# SERAWG -03-07 3 rd Meeting of the Stock and Ecological Risks Assessment (SERAWG3) A framework for mapping the distribution of seabirds by integrating tracking, demography and pheno...

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# A framework for mapping the distribution of seabirds by integrating tracking, demography and phenology

*Relates to agenda item: 8.2 Teleosts and others* Working paper ☒

Delegation of French Territory


## Abstract

Seabirds are amongst the most threatened birds in the world (Dias et al. 2019). Albatrosses and petrels are particularly vulnerable as they are long-lived, have a delayed sexual maturity, and low annual reproductive output. They have a wide at-sea distribution, occurring across all oceans and adjacent coastlines and islands. These extensive ranges overlap with multiple threats in national and international waters.

Incidental bycatch in fisheries is one of the primary causes of population declines for many seabird species. Although attention focused initially on industrial longlining, there is a growing number of studies highlighting the negative impact on seabirds of other fisheries, such as trawl and artisanal fisheries. The impact of bycatch can affect elements of seabird populations in different ways. For instance, sex- and age-biases are common features of seabird bycatch that appear to be associated largely with differences in at-sea distributions. Accounting for different life-history stages is therefore essential in threat assessment in order to direct management and conservation efforts towards areas where they have the greatest impact on populations.

The purpose of this paper is to identify areas and periods of greatest density for albatrosses and petrels within the South Indian Ocean Fisheries Agreement (SIOFA) area. We overlapped the SIOFA boundary to the maps presented by Carneiro et al., (2019, 2020), which includes information from across different life-history stages, to give an overview of the importance of SIOFA area for albatrosses and petrels year-round and by year-quarter. We aimed to fill in gaps in the knowledge of at-sea distributions for these species.

## Recommendations *(working papers only)*

It is recommended that the SERAWG and SC:

1. Note that the distribution of albatrosses and petrels are overlapped with SIOFA fishing effort in space and time.

2. Note that considering all life-history stage, the distributions of albatrosses and petrels are overlapped with SIOFA but also the Indian Ocean Tuna Commission (IOTC) fishing effort.

3. Note that taking the distribution of all life-history stages of albatrosses and petrels into account, we recommend:

- An ecological risk assessment based on overlap analysis can be a useful method to determine the risk posed to albatrosses and petrels by being caught as bycatch in SIOFA trawl and longline fisheries.
- a combined ecological risk assessment or a joint future iteration of the global risk assessment by the tuna Regional Management Fisheries Organisations is likely to be valuable, through being able to fully assess the cumulative impact of albatross seabird bycatch in the Indian Ocean.

4. Note that taking the distribution of albatrosses and petrels into account the 5th SC recommended the MoP:

- *"request CCPs adopt a protocol for documenting all interactions with seabirds for all vessels operating in the SIOFA Area.*
- *encourage CCPs to adopt effective and efficient mitigation measures to reduce seabird bycatch (i.e. measures should ideally be informed by ACAP best practice advice) to mitigate such interactions and report on the results of those actions at SC6."*

5. Recommend to the Meeting of the Parties adopt a protocol for documenting all interactions with seabirds for all vessels operating in the SIOFA Area.

6. Recommend to the Meeting of the Parties that operational actions (i.e. technical and operational measures) to mitigate such interactions while maintaining an intensive monitoring effort are urgently required (such as proposed for the trawl fisheries in SC-03-6.2_Vessel-Seabird_Management_Plan_VSMP_Cook_Islands.pdf).

7. Recommend to the Meeting of the Parties increasing surveillance efforts by adopting specific programmes such as the one described in the Sentinel Programme (PAEWG-02-07).

# Albatross and petrel distribution within the South Indian Ocean Fisheries Agreement area

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## INTRODUCTION

Seabirds are amongst the most threatened birds in the world (Dias et al. 2019). Albatrosses and petrels are particularly vulnerable as they are long-lived, have a delayed sexual maturity, and low annual reproductive output (Croxall et al. 2012, Phillips et al. 2016). They have a wide at-sea distribution, occurring across all oceans and adjacent coastlines and islands (Oppel et al. 2018). These extensive ranges overlap with multiple threats in national and international waters (Phillips et al. 2016, Oppel et al. 2018).

Incidental bycatch in fisheries is one of the primary causes of population declines for many seabird species. Although attention focused initially on industrial longlining, there is a growing number of studies highlighting the negative impact on seabirds of other fisheries, such as trawl and artisanal fisheries (Bugoni et al. 2008, Maree et al. 2014). The impact of bycatch can affect elements of seabird populations in different ways. For instance, sex- and age-biases are common features of seabird bycatch that appear to be associated largely with differences in at-sea distributions (Gianuca, Phillips, Townley, & Votier, 2017; Carneiro et al. 2020). Accounting for different life-history stages is therefore essential in threat assessment in order to direct management and conservation efforts towards areas where they have the greatest impact on populations.

The purpose of this paper is to identify areas and periods of greatest density for albatrosses and petrels within the South Indian Ocean Fisheries Agreement (SIOFA) area. We overlapped the SIOFA boundary to the maps presented by Carneiro et al., (2019, 2020), which includes information from across different life-history stages, to give an overview of the importance of SIOFA area for albatrosses and petrels year-round and by year-quarter. We aimed to fill in gaps in the knowledge of at-sea distributions for these species.

## METHODS

The results presented here were extracted from Carneiro et al., (2019, 2020). By using detailed information on migratory and breeding schedules, demographic parameters from population models and extensive tracking datasets, Carneiro et al., (2020) were able to identify areas and periods with highest density of Southern Ocean seabirds across different life-history stages and throughout the annual cycle. We overlapped the boundary of the geographic area of competence of SIOFA to their distribution maps to identify hotspots of use for albatrosses and petrels within the competence area.

We downloaded the geographic area of SIOFA from the FAO GeoNetwork website (http://www.fao.org/geonetwork/srv/en/main.home?uuid=fao-rfb-map-siofa), and we calculated the percentage of the entire population that was within the SIOFA area.

## Overview of the framework for estimating density maps

The framework consists of six steps, which require data on phenology, demography and tracking. The steps are: 1) estimating the proportion of the population in each life-history stage using age- and stage-structured population matrix models (Caswell 2001, Abraham et al. 2016); 2) estimating utilisation distributions (UDs) from tracking data for each species, breeding site, device type, age class and stage of the annual cycle (hereafter referred to as 'data group'); 3) assessing the representativeness of each data group; 4) combining data group UDs and weighting them based on phenological data to produce monthly distribution maps; 5) using the outputs of 1) to weight monthly distribution maps for each life-history stage by the proportion of the total population represented; 6) aggregating monthly distribution maps in time and space to the spatio-temporal resolution of management interest (in this case, maps were at a 5x5 degree resolution).

For a detailed understanding of the analysis to estimate density distribution maps, see Carneiro et al., (2020) and https://github.com/anacarneiro/DensityMaps. Over the next paragraphs, we provide a brief summary of the steps listed above.

## Study species and data compilation

We extracted information for 12 focus species (15 populations) which distributions overlapped with the SIOFA area. Table 1 lists all tracking datasets (all deposited in the Seabird Tracking Database; http://seabirdtracking.org/) that were available for the estimation of density distribution maps, and Table 2 lists all demographic parameters used to construct the population model.

## Population modelling

Population models consisted on a three-stage life cycle comprising juveniles (first year at sea after fledging), immatures (from the beginning of second year at sea until recruitment into the breeding population), and adults. Using breeding frequency, adults were split into breeding and non-breeding birds (those not attempting to breed in a given year), and using breeding success, they were further split into successful and failed breeders. Estimates of the annual breeding population (number of breeding pairs) were used to convert the proportions derived from the population models into number of birds.

## Density distribution maps

Utilization distributions were created for each data group, and then assigned to each life-history stage to create monthly distribution grids, incorporating differences in breeding and migration schedules (i.e. the grid was weighted by the number of days in that month represented by that stage). Utilization distributions during pre-laying, incubation and brood-guard were multiplied by 0.5 as one member of each pair is at the breeding colony at any given time during those stages (Hedd et al. 2014, Carneiro et al. 2016). When tracking data were not available for the pre-laying phase we used incubation data as a replacement.

The representativeness of each data group was tested following the bootstrapping methods described in Lascelles et al., (2016) and Oppel et al., (2018). Data replacements, from the same species but different age class or breeding stage, were used as replacements when tracking data were not available for that particular life-history stage. In several cases, when tracking data were not available for juvenile and immature birds, the juvenile distribution was replaced by the distribution of adults during the non-breeding season, when birds are away from the colony and not constrained by central place foraging, which in many species is likely to be broadly similar to the distribution of juveniles (Weimerskirch et al. 2006, Clay et al. 2019). For immatures, unavailable data were substituted with the annual distribution of non-breeding adults as immatures (particularly the older ones) tend to visit the breeding grounds and may have similar strategies to those of breeders, at least during certain periods of the breeding season (Jaeger et al. 2014, Fayet et al. 2015, Weimerskirch 2018, Campioni et al. 2019). Finally, monthly distribution grids are resampled to a 5x5 degree resolution and into year-quarters.

### Overlap with SIOFA area

The resulting density distribution maps encompassing the distribution of albatrosses and petrels for the Southern Ocean were overlapped to the SIOFA area. We calculated the percentage of the global population that were within the area, by year quarter.

## RESULTS

In total, the analysis included 2,009 individual tracks from 12 species and 15 populations (Table 1). Sufficient tracking data were available for all adult non-breeding datasets and for the majority of adult breeding datasets, except for the pre-laying stage where data from only 1 out of 15 populations were available (Table 1). Juvenile and immature data were lacking for 47% and 67%, respectively, of the populations; therefore, adult distributions were used as replacements when data were missing. Population models revealed that adult breeders represented on average 33% of the total number of individuals and up to c. 47% consisted of pre-recruits (juveniles and immatures; Figure 1).

The quarterly and annual distributions were mapped for each population (see Figures 2-16 and Figures 17-31, respectively). The spatial overlap between the annual distribution maps and SIOFA area revealed that nearly half (47%) of the populations that occurred within SIOFA spent more than 20% of their time in the SIOFA area (three, one, and three populations, spent between 20-40%, 41-50%, and >50% of their time in the SIOFA area, respectively). Similarly, the overlap between the quarterly distributions were greater than 20% for 32 (53%) of the 60 year-quarter combinations (between 20-40%, 41-50%, >50% for 14, five, and 13 populations, respectively) (Table 3).

## DISCUSSION

The analysis confirms the importance of the SIOFA area for albatross and petrel species of conservation concern. The area was used year-round by populations breeding in the Indian Ocean at Crozet, Kerguelen, Prince Edward, Amsterdam and St Paul islands but also by South Atlantic populations, especially during year-quarter 3 (Jul-Sep).

South Atlantic populations were represented by wandering and grey-headed albatrosses from South Georgia, and to a lesser extent by Tristan albatrosses from Gough. The populations of wandering and grey-headed albatrosses from South Georgia have halved over the last 35 years mainly because of fisheries bycatch (Pardo et al. 2017a). High overlap between these populations and pelagic longline fisheries have previously been reported for the south-west Indian Ocean, including for the SIOFA area, matching documented bycatch by Japanese and Taiwanese fleets (Clay et al. 2019). Tristan albatrosses are Critically Endangered and are declining because of a combination of bycatch and predation of chicks by introduced house mice *Mus musculus* (Wanless et al. 2009).

Several species breeding at Prince Edward Islands overlapped with SIOFA area. The islands are especially important for wandering albatrosses with approx. 44% of the world population. Prince Edward Islands also support more than 10% of grey-headed, 20% of Indian yellow-nosed, and 23% of sooty albatrosses. Our distribution maps and overlap analysis corroborates the importance of SIOFA for grey-headed (especially during quarters 3 and 4) and sooty albatrosses (throughout the year). Distribution maps for wandering and Indian yellow-nosed albatrosses tracked from Prince Edward Islands were not included in this analysis nonetheless recent studies highlighted the important overlap with SIOFA area (Makhado et al. 2018, Reisinger et al. 2018) .

The French Southern Territories (Crozet, Kerguelen and Amsterdam-Saint Paul Islands) are particularly important for albatross and petrel species. The three archipelagos support a significant portion of the world populations of several species: 100% of Amsterdam albatross, 80% Indian yellow-nosed albatross, 38% wandering albatross and 20% sooty albatross (Delord et al. 2008, Weimerskirch 2018). The overlap analysis highlights the particular importance of SIOFA area for Amsterdam albatross, wandering albatross, mainly the Crozet population, black-browed and Indian yellow-nosed albatross but also for sooty albatross, grey petrel and white-chinned petrel (Péron et al. 2010, Delord et al. 2013b, 2014, 2019, Weimerskirch et al. 2018, Heerah et al. 2019). Several species appear to be steadily decreasing probably because of the impact of fisheries (Barbraud et al. 2008, 2009, 2011, Michael et al. 2017, Desprez et al. 2018, Weimerskirch et al. 2018), but also of others factors such as disease outbreak (Weimerskirch 2004, Jaeger et al. 2018) and climate change (Rolland et al. 2009, Barbraud et al. 2012).

### Recommendations

In order to better characterise the risk posed to albatrosses and petrels by being caught as bycatch in SIOFA fisheries, we recommend that the distribution maps presented here are overlapped with SIOFA fishing effort data in space and time. Although overlap with fishing effort will still identify areas of potential, not confirmed risk, several studies focusing on fisheries bycatch have found a relationship between indices of seabird-fisheries overlap and bycatch rates or hotspots (Jiménez et al. 2016, Clay et al. 2019), suggesting that risk assessments based on overlap analysis provide a useful approach. We also recommend that the analysis includes data from all life-history stages, as omitting non-breeding stages may lead to an underestimation of seabird bycatch. Because SIOFA and the Indian Ocean Tuna Commission (IOTC) have overlapping boundaries, a combined risk assessment or a joint future iteration of the global risk assessment by the tuna Regional Management Fisheries Organisations is likely to be valuable, through being able to fully assess the cumulative impact of albatross seabird bycatch in the Indian Ocean.

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**FIGURE 1** The proportion of the population represented by each major life-history stage for 12 species of albatrosses and petrels (15 populations) breeding in the Southern Ocean that overlapped the SIOFA area. Five distinct life-history stages were considered here: juveniles during their first year at sea, immatures (from second year at sea until recruitment into the breeding population), adult breeders (further split into successful and failed breeders) and adult non-breeders (birds not attempting to breed in a given year).

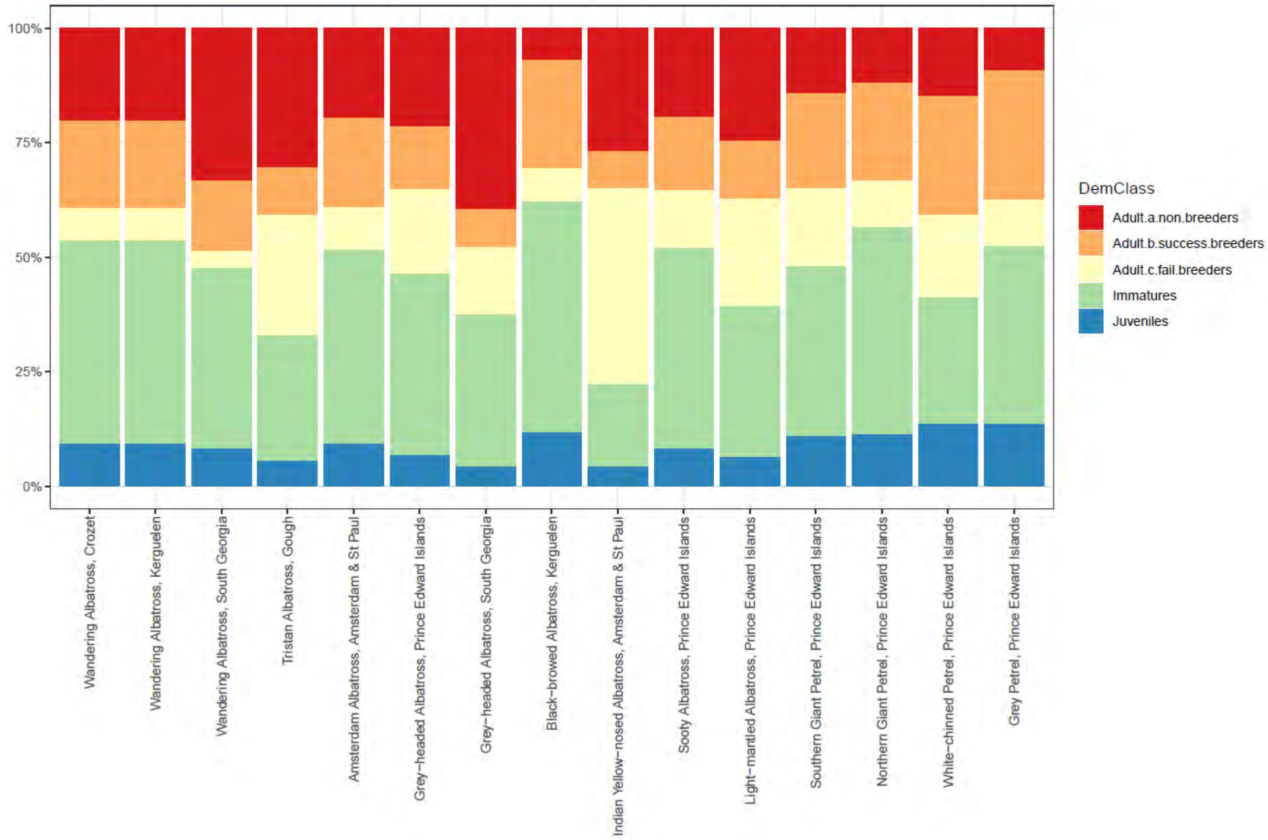

**FIGURE 2-16** Quarterly population-level density distributions for 12 species of albatrosses and petrels (15 populations) breeding in the Southern Ocean that overlapped with the SIOFA area based on tracking, phenology and demography data. The colour gradient refers to the percentage of the population represented within each 5 x 5° grid. Darker shades (of blue) depict a greater density of birds. For details on the number of individuals, and the percentage of the global population that occurs within SIOFA area, see Table 3.

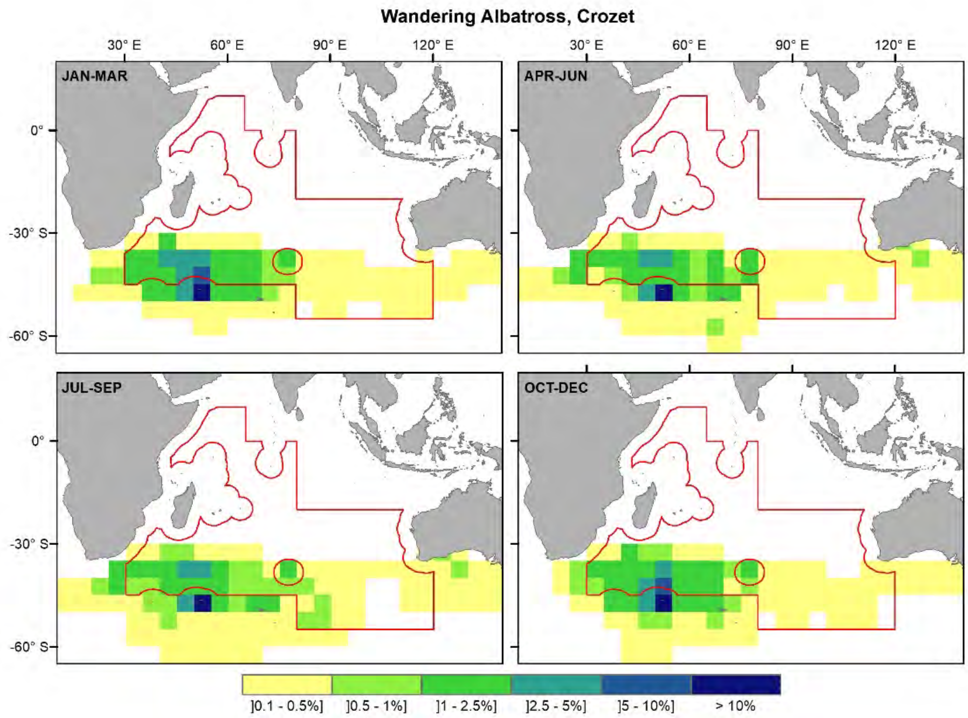


Figure 2: Wandering Albatross, Crozet

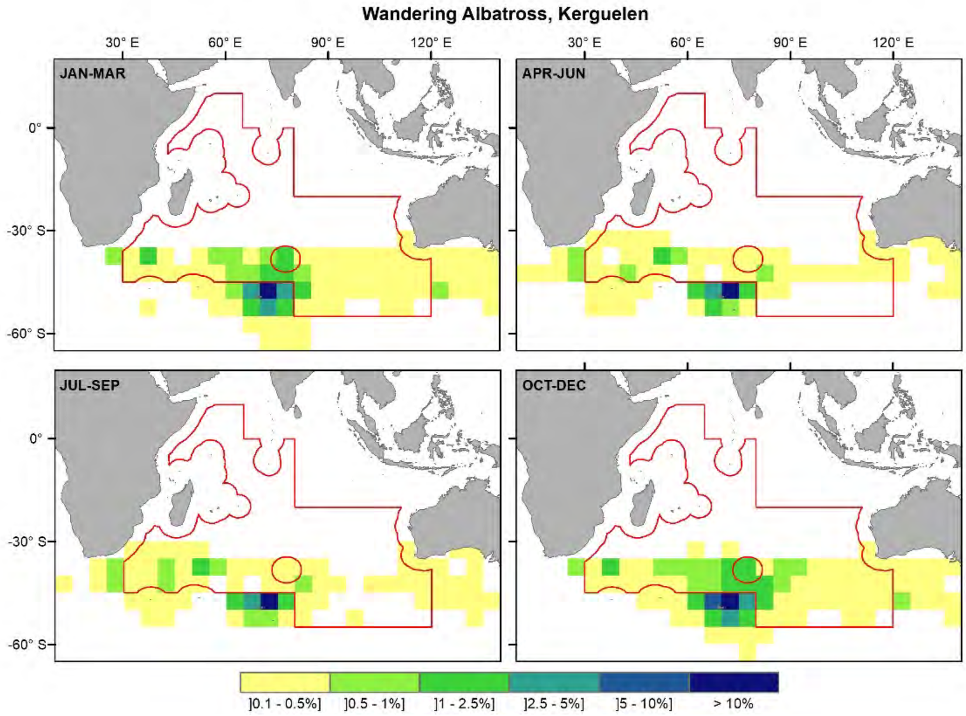


Figure 3: Wandering Albatross, Kerguelen

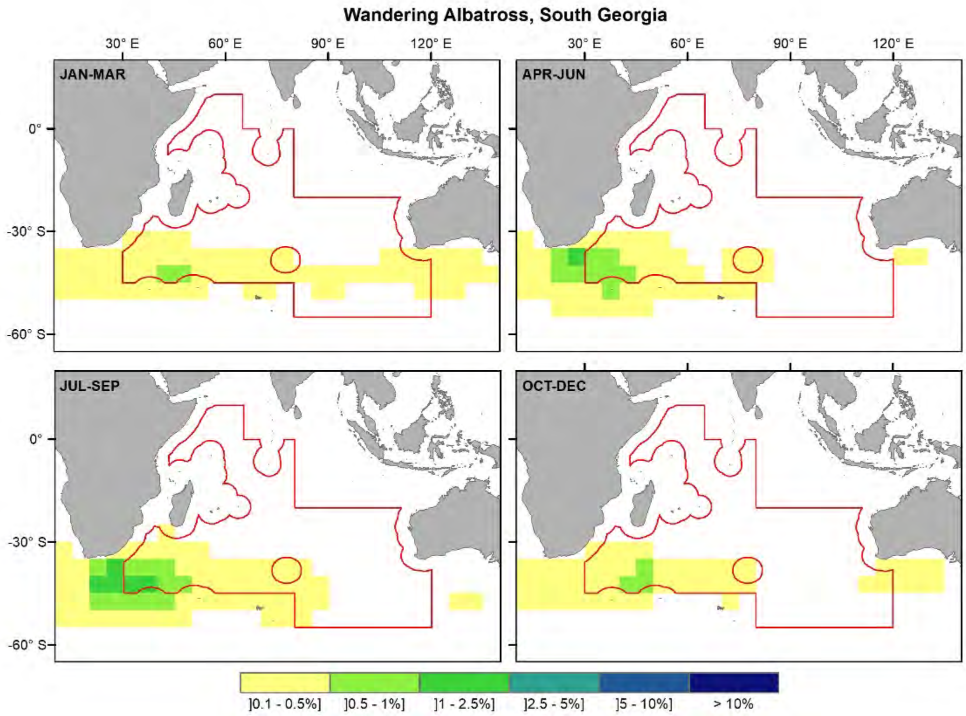


Figure 4: Wandering Albatross, South Georgia

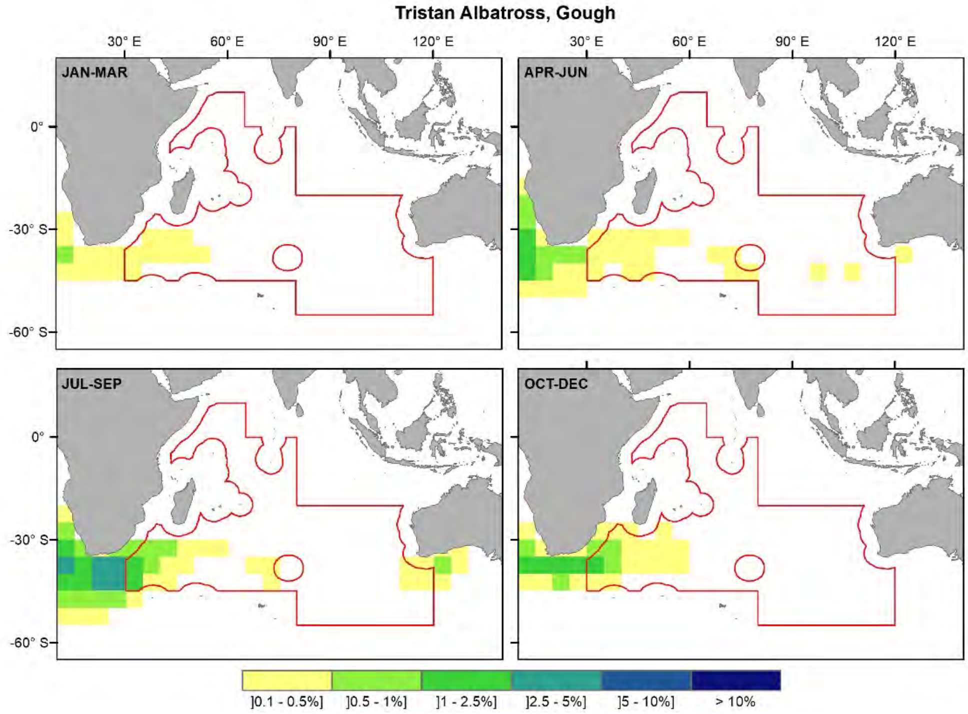


Figure 5: Tristan Albatross, Gough

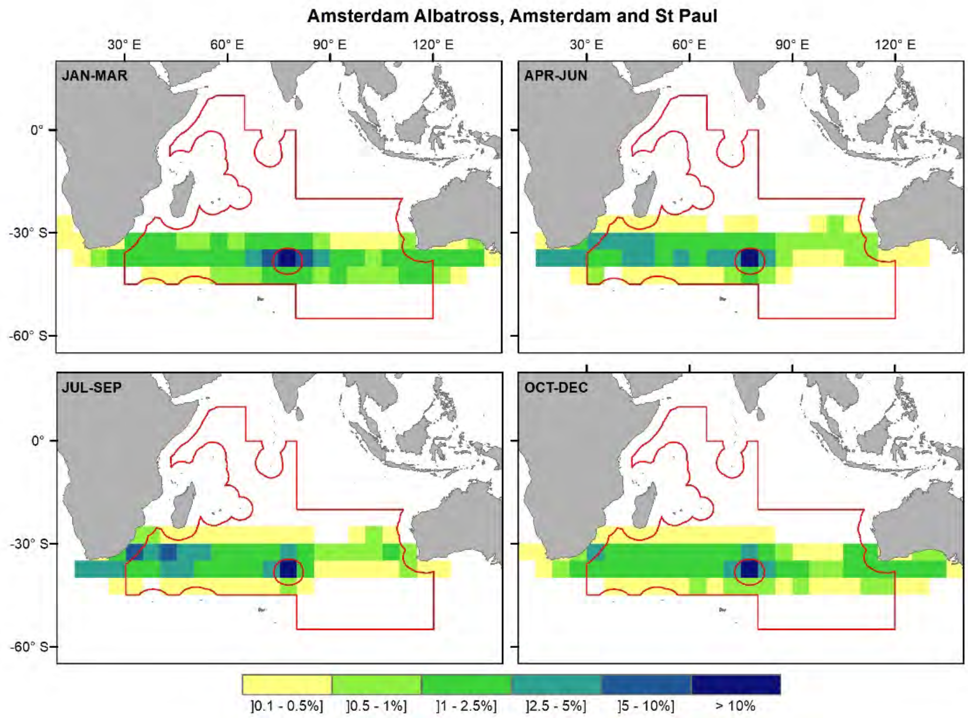

Figure 6: Amsterdam Albatross, Amsterdam and St Paul

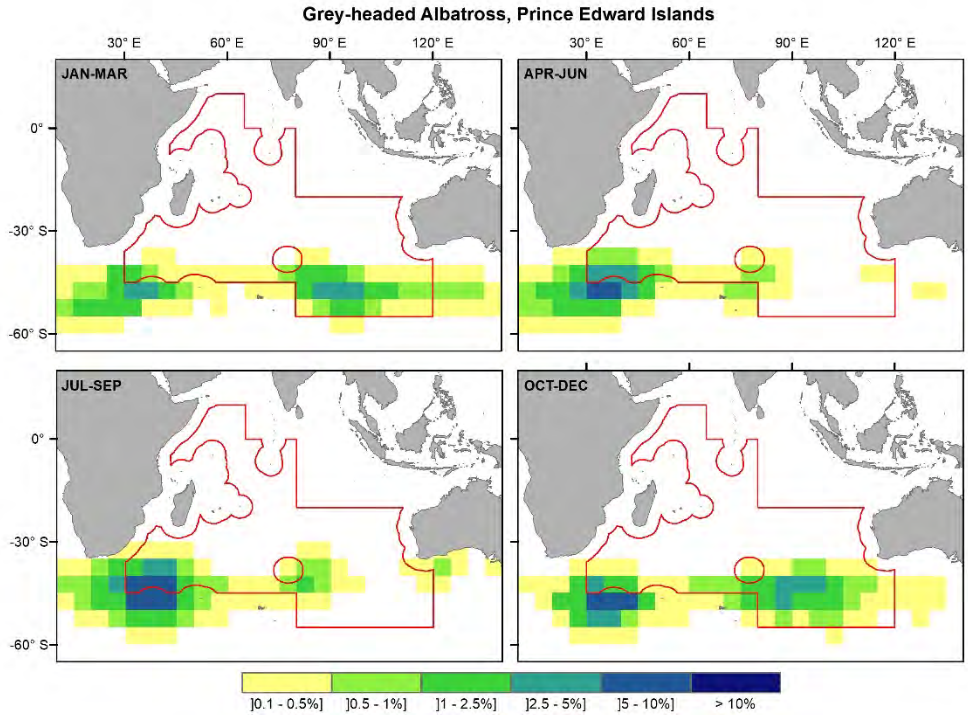


Figure 7: Grey-headed Albatross, Prince Edward Islands

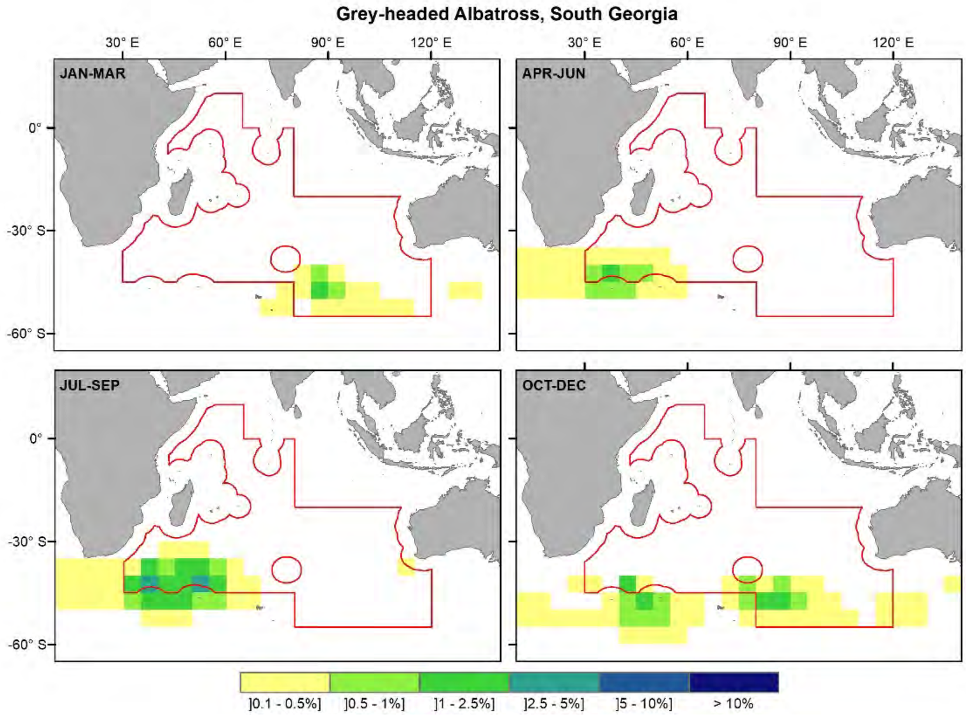


Figure 8: Grey-headed Albatross, South Georgia

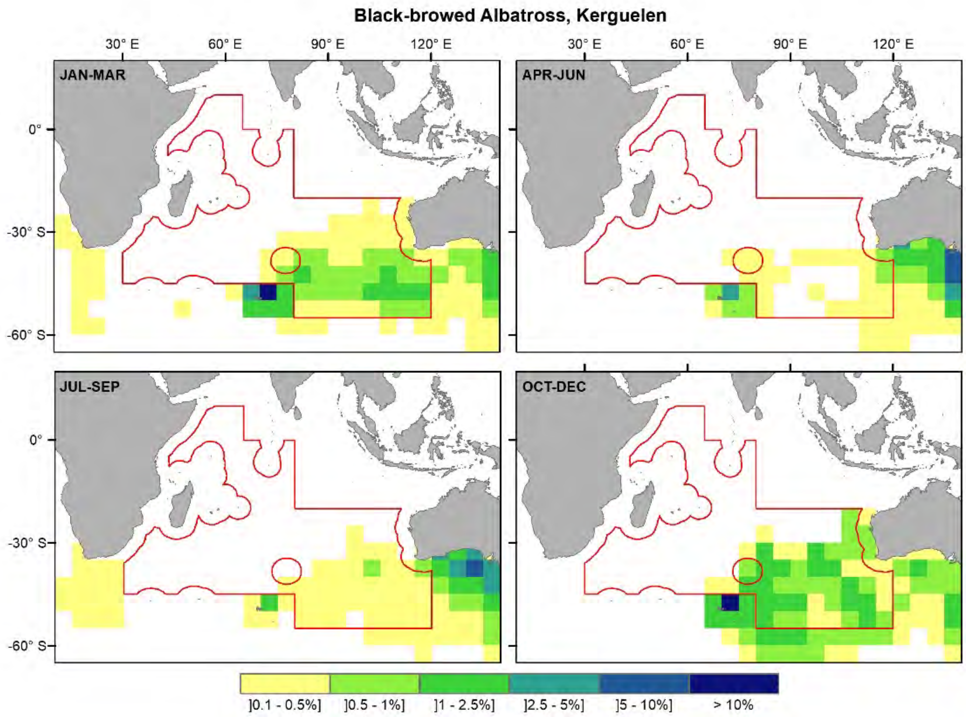


Figure 9: Black-browed Albatross, Kerguelen

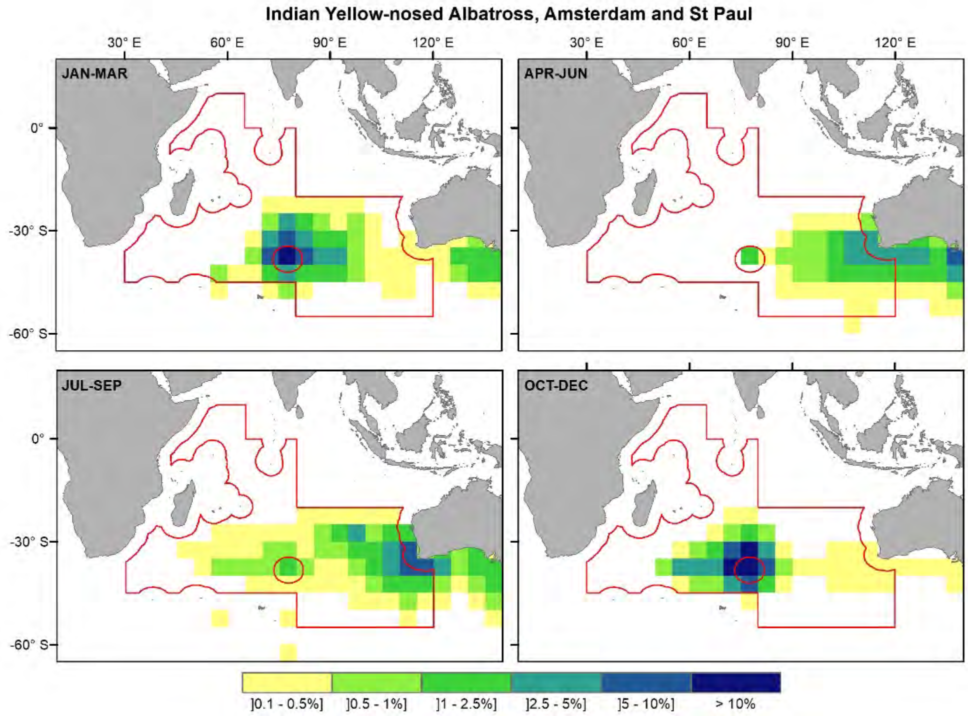


Figure 10: Indian Yellow-nosed Albatross, Amsterdam and St Paul

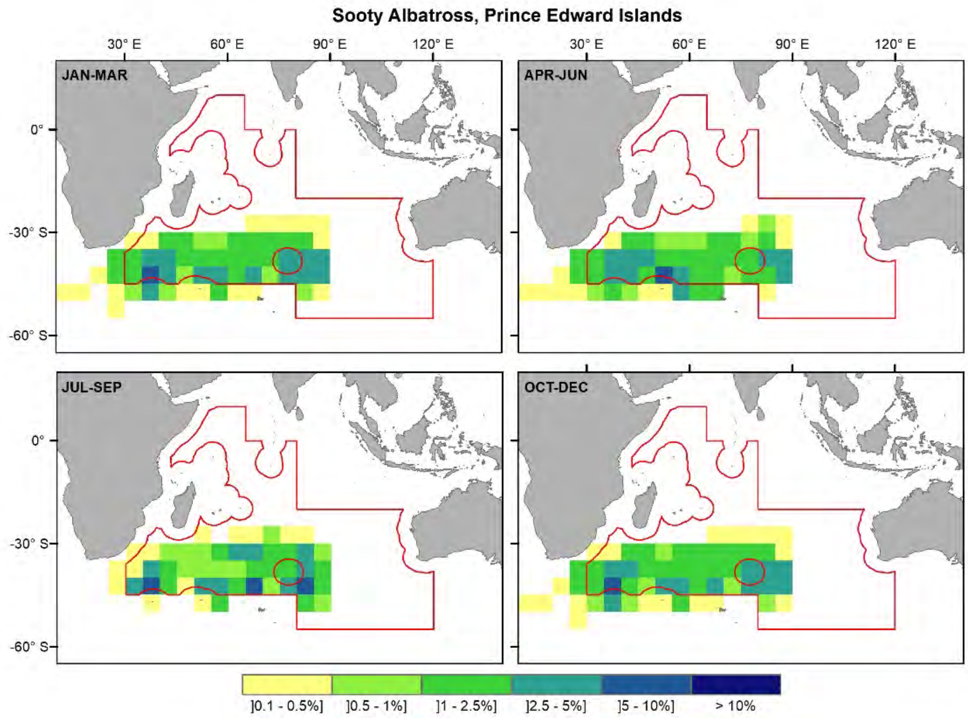


Figure 11: Sooty Albatross, Prince Edward Islands

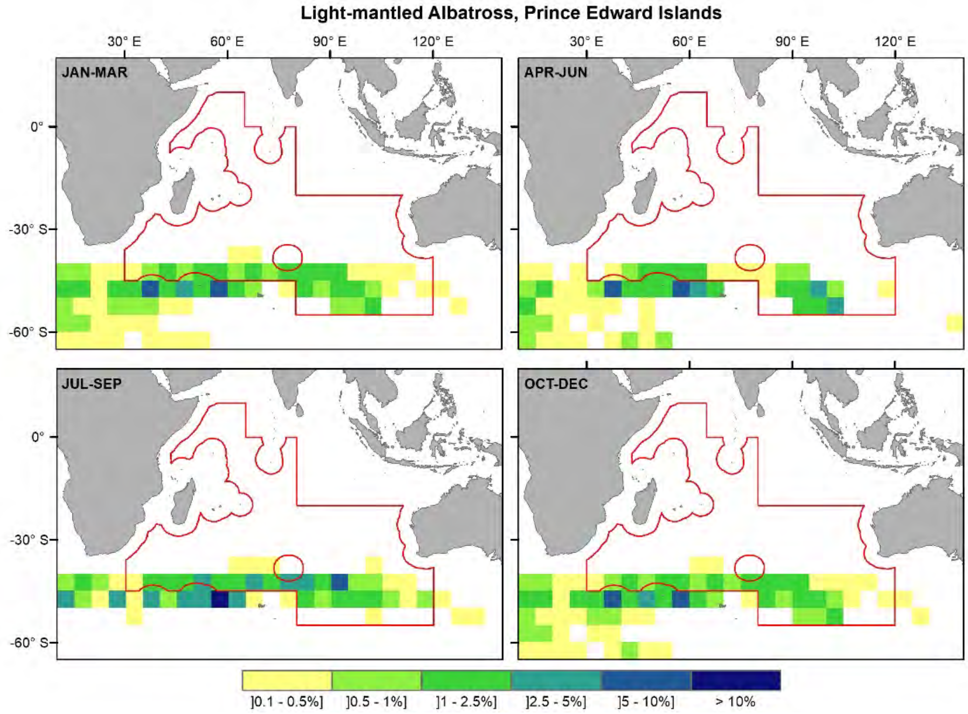


Figure 12: Light-mantled Albatross, Prince Edward Islands

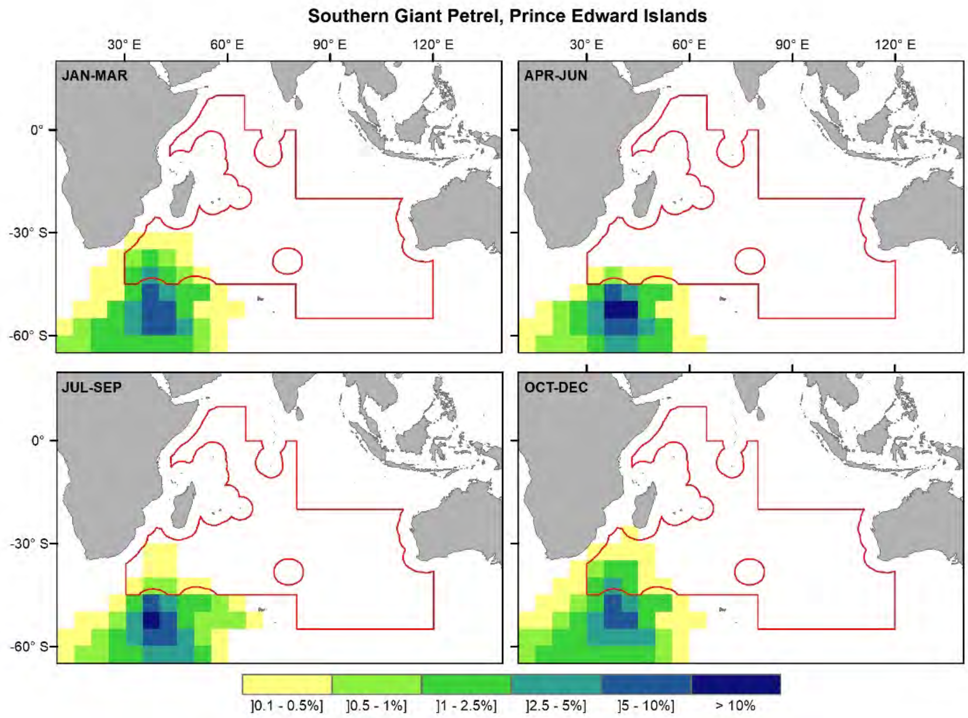

Figure 13: Southern Giant Petrel, Prince Edward Islands

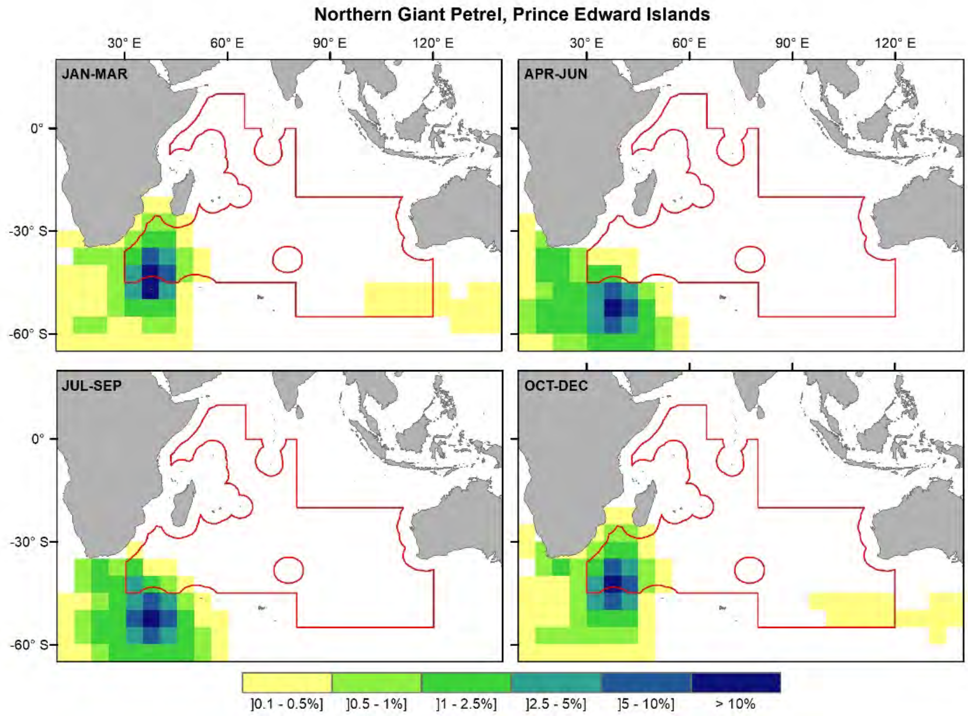


Figure 14: Northern Giant Petrel, Prince Edward Islands

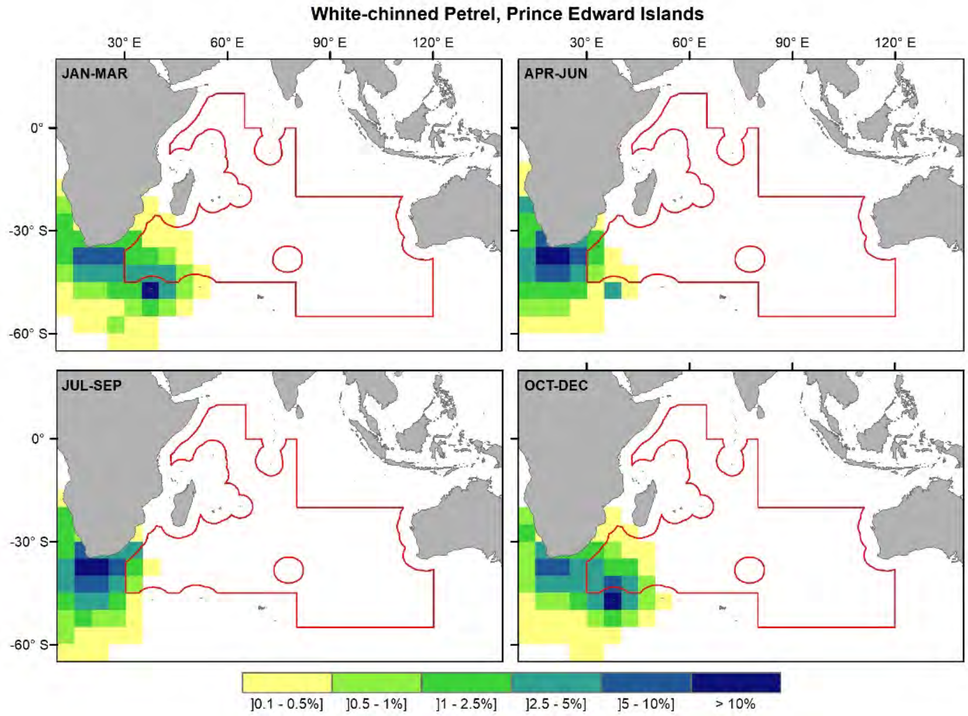


Figure 15: White-chinned Petrel, Prince Edward Islands

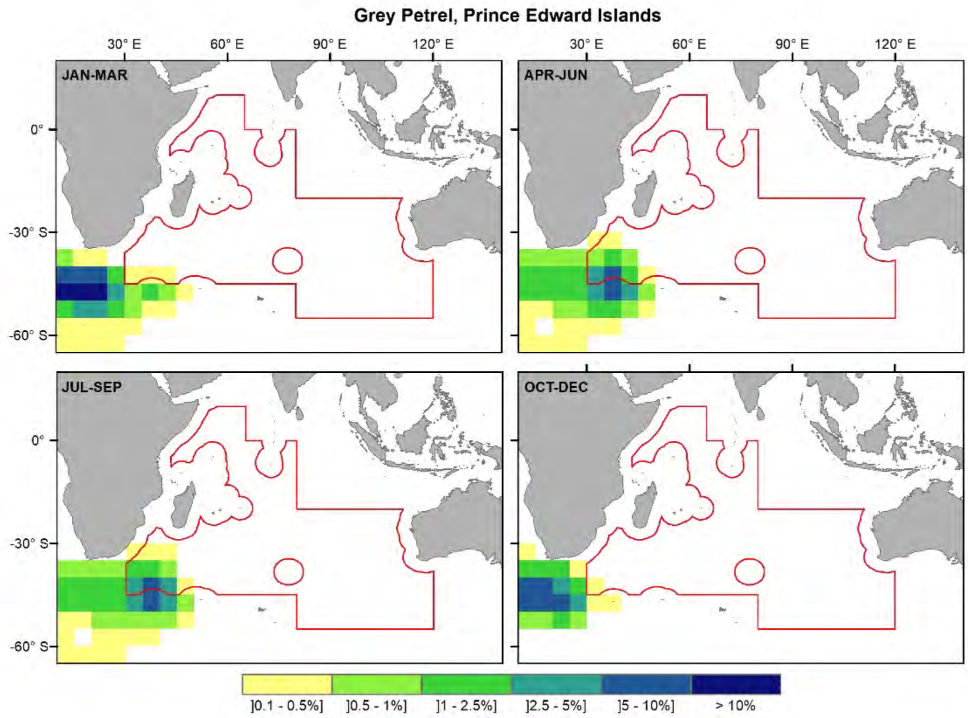


Figure 16: Grey Petrel, Prince Edward Islands

**FIGURE 17-31** Year-round population-level density distributions for 12 species of albatrosses and petrels (15 populations) breeding in the Southern Ocean that overlapped with the SIOFA area based on tracking, phenology and demography data. The colour gradient refers to the percentage of the population represented within each 5 x 5° grid. Darker shades (of blue) depict a greater density of birds. For details on the number of individuals, and the percentage of the global population that occurs within SIOFA area, see Table 3.

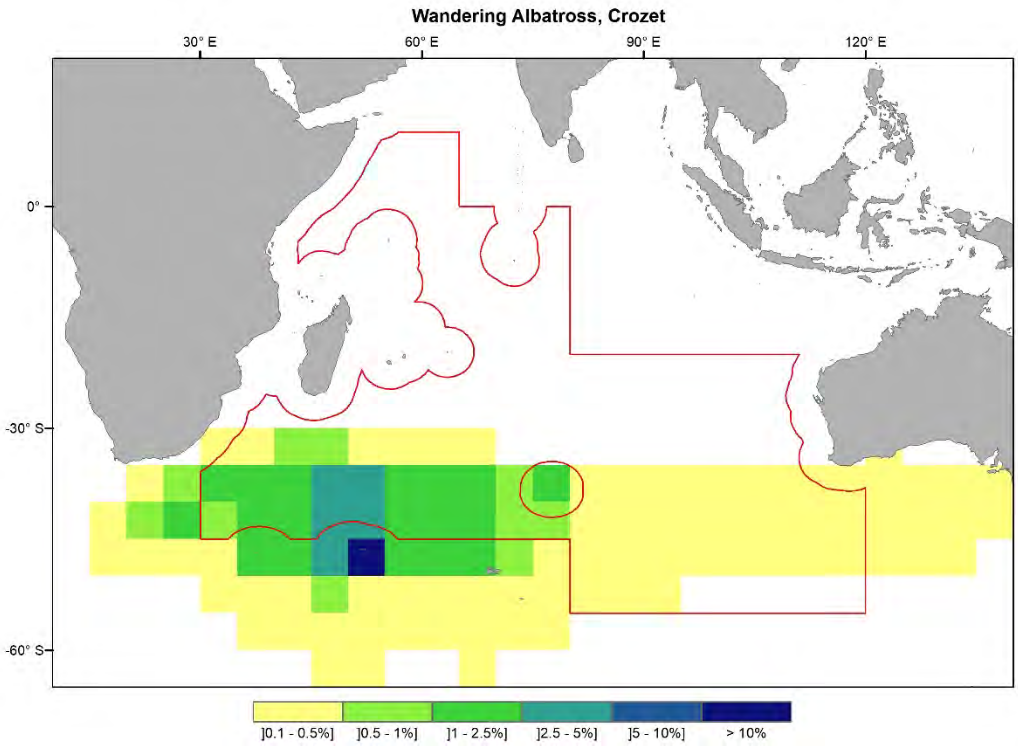


Figure 17: Wandering Albatross, Crozet

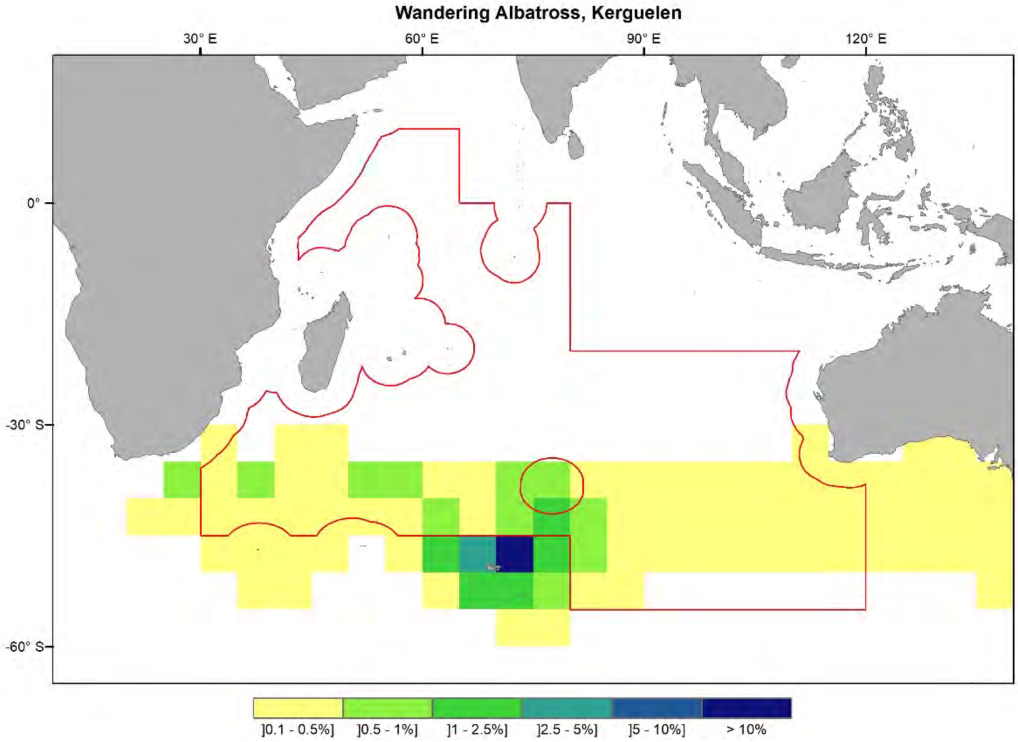


Figure 18: Wandering Albatross, Kerguelen

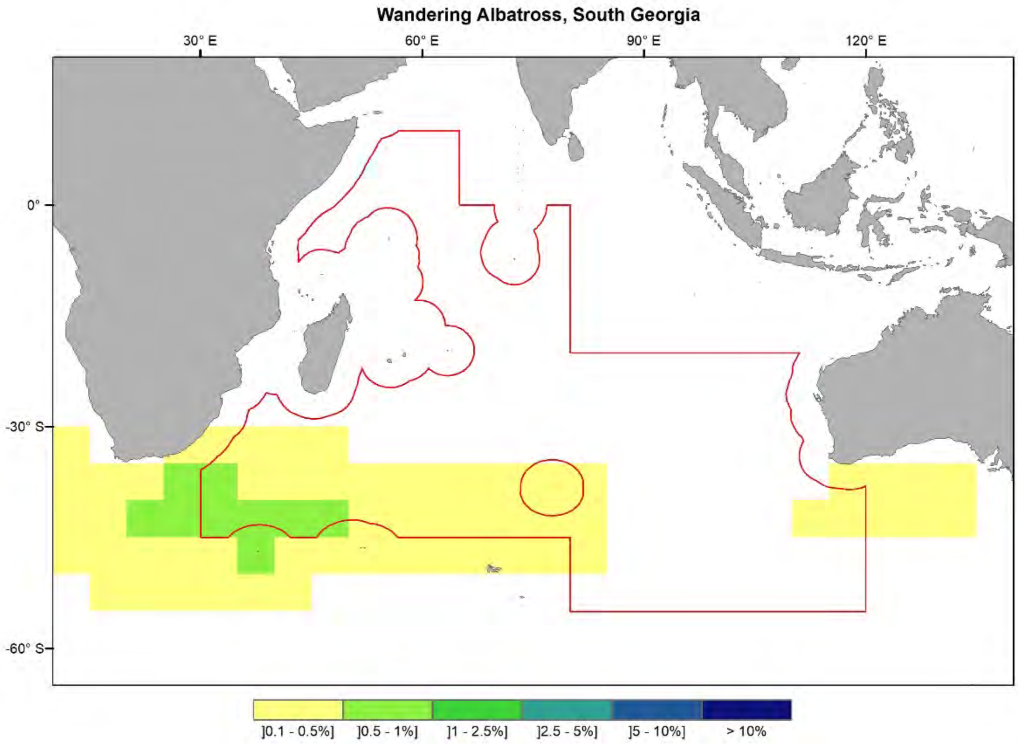


Figure 19: Wandering Albatross, South Georgia

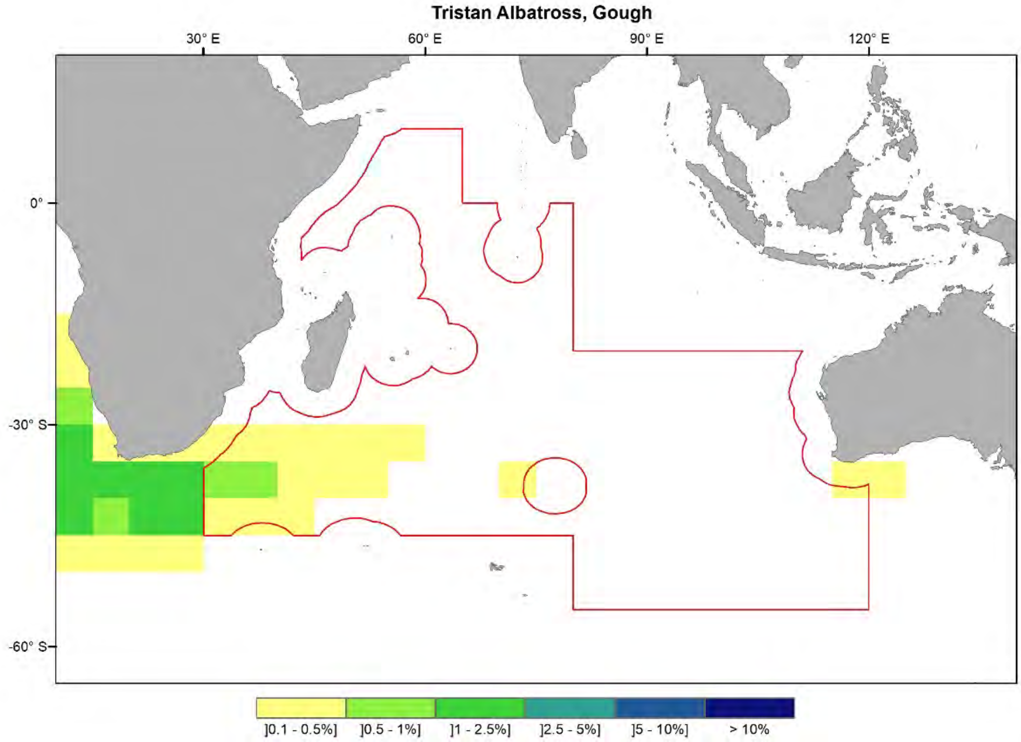


Figure 20: Tristan Albatross, Gough

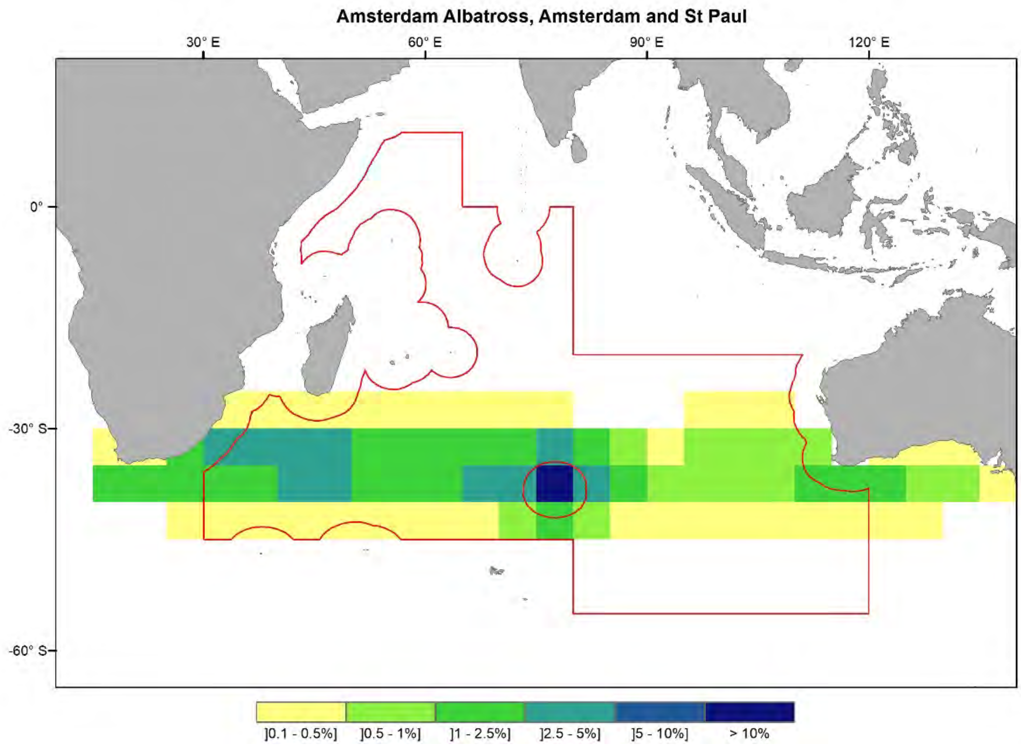


Figure 21: Amsterdam Albatross, Amsterdam and St Paul

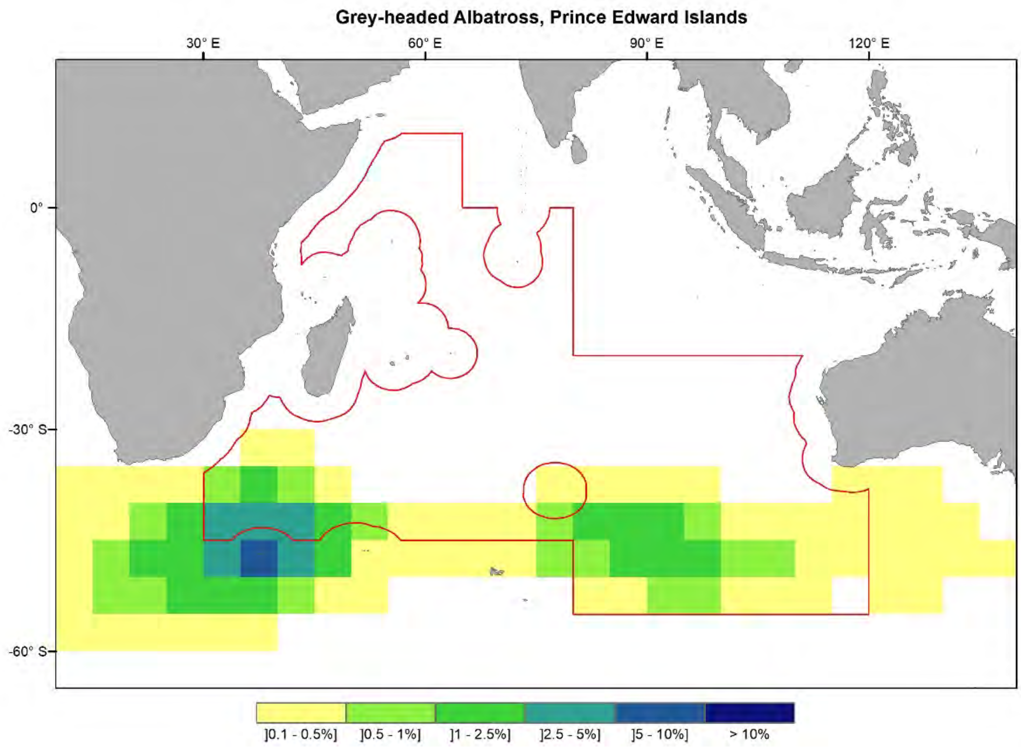


Figure 22: Grey-headed Albatross, Prince Edward Islands

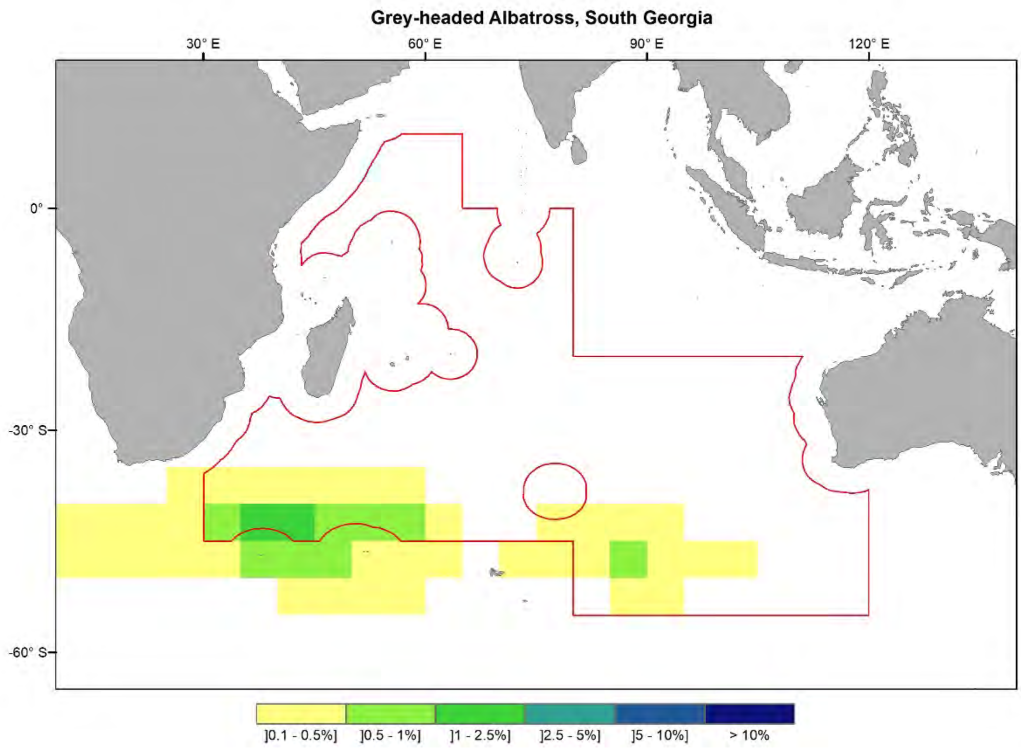


Figure 23: Grey-headed Albatross, South Georgia

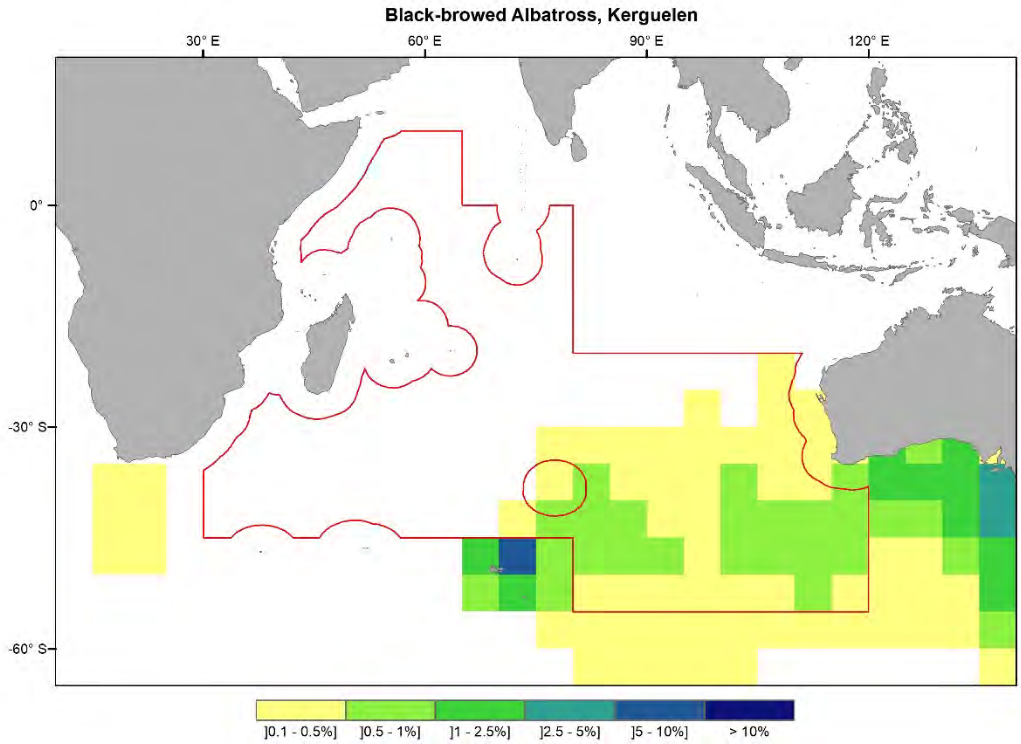


Figure 24: Black-browed Albatross, Kerguelen

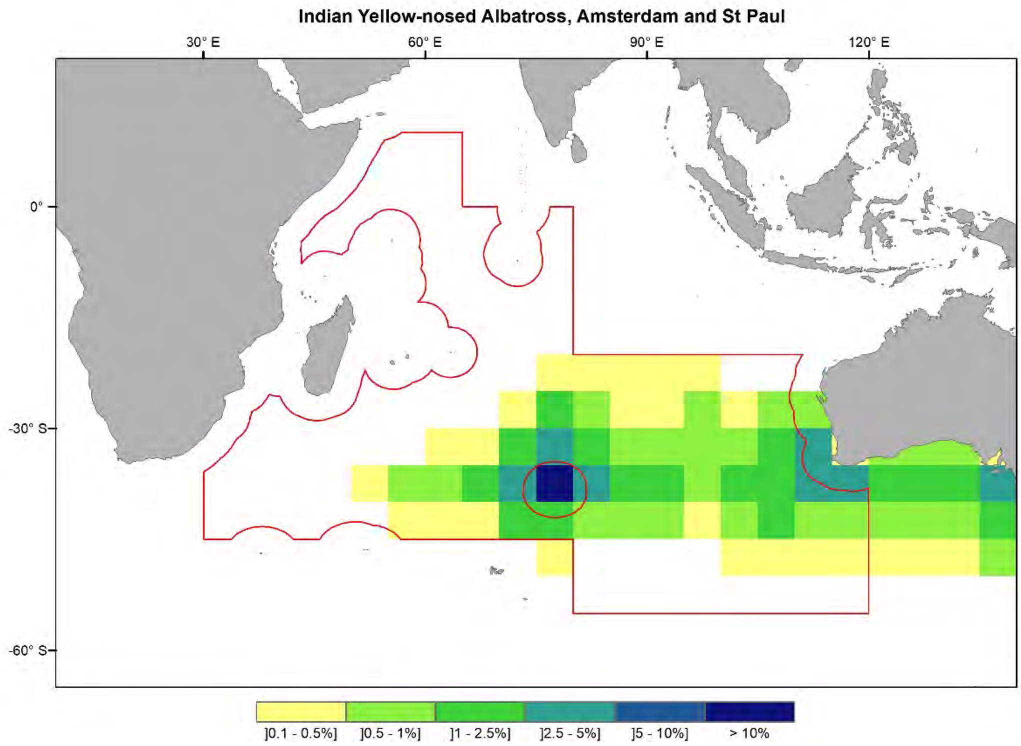


Figure 25: Indian Yellow-nosed Albatross, Amsterdam and St Paul

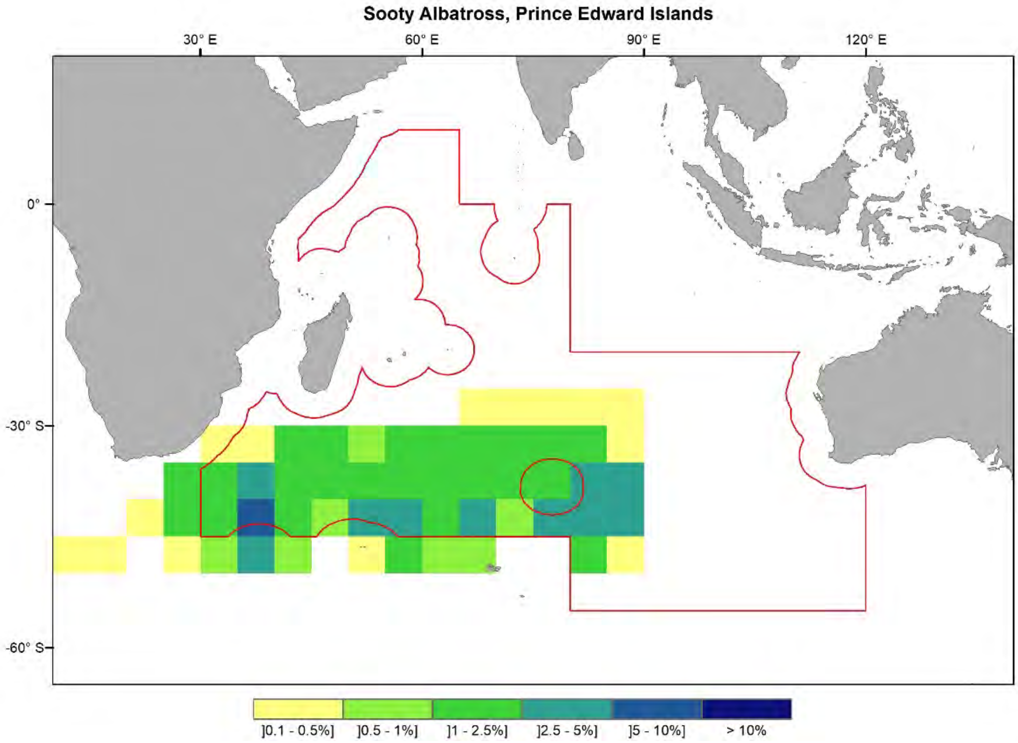


Figure 26: Sooty Albatross, Prince Edward Islands

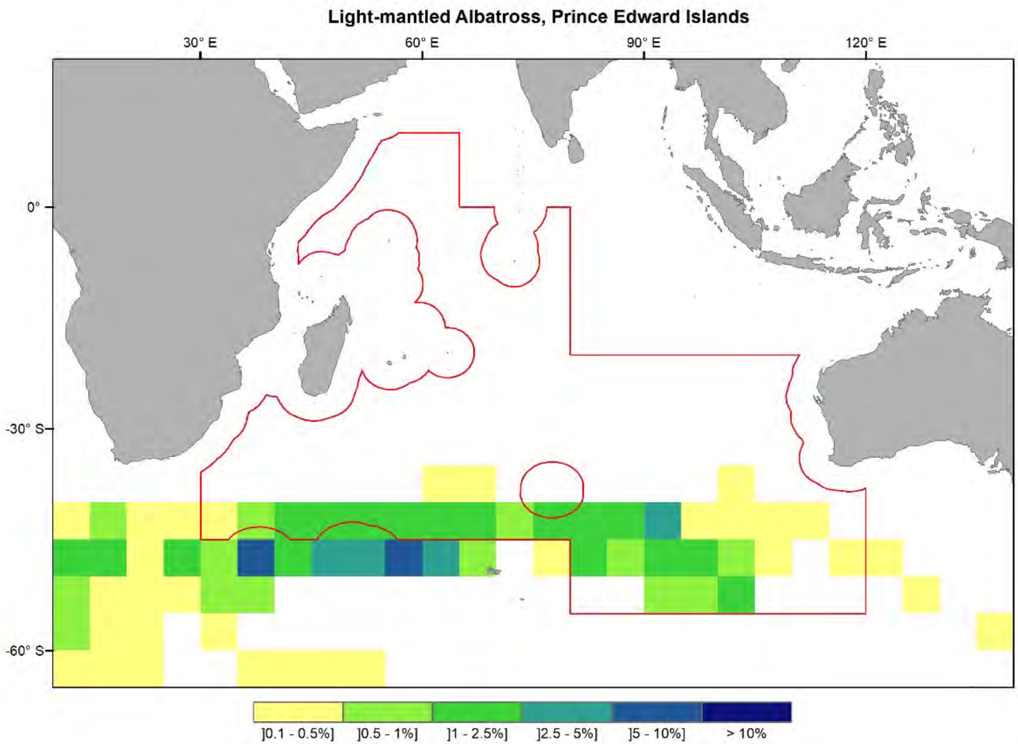


Figure 27: Light-mantled Albatross, Prince Edward Islands

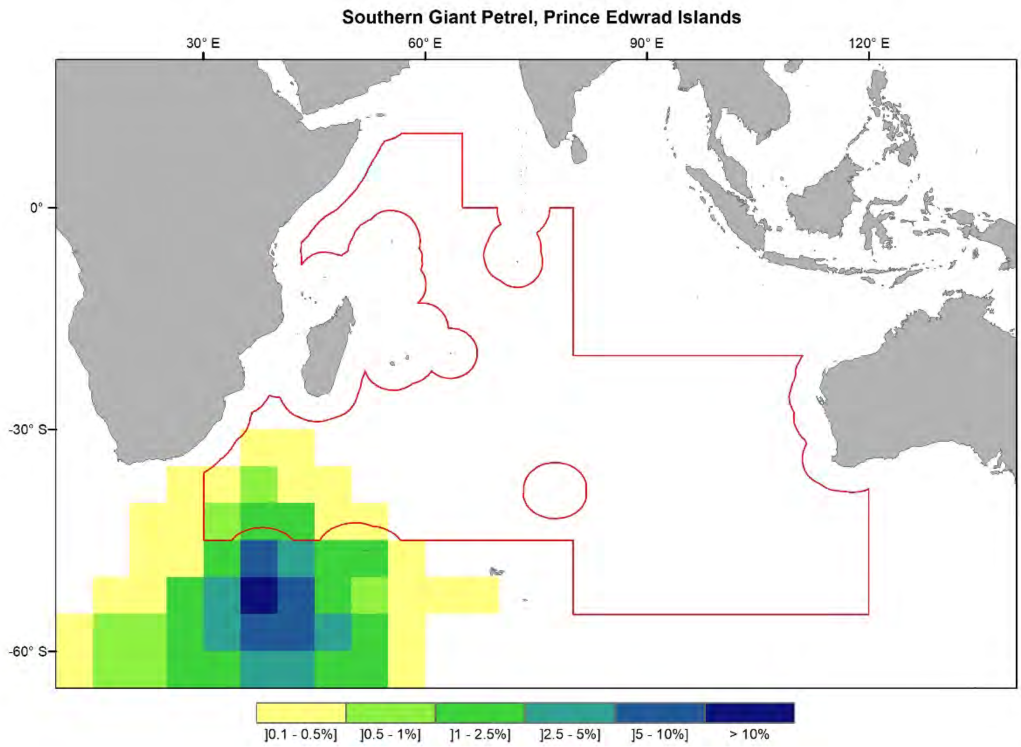


Figure 28: Southern Giant Petrel, Prince Edward Islands

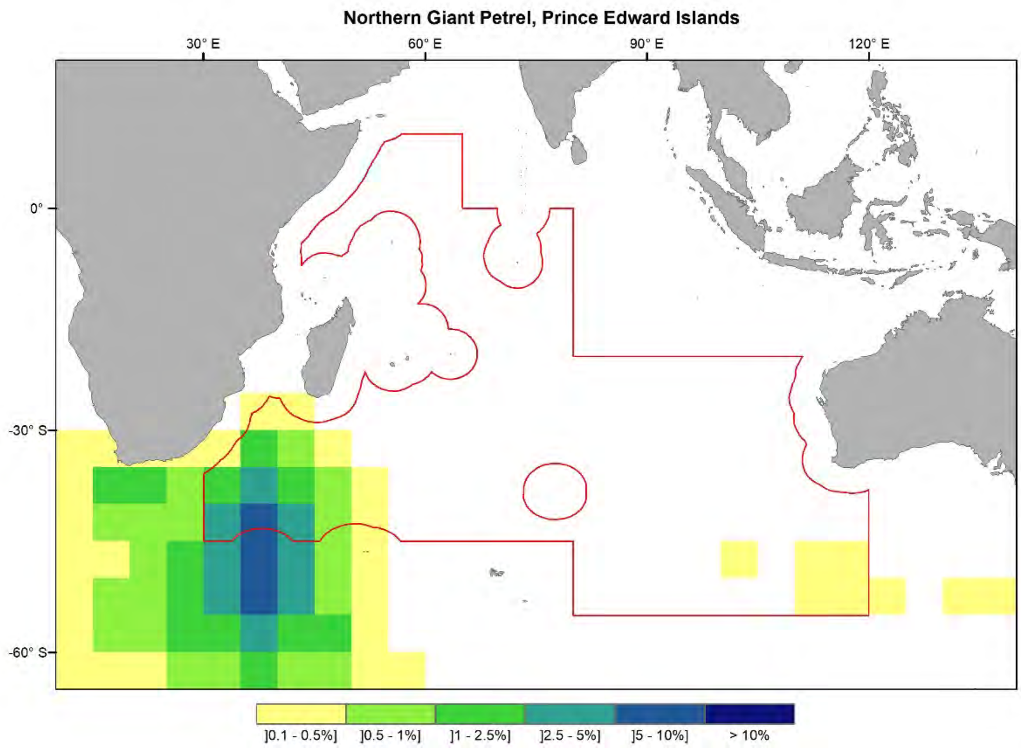


Figure 29: Northern Giant Petrel, Prince Edward Islands

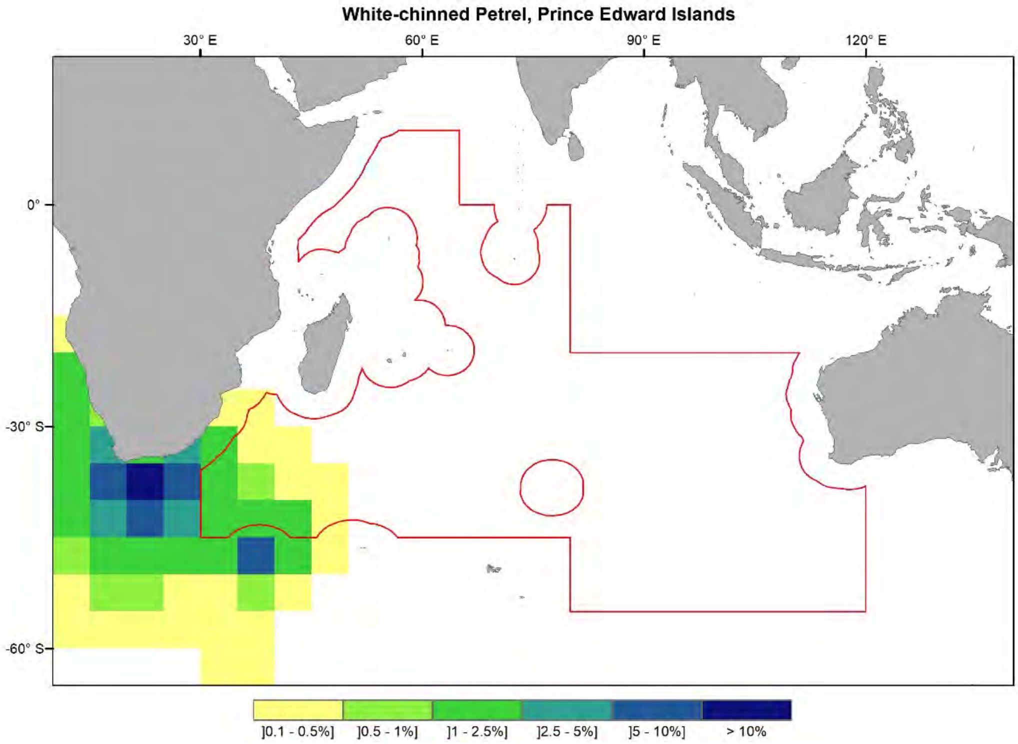


Figure 30: White-chinned Petrel, Prince Edward Islands

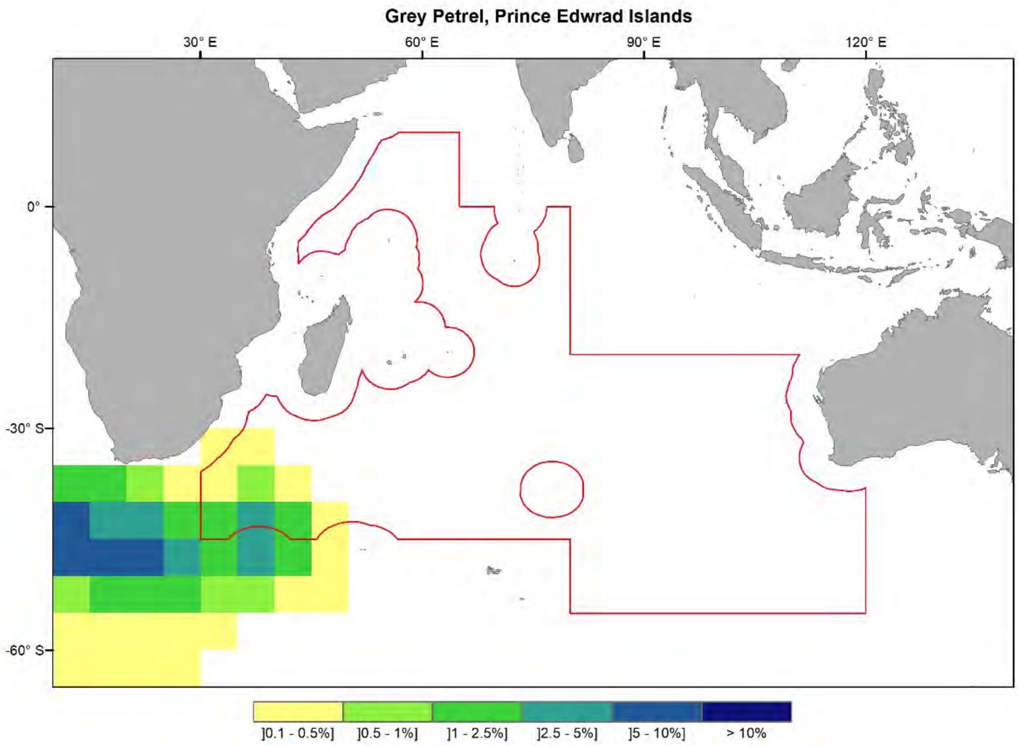


Figure 31: Grey Petrel, Prince Edward Islands

**TABLE 1** Sample sizes (number of birds) for tracking data by species, island or island group and stage of the annual cycle. Values in italics (never reached asymptote) and bold (not tested because of different smoothing factors) are those that may not have been representative of the tracked population. Where there were no tracking data or when data were not representative, appropriate data substitutions were used.

| Common name | Island or Island Group | Pre-egg | Incubation | Brood-guard | Post-guard | Non-breeding | Juvenile | Immature |
|---|---|---|---|---|---|---|---|---|
| Wandering Albatross | Crozet | No data | 319 | 79 | 30 | 95 | 13 | 11 |
| Wandering Albatross | Kerguelen | No data | 14 | 12 | 7 | 23 | *11* | 10 |
| Wandering Albatross | South Georgia | No data | 65 | 72 | 145 | 91 | **39** | 21 |
| Tristan Albatross | Gough | No data | 35 | 66 | 12 | 26 | 16 | No data |
| Amsterdam Albatross | Amsterdam and St Paul | No data | 29 | 17 | 10 | 14 | 11 | **8** |
| Grey-headed Albatross | Prince Edward Islands | No data | 27 | 11 | 40 [1] | 25 | No data | No data |
| Grey-headed Albatross | South Georgia | No data | 30 | 86 | 38 | 22 | 15 | No data |
| Black-browed Albatross | Kerguelen | No data | 8 | 24 [1] | | 123 | *2* | No data |
| Indian Yellow-nosed Albatross | Amsterdam and St Paul | No data | 45 | 16 | 10 [2] | 17 | *4* | No data |
| Sooty Albatross | Prince Edward Islands | | 10 [3] | | | *10* | No data | No data |
| Light-mantled Albatross | Prince Edward Islands | | *8* [3] | | | *6* | No data | No data |
| Southern Giant Petrel | Prince Edward Islands | No data | *8* | 7 [2] | | 8 | No data | No data |
| Northern Giant Petrel | Prince Edward Islands | No data | *14* | 16 [2] | | 16 | No data | No data |
| White-chinned Petrel | Prince Edward Islands | No data | 9 | 11 [2] | | 7 | No data | *3* |
| Grey Petrel | Prince Edward Islands | 7 | 8 | 9 [2] | | 8 | No data | No data |

[1] Combination of breeding, incubation and brood-guard

[2] Breeding-stage from the original dataset classified as chick-rearing

[3] Breeding-stage from the original dataset classified as breeding

**TABLE 2** Population estimates (i.e. annual breeding pairs), % of all sites (i.e. percentage in relation to global estimates), demographic estimates of juvenile/immature (average annual survival from fledging to average age of 1st breeding) and adult annual survival, breeding frequency and success and age at first breeding for the populations from which tracking data were available for the analysis. Where no estimates were available for particular demographic parameters from a given population or age class, we used parameters from another location or another species with similar life-history attributes. For some species, no estimates of juvenile survival existed, and we estimated juvenile survival from adult survival, using age effect: juvenile survival = adult survival multiplied by the average ratio of juvenile to adult survival calculated from all available data for the relevant genus (*Procellaria*, *Thalassarche*, or both). Species in bold were representative of island or island group(s) holding >50% of the global population estimates.

| Population (reference) | Annual pairs | % all sites | Juv/Imm survival | Adult survival | Br frequency | Br success | Age 1st br |
|---|---|---|---|---|---|---|---|
| **Wandering albatross** | | | | | | | |
| Crozet [1, 2, 3, 4, 5, 6] | 1,815 | 23.1 | 0.889 | 0.945[a] | 0.566[b] | 0.730 | 10.0 |
| Kerguelen [1, 2, 3] | 1,184 | 14.7 | 0.889[c] | 0.945[c] | 0.566[c] | 0.730[c] | 10.0[c] |
| South Georgia [1, 7] | 1,858 | 17.6 | 0.819 | 0.879 | 0.365[b] | 0.808 | 9.8 |
| **Tristan albatross** | | | | | | | |
| Gough [1, 8, 9] | 1,650 | 100.0 | 0.836 | 0.910 | 0.550 | 0.283 | 10.1 |
| **Amsterdam albatross** | | | | | | | |
| Amsterdam [1, 10, 11, 12] | 51 | 100.0 | 0.936 | 0.971 | 0.600 | 0.677 | 9.4 |
| **Grey-headed albatross** | | | | | | | |
| Prince Edward Islands [1, 13, 14] | 9,500 | 10.8 | 0.883[d] | 0.949[d] | 0.601[d] | 0.427[d] | 12.0[d] |
| South Georgia [1, 7] | 47,674 | 49.8 | 0.912 | 0.952 | 0.368[b] | 0.365 | 14.2 |
| **Black-browed albatross** | | | | | | | |
| Kerguelen [1, 5, 7, 15, 16] | 3,215 | 0.5 | 0.843 | 0.910 | 0.818[b,e] | 0.763 | 9.7 |
| **Indian yellow-nosed albatross** | | | | | | | |
| Amsterdam and St Paul [1, 10, 12, 17, 18] | 22,000 | 65.0 | 0.794 | 0.902 | 0.655[f] | 0.159 | 9.0 |
| **Sooty albatross** | | | | | | | |
| Prince Edward Islands [1, 19, 20, 21] | 2,493 | 18.8 | 0.842[g] | 0.920 | 0.600 | 0.560 | 11.8 |
| Light-mantled albatross | | | | | | | |
| Prince Edward Islands [1, 13] | 657 | 3.2 | 0.876 | 0.959[h] | 0.597[h] | 0.352[h] | 11.0[h] |
| Southern giant petrel | | | | | | | |
| Prince Edward Islands [1, 14, 20, 22, 23] | 2,800 | 4.7 | 0.795[i] | 0.890[l] | 0.730 | 0.550 | 8.0 |
| Northern giant petrel | | | | | | | |
| Prince Edward Islands [1, 14, 18, 20, 22, 24] | 750 | 3.9 | 0.795[i] | 0.890 | 0.730[j] | 0.680 | 10.0 |
| **White-chinned petrel** | | | | | | | |
| Prince Edward Islands [1, 20, 25, 26, 27, 28] | 36,000 | 2.7 | 0.700[k] | 0.895[k] | 0.750 | 0.590 | 6.1[k] |
| Grey petrel | | | | | | | |
| Prince Edward Islands [1, 20, 29, 30, 31] | 5,000 | NA | 0.819[l] | 0.940[m] | 0.810 | 0.735[n] | 7.0[m] |

[a] Average between males: 0.947 and females: 0.942; [b] Product of return and breeding probabilities; [c] Replaced from Crozet; [d] Replaced from grey-headed albatross at New Zealand, [e] Breeding probability from Kerguelen and return probability replaced from South Georgia; [f] Replaced from Atlantic yellow-nosed albatross at Gough; [g] AGE EFFECT - *Thalassarche*; [h] Replaced from light-mantled albatross at New Zealand; [i] AGE EFFECT - *Procellaria* and

*Thalassarche*; [j] Replaced from southern giant petrel; [k] Replaced from white-chinned petrel at Crozet; [l] AGE EFFECT - *Procellaria*; [m] Replaced from grey petrel at Crozet; [n] Replaced from black petrel at New Zealand.

[1] ACAP; [2] Delord et al., (2013); [3] Fayet et al., (2015); [4] Barbraud & Weimerskirch, (2012); [5] Pardo, Barbraud, Authier, & Weimerskirch, (2013); [6] Barbraud & Weimerskirch, (2012); [7] Pardo et al., (2017); [8] Davies, Dilley, Bond, Cuthbert, & Ryan, (2015); [9] Wanless et al., (2009); [10] Heerah et al., (2019); [11] Rivalan, Barbraud, Inchausti, & Weimerskirch, (2010); [12] Jaeger et al., (2018); [13] Abraham, Yvan, & Clements, (2016); [14] Ryan, Jones, Dyer, Upfold, & Crawford, (2009); [15] Nevoux, Weimerskirch, & Barbraud, (2010); [16] Pardo, Jenouvrier, Weimerskirch, & Barbraud, (2017); [17] Cuthbert, Ryan, Cooper, & Hilton, (2003); [18] NZ birds online; [19] Ryan pers. comm; [20] Dobson & Jouventin, (2007); [21] Schoombie, Crawford, Makhado, Dyer, & Ryan, (2016) ; [22] Richard, Abraham, & Berkenbusch, (2017); [23] Ryan et al., (2003); [24] Jones, Risi, Cleeland, & Ryan, (2019); [25] Ryan, Dilley, & Jones, (2012); [26] Rollinson, Dilley, Davies, & Ryan, (2018); [27] Barbraud, Marteau, Ridoux, Delord, & Weimerskirch, (2008); [28] Dilley et al., (2018); [29] Bell, Mischler, MacArthur, Sim, & Scofield, (2016); [30] Barbraud, Delord, Marteau, & Weimerskirch, (2009); [31] Dilley pers. comm.

**TABLE 3** Number of individuals per year-quarter and the percentage of the global population within the SIOFA area in parentheses. The population represented varies between quarters because one member of each pair is at the colony at any one time during the pre-laying, incubation and brood-guard stages, and this at-colony bird is not represented in our distributions.

| Common name | Island or Island Group | Quarter 1 (Jan-Mar) | Quarter 2 (Apr-Jun) | Quarter 3 (Jul-Sep) | Quarter 4 (Oct-Dec) | Year-round |
|---|---|---|---|---|---|---|
| Wandering Albatross | Crozet | 12,001 (46.13) | 13,418 (35.23) | 13,813 (37.43) | 13,310 (44.12) | 13,135 (40.55) |
| Wandering Albatross | Kerguelen | 7,896 (20.27) | 8,763 (10.91) | 9,020 (11.95) | 8,727 (23.49) | 8,601 (16.52) |
| Wandering Albatross | South Georgia | 17,630 (09.05) | 19,236 (09.37) | 19,447 (13.69) | 18,767 (08.48) | 18,770 (10.19) |
| Tristan Albatross | Gough | 7,310 (02.69) | 8,953 (05.44) | 8,956 (08.71) | 8,228 (06.15) | 8,362 (5.89) |
| Amsterdam Albatross | Amsterdam and St Paul | 318 (67.87) | 310 (67.45) | 352 (66.62) | 351 (63.69) | 333 (66.34) |
| Grey-headed Albatross | Prince Edward Islands | 57,719 (32.81) | 59,046 (22.07) | 56,352 (44.46) | 49,577 (45.66) | 55,674 (35.77) |
| Grey-headed Albatross | South Georgia | 403,862 (06.09) | 414,774 (06.34) | 411,548 (21.53) | 366,685 (10.26) | 399,217 (11.09) |
| Black-browed Albatross | Kerguelen | 20,337 (28.24) | 21,088 (05.48) | 20,744 (09.49) | 17,468 (37.83) | 19,909 (19.43) |
| Indian Yellow-nosed Albatross | Amsterdam and St Paul | 86,547 (62.86) | 86,994 (31.41) | 79,897 (51.03) | 65,954 (67.97) | 79,848 (52.39) |
| Sooty Albatross | Prince Edward Islands | 17,276 (74.46) | 17,345 (72.96) | 16,830 (81.08) | 14,837 (75.32) | 16,572 (75.94) |
| Light-mantled Albatross | Prince Edward Islands | 3,490 (27.41) | 3,603 (23.98) | 3,634 (40.23) | 2,997 (28.22) | 3,431 (30.08) |
| Southern Giant Petrel | Prince Edward Islands | 14,731 (12.38) | 14,723 (01.82) | 14,171 (03.04) | 12,332 (12.86) | 13,989 (7.34) |
| Northern Giant Petrel | Prince Edward Islands | 4,748 (52.43) | 4,736 (03.63) | 4,264 (07.64) | 4,434 (50.37) | 4,545 (28.71) |
| White-chinned Petrel | Prince Edward Islands | 162,890 (16.72) | 164,819 (03.08) | 164,417 (03.25) | 137,978 (20.74) | 157,526 (10.52) |
| Grey Petrel | Prince Edward Islands | 24,800 (00.98) | 22,671 (16.24) | 25,998 (18.69) | 25,992 (00.30) | 24,865 (8.91) |