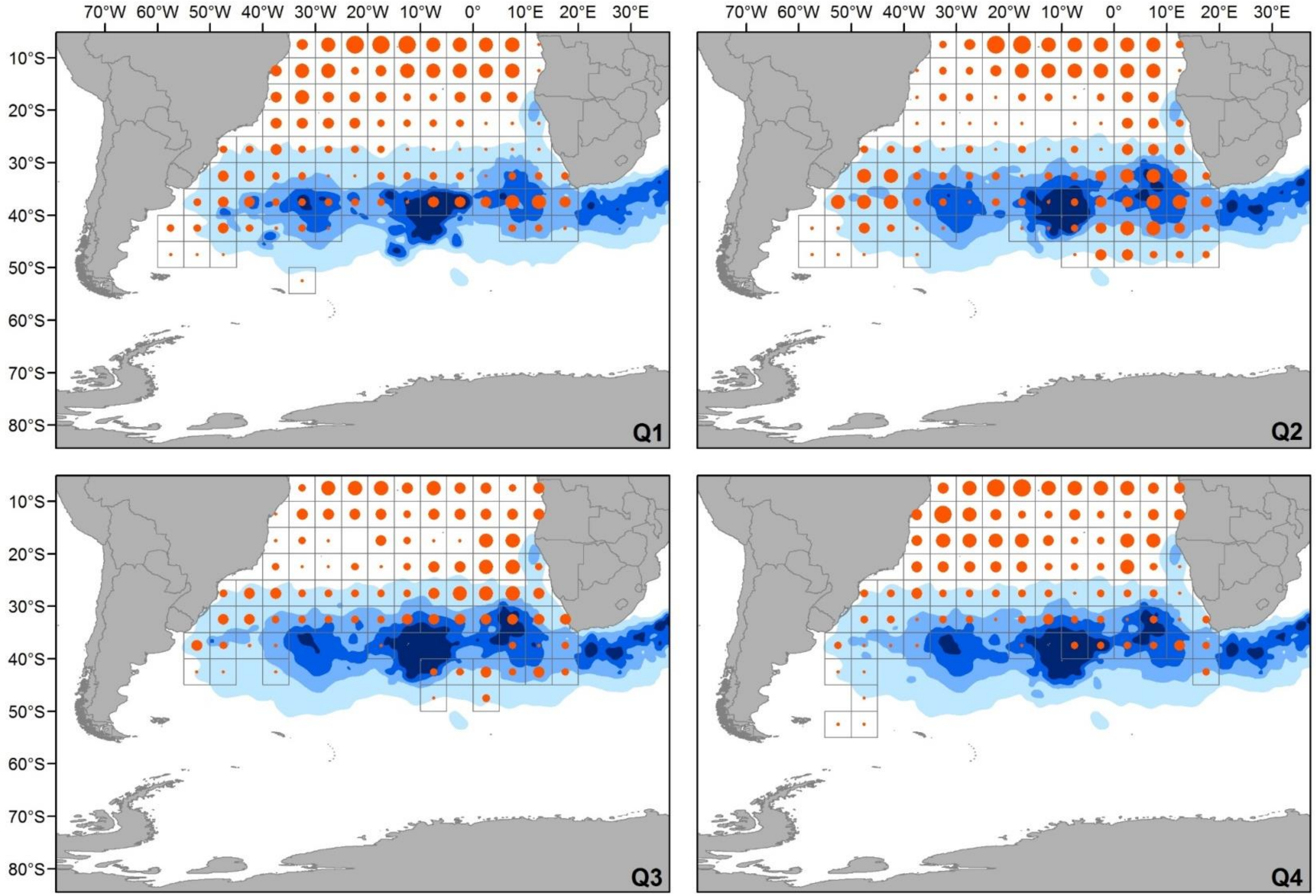


Figure 8. Tristan albatross (Gough Islands population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

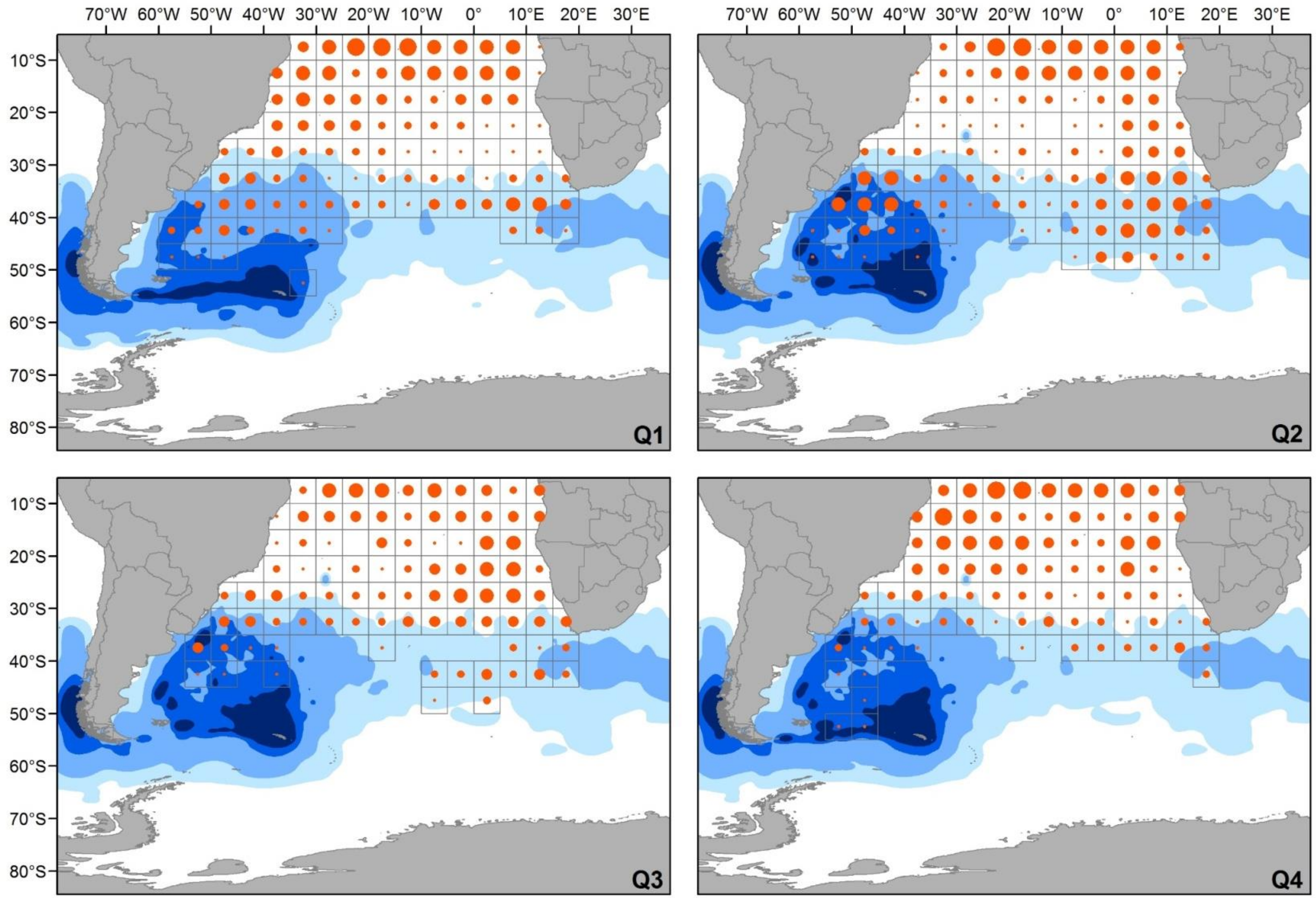


Figure 9. Wandering albatross (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

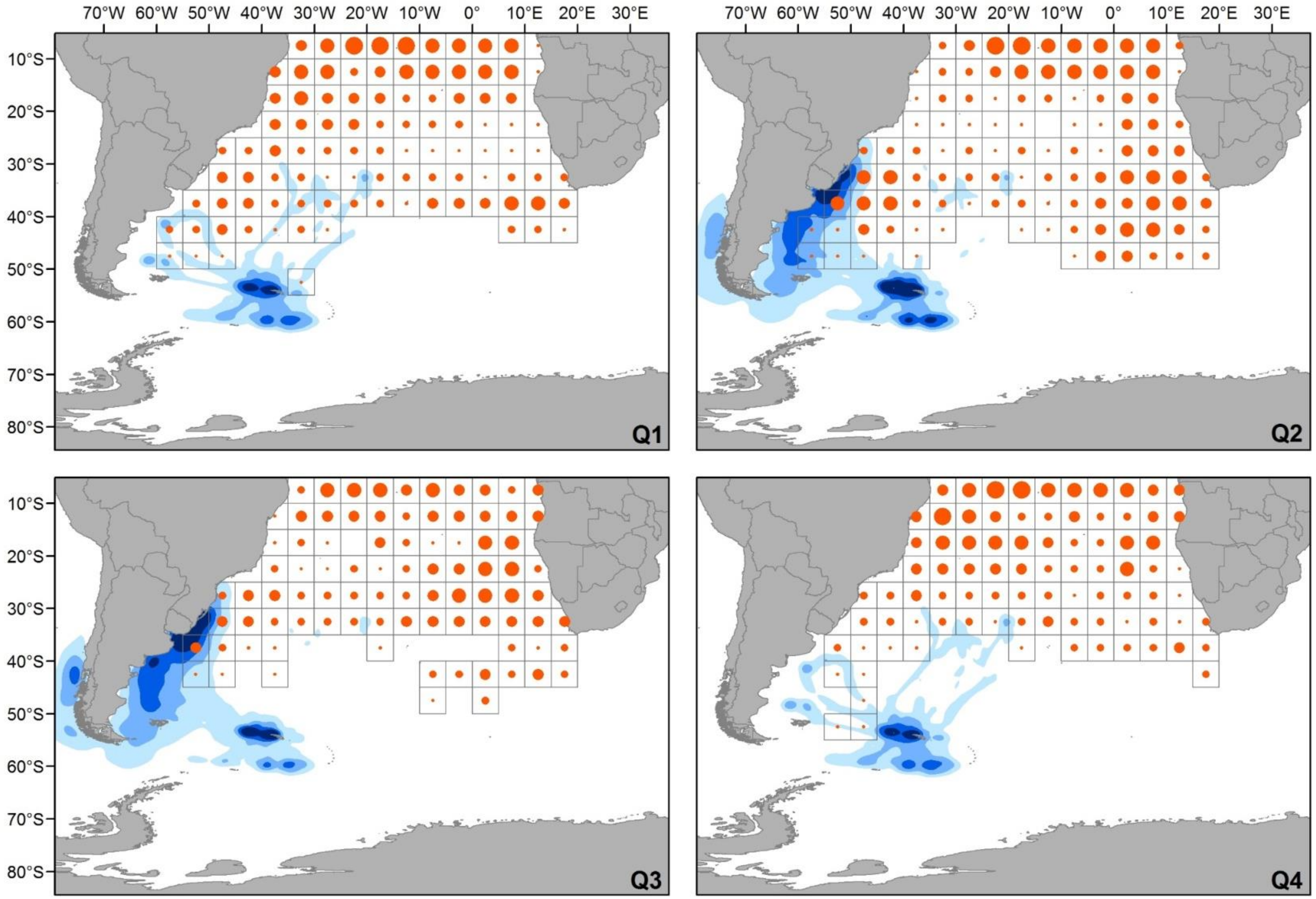


Figure 10. White-chinned petrel (South Georgia population) density distribution in the ICCAT area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with ICCAT longline fishing effort 2010-2014 (average number of hooks set per 5x5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue.

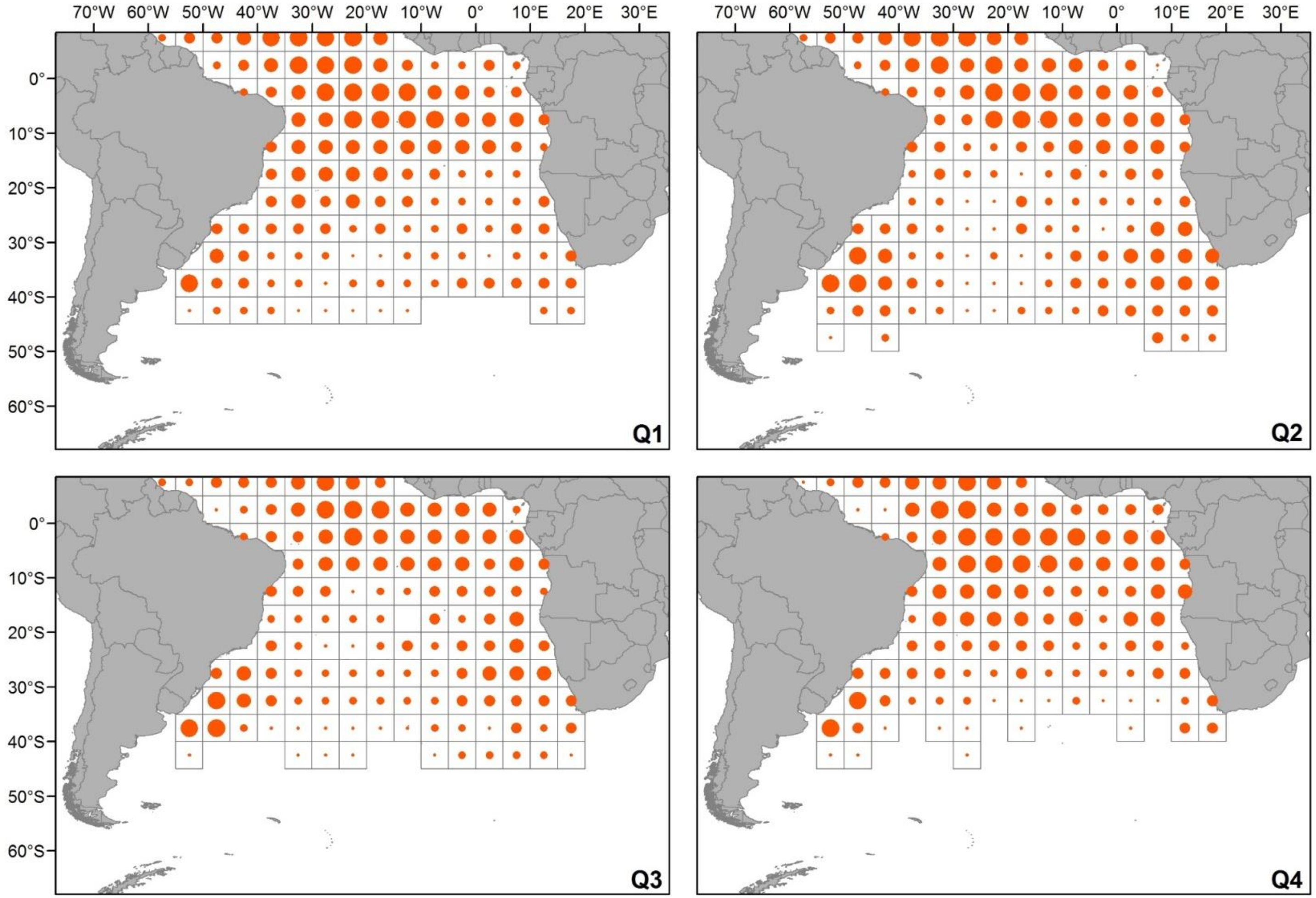


Figure 11. Average number of estimated hooks set per grid square per year quarter during 2000-2005.

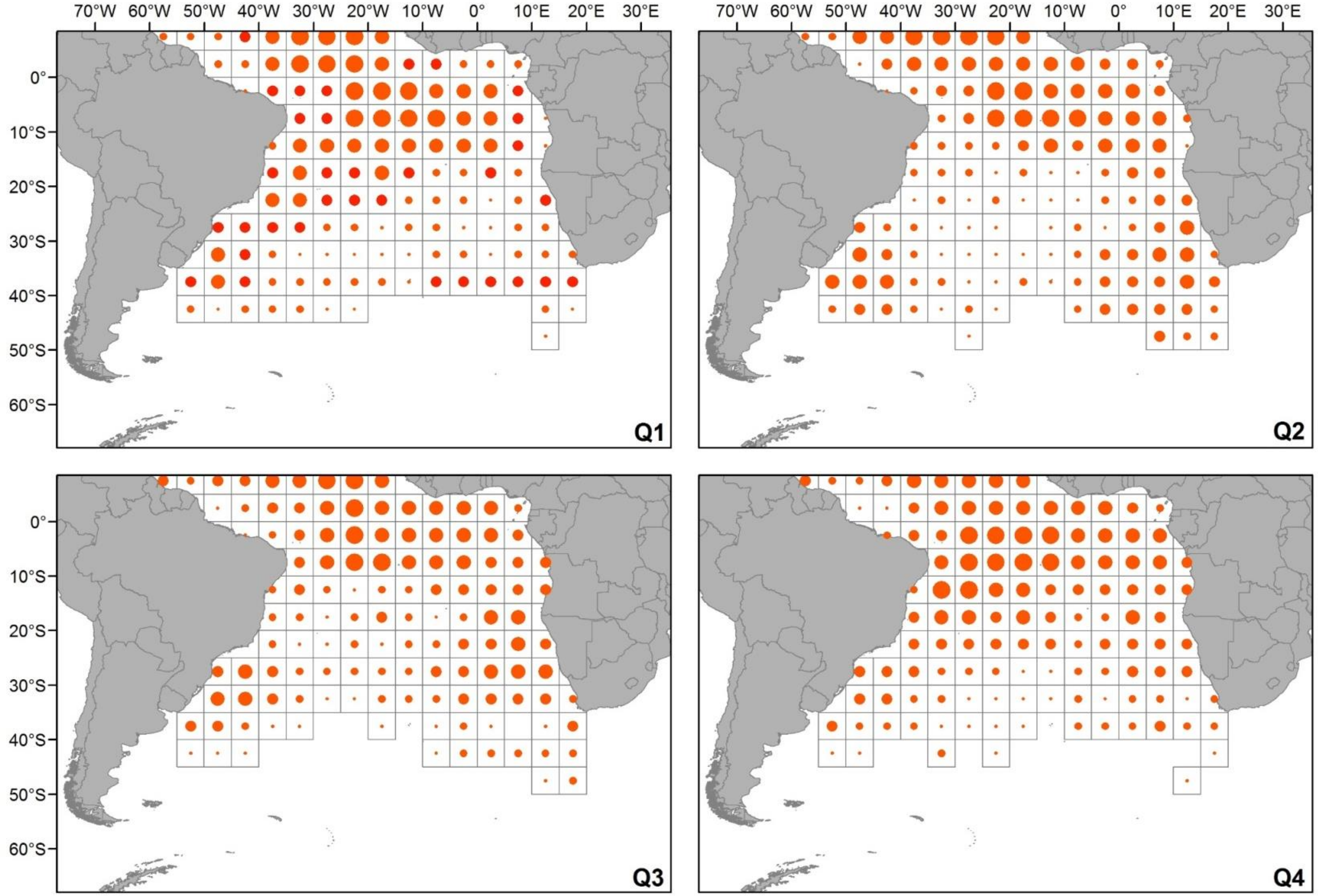


Figure 12. Average number of estimated hooks set per grid square per year quarter during 2005-2010.

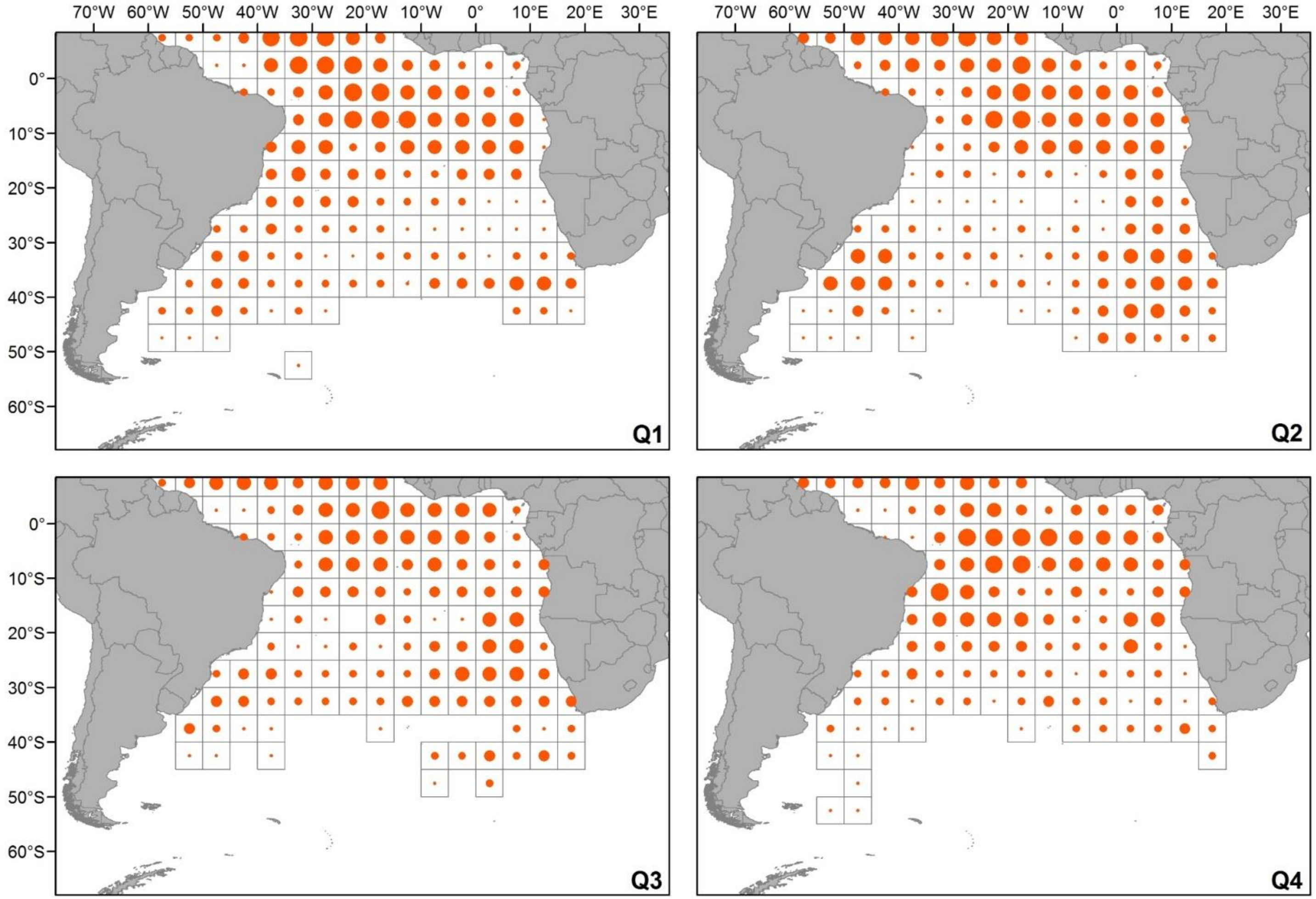


Figure 13. Average number of estimated hooks set per grid square per year quarter during 2010-14.

Appendix 1

Life history stages for the populations under consideration

Fortnights	*Quarters*	*Atlantic Yellow-nosed albatross*	*Grey-headed albatross*	*Sooty albatross*	*Tristan albatross*	*Wandering albatross*
Jan_1st	Q1	Post guard	Brood guard	Brood guard	Incubation / Post-guard	Incubation
Jan_2st	Q1	Post guard	Brood guard	Post guard	Incubation / Post-guard	Incubation
Feb_1st	Q1	Post guard	Brood guard	Post guard	Incubation	Incubation
Feb_2st	Q1	Post guard	Brood guard	Post guard	Incubation	Incubation
Mar_1st	Q1	Post guard	Brood guard	Post guard	Incubation	Brood guard
Mar_2st	Q1	Post guard	Post guard	Post guard	Brood guard	Brood guard
Apr_1st	Q2	Non-breeding	Post guard	Post guard	Brood guard	Post guard
Apr_2st	Q2	Non-breeding	Post guard	Post guard	Brood guard	Post guard
May_1st	Q2	Non-breeding	Post guard	Post guard	Post guard	Post guard
May_2st	Q2	Non-breeding	Post guard	Post guard	Post guard	Post guard
Jun_1st	Q2	Non-breeding	Post guard	Non-breeding	Post guard	Post guard
Jun_2st	Q2	Non-breeding	Non-breeding	Non-breeding	Post guard	Post guard
Jul_1st	Q3	Non-breeding	Non-breeding	Non-breeding	Post guard	Post guard
Jul_2st	Q3	Non-breeding	Non-breeding	Non-breeding	Post guard	Post guard
Aug_1st	Q3	Non-breeding	Non-breeding	Non-breeding	Post guard	Post guard
Aug_2st	Q3	Pre-egg	Non-breeding	Non-breeding	Post guard	Post guard
Sep_1st	Q3	Pre-egg	Pre-egg	Pre-egg	Post guard	Post guard
Sep_2st	Q3	Incubation	Pre-egg	Pre-egg	Post guard	Post guard
Oct_1st	Q4	Incubation	Incubation	Incubation	Post guard	Post guard
Oct_2st	Q4	Incubation	Incubation	Incubation	Post guard	Post guard
Nov_1st	Q4	Incubation	Incubation	Incubation	Post guard	Post guard
Nov_2st	Q4	Incubation	Incubation	Incubation	Post guard	Post guard
Dec_1st	Q4	Brood guard	Incubation	Incubation	Post guard / Pre-egg	Post guard / Pre-egg
Dec_2st	Q4	Brood guard	Brood guard	Brood guard	Post guard / Pre-egg	Post guard / Incubation

Appendix 1 (Continued)

Fortnights	*Quarters*	*White-chinned Petrel*	*Northern Giant Petrel*	*Southern Giant Petrel*	*Black-browed albatross (Falklands/Malvinas)*	*Black-browed albatross (South Georgia/Georgias del Sur)*
Jan_1st	Q1	Incubation	Post guard	Incubation	Brood guard	Brood guard
Jan_2st	Q1	Brood guard	Post guard	Brood guard	Brood guard	Brood guard
Feb_1st	Q1	Post guard	Post guard	Post guard	Brood guard	Brood guard
Feb_2st	Q1	Post guard	Post guard	Post guard	Post guard	Brood guard
Mar_1st	Q1	Post guard	Post guard	Post guard	Post guard	Brood guard
Mar_2st	Q1	Post guard	Post guard	Post guard	Post guard	Post guard
Apr_1st	Q2	Post guard	Post guard	Post guard	Post guard	Post guard
Apr_2st	Q2	Post guard	Non-breeding	Post guard	Non-breeding	Post guard
May_1st	Q2	Non-breeding	Non-breeding	Post guard	Non-breeding	Post guard
May_2st	Q2	Non-breeding	Non-breeding	Post guard	Non-breeding	Non-breeding
Jun_1st	Q2	Non-breeding	Non-breeding	Non-breeding	Non-breeding	Non-breeding
Jun_2st	Q2	Non-breeding	Non-breeding	Non-breeding	Non-breeding	Non-breeding
Jul_1st	Q3	Non-breeding	Non-breeding	Non-breeding	Non-breeding	Non-breeding
Jul_2st	Q3	Non-breeding	Non-breeding	Non-breeding	Non-breeding	Non-breeding
Aug_1st	Q3	Non-breeding	Pre-egg	Non-breeding	Non-breeding	Non-breeding
Aug_2st	Q3	Non-breeding	Pre-egg	Non-breeding	Non-breeding	Non-breeding
Sep_1st	Q3	Non-breeding	Pre-egg	Non-breeding	Pre-egg	Non-breeding
Sep_2st	Q3	Pre-egg	Pre-egg	Pre-egg	Incubation	Non-breeding
Oct_1st	Q4	Pre-egg	Incubation	Pre-egg	Incubation	Pre-egg
Oct_2st	Q4	Pre-egg	Incubation	Pre-egg	Incubation	Incubation
Nov_1st	Q4	Pre-egg	Incubation	Pre-egg	Incubation	Incubation
Nov_2st	Q4	Incubation	Incubation	Incubation	Incubation	Incubation
Dec_1st	Q4	Incubation	Brood guard	Incubation	Brood guard	Incubation
Dec_2st	Q4	Incubation	Brood guard	Incubation	Brood guard	Incubation

Appendix 2

Life history parameters. Parameters were estimated using a Leslie-Lefkovitch age/stage-structure matrix model
(based on estimates derived in Taylor & Small 2008)

Species	***Biennial***	***% Breeding***	***% Sabbatical***	***% Immature***	***% Juvenile***
Atlantic Yellow-nosed albatross	No	0.462	0.238	0.1	0.2
Black-browed albatross	No	0.4968	0.2232	0.09	0.19
Grey-headed albatross	Yes	0.406	0.294	0.1	0.2
Northern giant petrel	No	0.371	0.329	0.1	0.2
Southern giant petrel	No	0.49	0.21	0.1	0.2
Sooty albatross	Yes	0.406	0.294	0.1	0.2
Tristan albatross	Yes	0.351	0.299	0.14	0.21
Wandering albatross	Yes	0.378	0.322	0.1	0.2
White-chinned petrel	No	0.4362	0.1638	0.16	0.24

Appendix 3. Sample sizes and distribution of data used (including data substitutions in bold). Tristan and wandering albatross are biannual breeders with a more than 12 month long breeding season; there are no non-breeding adults during the non-breeding season – all are sabbatical adults. White-chinned Petrel breeding distribution data were uploaded in the database as ‘breeding’, with no distinction between breeding stages. Threat status: Critically Endangered CR, Endangered EN, Vulnerable VU, Near Threatened NT, Least Concern LC (IUCN 2016).

Species	***Threat Status***	***Pre-egg***	***Incubation***	***Brood-guard***	***Post-guard***	***Sabbatical***	***Immatures***	***Juveniles***	***Non-breeders***
Atlantic yellow nosed albatross	EN	**3 GLS (clumped Incubation)**	31 GLS	20 GLS	20 GLS	6 GLS	**Sabbatical**	**Non-breeder**	19 GLS
Grey-headed albatross	EN	**Incubation**	28 PTT	66 PTT	205 PTT	**Average Breeders**	**Average Breeders**	**Non-breeder**	22 GLS
Sooty albatross	EN	**Incubation**	7 GLS	12 GLS	10 GLS	7 GLS	**Sabbatical**	**Non-breeder**	13 GLS
Tristan albatross	CR	**Incubation**	21 PTT	28 PTT	14 GLS, 79 PTT	13 GLS	**Non-breeder**	5 GPS	
Wandering albatross	VU	**Incubation**	34 GLS, 15 GPS, 14 PTT	15 GLS, 20 GPS, 50 PTT	14 GLS, 31 GPS, 157 PTT	14 GLS	59 GLS	10 GLS	
White-chinned petrel	VU		19 PTT as Breeders			**Average Breeders**	**Average Breeders**	13 GLS	10 GLS
Northern giant petrel	LC	**Incubation**	34 GLS, 18 PTT	26 GLS	21 GLS	**Average Breeders**	**Average Breeders**	**Non-breeder**	14 GLS
Southern giant petrel	LC	**Incubation**	45 GLS, 11 PTT	17 GLS	16 GLS	4 GLS	**Sabbatical**	**Non-breeder**	13 GLS
Black-browed albatross (Falklands/Malvinas)	NT	23 GLS	54 GLS, 71 GPS, 33 PTT	416 GPS	310 GPS, 117 PTT	**Average Breeders**	**Average Breeders**	**Non-breeder**	42 GLS
Black-browed albatross (S. Georgia /Georgias del Sur)	NT	39 GLS	20 GLS, 29 PTT	22 PTT	314 PTT	26 GLS	**Sabbatical**	**Non-breeder**	49 GLS

Appendix 4. Equations used to create the quarterly spatial distribution maps including stage replacements presented in Appendix 3. Acronyms are for PE (Pre-egg), INC (incubation), PG (Post-guard), SAB (Sabbatical), IMM (Immatures), JUV (Juveniles), NB (Non-breeders), and AVE_BREED (Average breeding).

Species	***Equations Q1***
Atlantic Yellow-nosed albatross	(0.46*(PG)) + (0.34*SAB) + (0.2*NB)
Grey-headed albatross	(0.41*(0.8333333*BG + 0.1666667*PG)) + (0.39*AVE_BREED) + (0.2*NB)
Sooty albatross	(0.41*(0.1666667*BG + 0.8333333*PG)) + (0.39*SAB) + (0.2*NB)
Tristan albatross	(0.35*(0.6666667*INC + 0.1666667*PG + 0.1666667*BG)) + (0.44*NB) + (0.21*JUV)
Wandering albatross	(0.38*(0.6666667*INC + 0.3333333*BG)) + (0.32*NB) + (0.1*IMM) + (0.2*JUV)
White-chinned petrel	(0.44*BREEDING) + (0.32*AVE_BREED) + (0.24*JUV)
Northern giant petrel	(0.37*PG) + (0.43*AVE_BREED) + (0.2*NB)
Southern giant petrel	(0.49*(0.1666667*INC + 0.1666667*BG + 0.6666667*PG)) + (0.31*SAB) + (0.2*NB)
Black-browed albatross - Falklands	(0.50*(0.50*BG + 0.50*PG)) + (0.31*AVE_BREED) + (0.19*NB)
Black-browed albatross - South Georgia	(0.50*(0.8333333*BG + 0.1666667*PG)) + (0.31*SAB) + (0.19*NB)

Species	***Equations Q2***
Atlantic Yellow-nosed albatross	NB
Grey-headed albatross	(0.8333333*((0.41*PG) + (0.39*AVE_BREED) + (0.2*NB))) + (0.1666667*NB)
Sooty albatross	(0.6666667*((0.41*PG) + (0.39*SAB) + (0.2*NB))) + (0.3333333*NB)
Tristan albatross	(0.35*(0.3333333*BG + 0.6666667*PG)) + (0.44*NB) + (0.21*JUV)
Wandering albatross	(0.38*PG) + (0.32*NB) + (0.1*IMM) + (0.2*JUV)
White-chinned petrel	(0.3333333*((0.44*BREED) + (0.32*AVE_BREED) + (0.24*JUV))) + (0.6666667*NB)
Northern giant petrel	(0.1666667*((0.37*PG) + (0.43*AVE_BREED) + (0.2*NB))) + (0.8333333*NB)
Southern giant petrel	(0.6666667*((0.49*PG) + (0.31*SAB) + (0.2*NB))) + (0.3333333*NB)
Black-browed albatross - Falklands	(0.1666667*((0.50*PG) + (0.31*AVE_BREED) + (0.19*NB))) + (0.8333333*NB)
Black-browed albatross - South Georgia	(0.50*((0.50*PG) + (0.31*SAB) + (0.19*NB))) + (0.50*NB)

Species	***Equations Q3***
Atlantic Yellow-nosed albatross	(0.5*NB) + (0.5*((0.46*(0.6666667*PE + 0.3333333*INC)) + (0.34*SAB) + (0.2*NB)))
Grey-headed albatross	(0.6666667*NB) + (0.3333333*((0.41*INC) + (0.39*AVE_BREED) + (0.2*NB)))
Sooty albatross	(0.6666667*NB) + (0.3333333*((0.41*INC) + (0.39*SAB) + (0.2*NB)))
Tristan albatross	(0.35*PG) + (0.44*NB) + (0.21*JUV)
Wandering albatross	(0.38*PG) + (0.32* NB) + (0.1*IMM) + (0.2*JUV)
White-chinned petrel	(0.8333333*NB) + (0.1666667*((0.44*BREED) + (0.32*AVE_BREED) + (0.24*JUV)))
Northern giant petrel	(0.3333333*NB) + (0.6666667*((0.37*INC) + (0.43*AVE_BREED) + (0.2*NB)))
Southern giant petrel	(0.8333333*NB) + (0.1666667*((0.49*INC) + (0.31*SAB) + (0.2*NB)))
Black-browed albatross - Falklands	(0.6666667*NB) + (0.3333333*((0.5*((0.5*PE) + (0.5*INC))) + (0.31*AVE_BREED) + (0.19*NB)))
Black-browed albatross - South Georgia	NB

Species	***Equations Q4***
Atlantic Yellow-nosed albatross	(0.46*(0.6666667*INC + 0.3333333*BG)) + (0.34*SAB) + (0.2*NB)
Grey-headed albatross	(0.41*((0.8333333*INC) + (0.1666667*BG))) + (0.39*AVE_BREED) + (0.2*NB)
Sooty albatross	(0.41*(0.8333333*INC + 0.1666667*BG)) + (0.39*SAB) + (0.2*NB)
Tristan albatross	(0.35*(0.8333333*PG + 0.1666667*INC)) + (0.44*NB) + (0.21*JUV)
Wandering albatross	(0.38*(0.8333333*PG + 0.1666667*INC)) + (0.32*NB) + (0.1*IMM) + (0.2*JUV)
White-chinned petrel	(0.44*BREED) + (0.32*AVE_BREED) + (0.24*JUV)
Northern giant petrel	(0.37*(0.6666667*INC + 0.3333333*BG)) + (0.43*AVE_BREED) + (0.2*NB)
Southern giant petrel	(0.49*INC) + (0.31*SAB) + (0.2*NB)
Black-browed albatross - Falklands	(0.50*((0.6666667*INC) + (0.3333333*BG))) + (0.31*AVE_BREED) + (0.19*NB)
Black-browed albatross - South Georgia	(0.50*((0.1666667*PE) + (0.8333333*INC))) + (0.31*SAB) + (0.19*NB)