INTER-AMERICAN TROPICAL TUNA COMMISSION

9TH STOCK ASSESSMENT REVIEW MEETING

LA JOLLA, CALIFORNIA (USA)
12-16 MAY 2008

DOCUMENT SAR-9-11b

Agreement on the Conservation
of Albatrosses and Petrels

Albatross and petrel distribution within the IATTC area

Agreement for the Conservation of Albatrosses and Petrels (ACAP)

Paper prepared for 9th IATTC Stock Assessment Review Meeting

La Jolla, California, 12-16 May 2008

ABSTRACT

This paper presents an analysis of the seasonal distribution of albatrosses and petrels within the IATTC area, using remote tracking data from the Global Procellariiform Tracking Database. The analysis highlights the importance of the IATTC area for Waved Albatross, Black-footed Albatross and Chatham Albatross. At a species level, overlaps between the IATTC area and Laysan Albatross and Black-browed Albatross distributions are relatively low, but overlap is highly important for some colonies of these species (including Laysan Albatross from Isla Guadalupe and Black-browed Albatross from Chile). No remote tracking data are currently available for Buller's and Salvin's Albatross in the south-east Pacific, but at-sea observations indicate the importance of the IATTC area for these species, and the degree of overlap would be expected to be similar to that of Chatham Albatross. Waved Albatross and Blackfooted Albatross have a high overlap with the IATTC area throughout the year. In contrast, the distribution of albatrosses in the south-east Pacific is highest between April-September, corresponding to the non-breeding periods, when birds are not constrained to returning to breeding sites to feed their chicks and are able to disperse to the rich foraging grounds of the Humboldt Current. The analysis indicates that the mitigation areas suggested in IATTC-75-07c incorporate a high proportion of the distribution of albatrosses, petrels and shearwaters in the East Pacific, the species considered most at risk of bycatch in longline fisheries.

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1. INTRODUCTION

Nineteen of the world's 22 albatross species are globally threatened with extinction (IUCN 2007), and incidental catch in fisheries, especially longline fisheries, is recognised as one of the principal threats to many of these species (Robertson & Gales 1998). Albatrosses, petrels and some shearwater species are considered particularly vulnerable to longline bycatch. At its 73rd meeting, the IATTC adopted Resolution C-05-01, requesting, when feasible and appropriate, an assessment of the impact of incidental catch of seabirds resulting from IATTC fisheries, and requesting that this assessment should include an identification of the geographic areas in which seabird interactions may be occurring. This paper presents analysis of data from the Global Procellariiform Tracking Database, a database that has been established through a unique collaboration between scientists from around the world. The paper explores the spatial and seasonal distribution of albatrosses and petrels in the East Pacific, and overlap IATTC longline fishing effort.

2. METHODS

Over 90% of existing albatross and petrel tracking data have been submitted to the Global Procellariiform Tracking Database, representing 20 of the 22 species of albatross, both species of giant-petrel, and several species of petrel and shearwater. Remote tracking data have the advantage of providing distribution data for birds of known life history stage and provenance. However, gaps in tracking data remain, particularly for juvenile and immature life stages of many species. Assumptions on distribution must be applied in some cases, using data on known range and other sources.

Procellariiform distribution can vary markedly with life history stage and the breeding cycle. Analysis of overlap with IATTC longline fisheries must therefore take this seasonal variation into account, particularly given that longline fishing effort also varies seasonally. The analysis presented in this paper differs from previous analyses (e.g. BirdLife 2006) in that, rather than producing separate maps for breeding and non-breeding birds, it estimates the total distribution of each seabird species on a seasonal basis (year quarter), by combining juvenile, immature, breeding and non-breeding distributions. This allows a fuller understanding of overlap with fisheries. While there may also be variations in seabird distribution between years, studies have indicated that interannual differences in distribution are not as substantial as the variation between the different stages of the breeding cycle, and between breeding and non-breeding birds (Weimerskirch *et al.* 1993, Prince *et al.* 1998, Weimerskirch 2004, Phillips *et al.* 2004a). Table 1 gives the species names used in the text.

Table 1. Seabird species referred to in the text

Common name	Scientific name	Threat status[1]
Antipodean Albatross	*Diomedea antipodensis*	Vulnerable
Black-browed Albatross	*Thalassarche melanophrys*	Endangered
Black-footed Albatross	*Phoebastria nigripes*	Endangered
Buller's Albatross	*Thalassarche bulleri*	Vulnerable
Chatham Albatross	*Thalassarche eremita*	Critically Endangered
Grey-headed Albatross	*Thalassarche chrysostoma*	Vulnerable
Laysan Albatross	*Phoebastria immutabilis*	Vulnerable
Northern Royal Albatross	*Diomedea sanfordi*	Endangered
Salvin's Albatross	*Thalassarche salvini*	Vulnerable
Short-tailed Albatross	*Phoebastria albatrus*	Vulnerable
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable
Wandering Albatross	*Diomedea exulans*	Vulnerable
Waved Albatross	*Phoebastria irrorata*	Vulnerable
Black Petrel	*Procellaria parkinsoni*	Vulnerable
Grey Petrel	*Procellaria cinerea*	Near Threatened
Westland Petrel	*Procellaria westlandica*	Vulnerable
White-chinned Petrel	*Procellaria aequinoctialis*	Vulnerable
Sooty Shearwater	*Puffinus griseus*	Near Threatened

[1] Source IUCN 2007.

2.1 Processing seabird remote tracking data

When satellite tracking (PTT) data are submitted to the Tracking Database, data are processed using standardised methods agreed among data-holders. Data points are first validated using a filter based on McConnell *et al.* (1992), which calculates the average velocity between the current satellite uplink and the preceding and following two uplinks. Where the velocity is over the maximum velocity *vMax* (set at 100km.hr^{-1} for all species) and an alternative latitude and longitude is provided, the filter substitutes the alternative point. In an iterative process, the filter then removes the uplink with the highest velocity over *vMax*, although a point with high accuracy is not removed (location classes 1, 2 and 3 with accuracies of up to 1km (Argos 1989, 1996)). The velocities for the four points adjacent to the removed point are then recalculated and the process repeated, until no low quality point has a velocity above *vMax* (BirdLife International 2004). In order to convert the PTT tracking data into density distributions, the assumption is made that birds travel at constant speed and in a straight line between each pair of uplinks. The path of the bird is then resampled at hourly intervals. If the interval between two uplinks is more than 24 hours (as in the case with duty-cycled data), no resampling is conducted between these points.

Geolocator (GLS) devices are generally less accurate than PTTs and provide only two locations per day, but are ideal for tracking the wintering ranges of pelagic species (Phillips *et al.*, 2004a) and, being lighter than PTT devices, can be used on smaller birds. Data holders submit GLS data to the database in a processed form, since the variety of geolocators available made it unrealistic to develop a standardised validation. GLS data did not require resampling since the locations are available from tracked birds at regular (approximately 12-hour) intervals.

2.2. Estimating total population distribution

To estimate total population distribution, the annual cycle of each species was split into stages, representing groups of individuals that are likely to have different distributions (Table 2). Where tracking data were available, kernel density distributions were derived for each stage (and sex if known) of a particular population. This was done in ArcGIS 8.2 using a smoothing (*h*) parameter of 1° and a grid size of 0.1° for PTT data (selected on the basis that this was likely to be the smallest practical unit for management on the high seas), and for GLS data a smoothing parameter *h* of 2°, (corresponding to the nominal resolution of the data) and a cell size of 0.5°. Data points were usually not separated into 'commuting' or 'foraging' points[1]. It is thus recognised that not all areas used by the albatrosses and petrels will be areas of foraging, although these still represent areas where there is potential interaction with fisheries. Grids were combined to produce an overall density distribution for the species for each year quarter (where Q1=Jan-March, Q2=Apr-Jun, Q3=Jul-Sept, Q4=Oct-Dec), based on the length of the stage (start/end dates rounded up to 0.5 months), the proportion of time spent at sea during the stage, and the proportion of birds in the stage.

Estimation of total distribution requires assumptions on the population structure of each species. In albatrosses and petrels, fledged chicks do not return to their natal colony for several years, and once they do it can take several more years to form a pair-bond and start breeding. Similarly, the proportion of non-breeding adults in a population is difficult to ascertain without a long-term banding study. Non-breeding adults consist of failed breeders, those that do not attempt breeding in a given year (on 'sabbatical'), and all adults out of the breeding season ('non-breeders') (Table 2). Birds in each of these stages have differing ties to the colony and provisioning demands, which can lead to differing distributions. For the purposes of this analysis, populations were assumed to comprise 20% juveniles, 10% immatures (pre-breeders) and 70% adults. These are considered reasonable assumptions for a long-lived species with a low reproductive rate (e.g. Arnold *et al.* 2006, Anderson *et al.* 2002, Inchausti & Weimerskirch 2001). Non-breeding adults outside the breeding season include 100% of adults for annual breeders and biennial breeders with a short breeding season. For those biennial breeders with a breeding season spanning most of the year (i.e. the great albatrosses) the 'non-breeding' birds all fall under the "sabbatical" grouping. In the absence of detailed studies for a large

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[1] For Sooty Shearwater see notes in Appendix 1.

proportion of the species under consideration, it was decided to group late-failing birds with breeding birds, and sabbatical birds with early-failing birds, and assume an even number of adults falling in these two groups. If no tracking data were available for a particular stage then distribution was estimated based on the most appropriate distribution for which there were tracking data. Details of the parameters and assumptions used to create the grids for each of the species considered in this paper are given in Appendix 1.

Table 2. Annual stages for seabird species under consideration

Stage	Season	Age class	Notes	Proportion time at sea
Incubation	Breeding	Adult	The pre-egg period was included in this stage as no tracking data was available	0.5
Brood-guard	Breeding	Adult	In the case of burrowing petrels, where the brood period is very short, lasting only a few days, this stage was ignored	0.5
Post-guard	Breeding	Adult		1
Early fail	Breeding	Adult	Breeding adults that fail before brood-guard – combined with sabbaticals	1
Late fail	Breeding	Adult	Breeding adults that fail after brood-guard – combined with breeders	1
Sabbatical	Breeding	Adult	Non-breeding adults during the breeding season	1
Immatures (B)	Breeding	Immature	Pre-breeders that have returned to the colony	1
Non-breeders	Non-breeding	Adult	Non-breeding adults during the non-breeding season - in annual breeders this is all adults	1
Immatures (NB)	Non-breeding	Immature	Pre-breeders that have returned to the colony	1
Juveniles	Breeding & Non-breeding	Juvenile	Juveniles that have not returned to the colony since fledging	1

In interpreting the resulting distributions, it is important to note that density distributions may include some bias in favour of areas near to the locations at which tracking devices were deployed, particularly in the case where birds were tracked after being caught at sea ('at-sea deployments'), where the tracks are not independent samples of the species' distribution.

An additional point that applies to all tracking analyses is that care must be taken when interpreting maps which have been based on small sample sizes. Ideally, analysis would be based on at least 10-15 tracks for each breeding stage, and preferably each sex, before results would be considered to approach reliability, though the effect of sample size varies between species (BirdLife International 2004).

2.1 Overlap with IATTC longline fishing effort data

The IATTC area used for analysis in this paper is that defined under the Antigua Convention, extending to 50°N and 50°S, bounded to the west by 150°W. Quarterly longline effort per 5° grid square was obtained for the period 2000-2005 from the IATTC public domain data. As over 60% of the effort data are sample data i.e. it have not been raised to agree with nominal catches, the effort data represent the extent and relative intensity fishing of fishing effort, rather than actual number of hooks.

For each species, the percent at-sea time spent within the IATTC area was obtained using the distribution grids produced in Section 2.2. The percentage at-sea time spent within each 5x5° grid square for which longline fishing effort occurred in 2000-2005, was also calculated. In addition, the proportion of average quarterly IATTC longline effort falling within the range defined by the seabird distribution gird for the relevant quarter was calculated. The actual magnitude of effort should not have a significant effect on these overlap statistics.

3. RESULTS

The Global Procellariiform Tracking Database holds relevant remote tracking data for 11 of the 13 albatross species whose ranges overlap with the IATTC area, as well as for one of the four petrel species, and Short-tailed Shearwater. Figures 1-13 show the seasonal distribution of these seabird species within the IATTC area and their overlap with IATTC longline fishing effort (based on IATTC longline effort data for 2000-2005). The percent time that each seabird species is estimated to spend within the IATTC area is summarised in Table 3. Table 4 refines this to the % time spent within IATTC 5x5 grid squares in which longline fishing effort occurred during 2000-2005 (based on data from the IATTC longline effort database).

On the maps, the 50%, 75% and 95% contours indicate the areas of highest density of seabird distribution (50% areas are highest density), while the 100% contour shows the full extent of tracked birds. In some cases, this 100% contour covers a smaller area than the estimated full range, which is shown on the map for comparison. The full ranges are based on maps held by BirdLife International and have been defined using data from a range of sources including at-sea and on-shore observations, bird band recovery data, and sources such as Harrison 1989, Tickell 2000, and Robertson *et al.* 2003. In some cases, tracked birds are located outside the estimated full range, emphasising the fact that the full ranges are estimates, and continue to be updated as new data are available.

Waved Albatross (Figure 1) has the highest degree of overlap with the IATTC area, being distributed entirely within the IATTC area at all times of the year (Table 3). Overlap with 5x5 grid squares in which longline fishing effort occurs is estimated to be in the region of 70% (Table 4).

Black-footed Albatross and **Chatham Albatross** distributions also have high overlap with the IATTC area. Year round, over 30% of Black-footed Albatross distribution is estimated to be in the IATTC area (Figure 2, Table 3). Tuna and swordfish longline effort does not extend all the way to the north IATTC boundary (particularly during the 1st and 2nd quarters of the year), meaning that the overlap between Black-footed Albatross distribution and actual IATTC longline effort is lower (13-17% overlap in Q1, Q3, Q4 and 6% in Q2). Chatham Albatross (Figure 3) has highest overlap with the IATTC area between April-September, which corresponds to its non-breeding season, when birds migrate from New Zealand to the south-west coast of South America and then transit northwards, foraging in the Humboldt Current, up to the coastal waters of Peru. During this period, more than one-third of total Chatham Albatross distribution is in the IATTC area. Outside this period, some juveniles and non-breeders remain in the Humboldt Current area, but densities are lower.

At the species level, the overlap between **Laysan Albatross** distribution and the IATTC area is relatively low (4 to 7% distribution within the IATTC across the year, Figure 4 & Table 3). However, at the colony level, overlap is high (>90%, see BirdLife International 2006) for the small population (337 pairs, or approx 0.05% total population, see Naughton *et al.* 2007) that breeds on Isla Guadalupe. Overlap would be expected to be equally high for the small Laysan Albatross populations on Rocas Alijos, San Benedicto and San Clarion (total 69 pairs, or approx 0.01% total population), for which no remote tracking data are currently available.

Similarly, at a species level the overlap between **Black-browed Albatross** and the IATTC area is relatively low (peaking at 12-14% overlap in Q2 and Q3, during the non-breeding period, Figure 5 & Table 3), and a significant proportion of this distribution is south of actual IATTC longline fishing effort (Table 4). However, at a colony level, overlap is high for the Black-browed Albatrosses that breed in Chile (20% global population), particularly during the non-breeding period (April-September) when they forage further north than during the breeding season, and when overlap with the IATTC area is up to 65% (BirdLife International 2006).

Tracking data indicate that **Sooty Shearwaters** (Figure 6) are widely distributed in the North and South Pacific, but one of the preferred hot-spots during the non-breeding period is off the coast of California (Shaffer *et al.* 20006). Tracking data for White-chinned Petrels is far from complete, but some overlap is indicated (Figure 7).

For the other tracked species of albatross, the overlap with the IATTC area is estimated to be low (<=3% overlap), and overlap with grid squares in which longline fishing effort occurred in 2000-2005 is even lower (<=2% overlap). This includes Short-tailed Albatross (Figure 8), for which the tracking data indicate that 2% of total distribution time is spent within the IATTC. However, the full range of Short-tailed Albatross is considered to be substantially larger, as shown on the map.

Figure 14 shows the ranges of the two albatross species and three petrels for which there are no tracking data in the database that are relevant to the IATTC area (i.e. no non-breeding data). Figure 14 gives an indication of the overlap between the estimated ranges of these species and the IATTC area and longline fishing effort.

The tracking data indicate that the mitigation measure areas proposed in IATTC-75-07c incorporate a high proportion of the areas in which seabird distribution and IATTC longline fishing effort overlap, in which there will be risk of seabird bycatch (Table 3).

In terms of the proportion of IATTC longline fishing effort that occurs in the regions overlapping with seabird distribution, this is relatively low (Table 5). Less than 3% of IATTC longline effort overlaps with the proposed northern mitigation area during any period of the year. The suggested southern mitigation area has a higher level of overlap with IATTC longline effort, ranging from 5% longline effort in Q1 to 17.5% longline effort in Q3.

Table 3. Percent time of each species that is spent in the IATTC area, by year quarter, based on available remote-tracking data (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec). The IATTC area is that defined under the Antigua Convention. Time spent in the mitigation areas recommended in IATTC-75-07c are also given.

Species		Q1	Q2	Q3	Q4	Average
Waved Albatross	**Total**	**100**	**100**	**100**	**100**	**100**
	S proposed mitigation area	100	100	100	100	100
Black-footed Albatross	**Total**	**32**	**34**	**40**	**31**	**34**
	N proposed mitigation area	31	34	40	31	34
Chatham Albatross	**Total**	**11**	**46**	**32**	**11**	**25**
	S proposed mitigation area	11	46	32	11	25
Sooty Shearwater	**Total**	**9**	**14**	**18**	**10**	**13**
	N proposed mitigation area		9	16	4	10
	S proposed mitigation area	8	6	1	6	5
Black-browed Albatross	**Total**	**5**	**12**	**14**	**6**	**9**
	S proposed mitigation area	5	12	14	6	9
Laysan Albatross	**Total**	**7**	**7**	**4**	**5**	**6**
	N proposed mitigation area	7	7	4	5	6
White-chinned Petrel	**Total**	**2**	**9**	**10**	**2**	**6**
	S proposed mitigation area	2	9	10	2	6
Antipodean Albatross	**Total**	**3**	**3**	**3**	**3**	**3**
	S proposed mitigation area	3	3	3	3	3
Buller's Albatross	**Total**	**1**	**1**	**1**	**2**	**1**
	S proposed mitigation area	1	1	1	2	1
Grey-headed Albatross	**Total**	**1**	**2**	**3**	**2**	**2**
	S proposed mitigation area	1	2	3	2	2
Northern Royal Albatross	**Total**	**1**	**1**	**1**	**2**	**1**
	S proposed mitigation area	1	1	1	2	1
Short-tailed Albatross	**Total**	**2**	**2**	**2**	**1**	**2**
	N proposed mitigation area	2	2	2	1	2
Wandering Albatross	**Total**	**1**	**1**	**1**	**1**	**1**
	S proposed mitigation area	1	1	1	1	1

Table 4. Percent time spent within IATTC 5x5° grid squares for which there was longline fishing effort reported during 2000-2005, by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec).

Species	Q1	Q2	Q3	Q4	Average
Waved Albatross	70	65	70	67	68
Black-footed Albatross	13	6	16	17	13
Chatham Albatross	6	26	20	2	14
Sooty Shearwater	8	5	6	4	6
Black-browed Albatross	1	4	6	0	4
Laysan Albatross	3	1	2	2	2
White-chinned Petrel	0	1	0	0	1
Antipodean Albatross	2	2	1	1	2
Buller's Albatross	0	1	0	0	1
Grey-headed Albatross	0	1	1	0	1
Northern Royal Albatross	0	0	0	0	0
Short-tailed Albatross	0	0	0	0	0
Wandering Albatross	0	0	0	0	0

Table 5. Percent distribution of IATTC longline effort within the combined 50, 75 and 95% distribution contours of the species in this study, and within the mitigation areas suggested in IATTC-75-07c, by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec).

	Q1	Q2	Q3	Q4
50% contour	0.4	0.0	0.0	0.0
75% contour	0.4	0.8	0.6	0.5
95% contour	0.4	1.2	4.2	1.7
N mitigation area	2.8	0.4	2.6	2.8
S mitigation area	5.1	16.6	17.5	9.9

4. DISCUSSION

4.1 Data gaps

The analysis presented here is based on available remote-tracking data. Although the sample sizes for some of these species are relatively large (especially for Short-tailed, Black-footed and Laysan Albatross species in the North Pacific), they are still based on restricted numbers of birds, and relatively few colonies, and the density distributions are therefore likely to underestimate the full range of each species to some extent. This limitation is offset by the ability of tracking data to provide indications of density distribution, which are highly valuable for assessment of overlap with fisheries.

Nevertheless, key data gaps remain. In relation to this analysis, priority tracking data gaps include: (1) lack of tracking data for non-breeding Waved Albatross, (2) lack of tracking data for Salvin's Albatross and Buller's Albatross during the non-breeding period, (3) lack of tracking data for non-breeding Grey Petrel and Black Petrel, (4) lack of tracking data from some major colonies of Laysan and Black-footed Albatross, (5) lack of tracking data for non-breeding Southern Royal Albatross.

While this analysis has had to estimate the non-breeding distribution of Waved Albatross, data from other sources has found that observations of Waved Albatross are rarely made outside the Peruvian Upwelling area (Tickell, 2000), and observational data from other sources indicate the highest aggregations of Waved Albatross on the Peruvian continental shelf occur during the non-breeding season (Goya & Cardenas, 2003).

Seabird-at-sea observations are also an important source of distribution data for other seabird species within the IATTC area. While few or no non-breeding tracking data are currently available for the distribution of Buller's, Salvin's and Southern Royal Albatross, observations from other sources indicate that they are commonly observed off the South American coast (Jehl 1973, Stahl *et al*. 1998, Robertson *et al*. 2003, Spear *et al*. 2003, Goya & Cardenas, 2003). In surveys from 15 research cruises, Salvin's Albatross had a somewhat similar distribution to Chatham Albatross, being abundant between 10-40°S, with Buller's Albatross distributed slightly further south, being most abundant below 30-40°S (Spear et al, 2003). All species would be expected to be present in the Southeast Pacific in some number year-round, although peak abundances of Chatham and Salvin's albatross have been recorded in April –September, with Buller's most abundant in Sept-December (Stahl et al, 1998, Spear et al, 2003).

In addition, there are data gaps within the current IATTC longline effort database, meaning that overlaps calculated here are in terms of overlap with areas fished, rather than actual number of hooks.

4.2 Importance of the IATTC area for albatross and petrel species
The analysis has highlighted the importance of the IATTC area for Waved Albatross, Black-footed Albatross and Chatham Albatross. At a species level, overlaps between the IATTC area and Laysan Albatross and Black-browed Albatross distributions are relatively low, but overlap is highly important at a colony level for some colonies of these species (including Laysan Albatross from Isla Guadalupe and Black-browed Albatross from Chile). No remote tracking data are currently available for Buller's and Salvin's Albatross in the south-east Pacific, but at-sea observations indicate the importance of the IATTC area for these species, and the degree of overlap would be expected to be similar to that of Chatham Albatross (see section above).

This analysis has provided for the first time an estimate of the seasonal distribution of the total population of each species. Waved Albatross and Black-footed Albatross have a high overlap with the IATTC area throughout the year. In contrast, the distribution of birds in the south-east Pacific is highest during April-September, corresponding to non-breeding periods, during which birds are not constrained to returning to breeding sites to feed their chicks, and are able to forage in the rich foraging grounds of the Humboldt Current.

The analysis indicates that the mitigation areas suggested in IATTC-75-07c incorporate a high proportion of the distribution of albatrosses, petrels and shearwaters (the species considered most at risk of bycatch in longline fisheries) in the East Pacific. In the northern area, the tracking data distribution of Laysan and Black-footed Albatross extends slightly to the south of the suggested boundary. In the southern area, the suggested area is slightly larger than the observed seabird distribution. However, the lack of distribution data for a number of seabird species suggests that this area is likely to be appropriately precautionary, as can be seen by comparison with estimated total ranges.

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APPENDIX 1.

Table A. Breeding Chronology (values in brackets are assumed from similar species or inferred from other data presented in this table)

Species	Return date[a,b]	Laying period date[a,b]	Median egg date[a,b]	Incubation (days)[a,d]	Hatch date[a,b]	Brood-guard period[a,b]	End brood-guard date[a,c]	Fledging (days)[a,d]	Fledge date[a,b]
Antipodean Albatross[e]	(end Dec)[f]	end Jan	25 Jan	(c. 2.5 months)[g]	end Apr	(c. 1 month)[g]	end May[h]		mid Jan
Black-browed Albatross	early Sep-early Oct	19-27 Oct	(23 Oct)	65-72, 68±1.2	most early Dec	c. 3 weeks[i]	(late Dec)	116-125[j]	late Apr
Black-footed Albatross[k]	mid Oct	mid-late Nov		60[l]	mid Jan- early Feb	1 month[l]	(mid Feb-early Mar)		Jun-Jul[k,l]
Buller's Albatross[m]	mid Dec-mid Jan	late Jan	3rd week Jan	69.1±1.3	2 Apr	23-25 days	(end Apr)	167±9.7	13 Sep
Chatham Albatross[n]	(Aug)[o]	Aug-Sep		66-72	Oct-Dec	(c. 3 weeks)[g]	(Nov-Jan)		Feb-Apr
Grey-headed Albatross	early Sep-early Oct	20 Oct	20 Oct	69-78, 72±1.6	most Dec	c. 3 weeks[i]	(Jan)	141	May
Laysan Albatross[k]	early Nov	mid Nov-mid Dec		60[l]	late Jan- mid Feb	1 month	(late Feb- mid Mar)		early Jul
Northern Royal Albatross[p]	(Oct)[f]	Nov		79	(Nov-Jan)	(c. 1 month)[g]	Mar[q]	240	Sep
Short-tailed Albatross[r]	Oct	late Oct-late Nov		64-65	Dec-Jan	"few weeks"	Feb[s]	c. 5 months	mid May - Jun[s]
Wandering Albatross	Nov	10 Dec-17 Jan	24 Dec	78.4±1.2	most Mar	c. 1 month	(Apr)	278±17	most Dec
Waved Albatross[t]	late Mar	mid April-early Jun[x]	4 May	62[x]	3 Jul	(1 month)[u]	(early Aug)	170	17 Dec
White-chinned Petrel	mid Sep	mid Nov-mid Dec	22 Nov	57-62, mean 58.9	(20 Jan)	3.8 days[v]	(late Jan)	87-106, mean 98.1[w]	(late Apr)
Sooty Shearwater	late Sep	mid Nov-early Dec	(end Nov)	52.7-56	24 Jan	5 days	(end Jan)	97	late Apr-mid May

Appendix 1 (continued).

Notes to Table A.

[a] Assume the same for all colonies. Brooke 2004 unless otherwise stated
[b] Brooke 2004 unless otherwise stated
[c] Inferred from hatch and brood-guard period unless otherwise stated
[d] Schreiber unless otherwise stated
[e] Walker *et al.* 2002 unless otherwise stated
[f] No information - assumed the pre-egg period was 27 days, similar to congeners
[g] No information - assumed similar to congeners
[h] Imber 2005
[i] Phillips *et al.* 2004b
[j] Brooke 2004 gives 116 days
[k] Fefer *et al.* 1983 unless otherwise stated
[l] Naughton *et al.* 2007
[m] Sagar & Warham 1998
[n] Robertson *et al.* 2000 unless otherwise stated

[o] No information - assumed pre-egg period c. 3 weeks similar to congeners
[p] Gales 1998 unless otherwise stated
[q] Robertson 1998
[r] USFWS 2005 unless otherwise stated
[s] R. Suryan, pers comm.
[t] Harris 1972 unless otherwise stated
[u] Harris 1972 gives brood as "several weeks" and guard as "several weeks", assume the same as congeners
[v] Marchant 1991
[w] Hall 1987
[x] D. Anderson, pers comm..

Table B. Distribution data used[1] - see Appendix 2 for colonies tracked and sample size

	Distribution data used[1] - see Appendix 2 for colonies tracked and sample sizes							
Species	**Incubation**	**Brood-guard**	**Post-guard**	**Sabbatical**	**Immatures (B)**	**Non-breeders**	**Immatures (NB)**	**Juveniles**
Antipodean Albatross	PTT tracking (also pre-egg)	PTT tracking	PTT tracking	Breeders	Breeders		PTT tracking	
Black-browed Albatross	PTT tracking	PTT tracking	PTT tracking	Breeders	Breeders	GLS tracking	Non-breeders	Non-breeders
Black-footed Albatross	PTT tracking	PTT tracking	PTT tracking	Non-breeders	Non-breeders		PTT & GLS tracking	
Buller's Albatross	PTT tracking (also pre-egg)	PTT tracking	PTT tracking	Breeders	Breeders		PTT & GPS tracking	
Chatham Albatross	Breeders	PTT tracking		Breeders	Breeders		PTT tracking	
Grey-headed Albatross	PTT tracking	PTT tracking	PTT tracking	Breeders	Breeders	GLS tracking	Non-breeders	Non-breeders
Laysan Albatross	PTT tracking	PTT tracking	PTT tracking	Non-breeders	Non-breeders	PTT & GLS tracking	Non-breeders	Non-breeders

Northern Royal Albatross	PTT & GPS tracking	PTT tracking		Breeders	Breeders		PTT tracking	
Short-tailed Albatross	Breeders	Breeders	PTT tracking	Non-breeders	Non-breeders		PTT tracking	
Wandering Albatross	PTT & GPS tracking	PTT & GPS tracking	PTT & GPS tracking	Breeders	Breeders	PTT tracking	Non-breeders	Non-breeders
Waved Albatross	PTT tracking	PTT & GPS tracking	PTT tracking	Breeders	Breeders	Range	Range	Range
White-chinned Petrel	PTT tracking	PTT tracking		Breeders	Breeders	GLS tracking	Non-breeders	Non-breeders
Sooty Shearwater	GLS tracking	GLS tracking		*See notes*	*See notes*	GLS tracking	*See notes*	*See notes*

Notes to Table B.

Antipodean Albatross	Separate breeding/non-breeding grids were created for each colony and weighted by colony size. The pre-egg-laying period was modelled separately from incubation as tracking data were available. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole. All non-breeding tracks (adults and juveniles) were pooled to create the non-breeding distribution as juvenile sample sizes were small.
Black-browed Albatross	Separate breeding/non-breeding grids were created for each colony and weighted by colony size. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole.
Black-footed Albatross	All non-breeding tracks (from adults, juveniles and immatures) were pooled to create the non-breeder distribution[2]. As this species has a restricted range without long migration routes to over-wintering grounds, it was assumed that non-breeders during the breeding season would follow the same distribution as during the non-breeding season.
Buller's Albatross	Separate breeding/non-breeding grids were created for each colony and weighted by colony size. The pre-egg-laying period for the Snares was modelled separately from incubation as tracking data were available. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole. All non-breeding tracks (adults and juveniles) were pooled to create the non-breeding distribution as age class was unknown for a large proportion of the tracks.
Chatham Albatross	Breeding data only consisted of chick-rearing tracks, and these were not separated into brood-guard and post-guard stages. Thus all breeding tracks were pooled and used to model the breeding distribution irrespective of breeding stage. Non-breeding birds (except juveniles) during the breeding season were assumed to have the same distribution as breeders. All non-breeding tracks (adult and juvenile) were pooled to create the non-breeder distribution as sample sizes were small.
Grey-headed Albatross	Separate breeding/non-breeding grids were created for each colony and weighted by colony size. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole.
Laysan Albatross	Separate breeding grids were created for each colony and then combined, weighted by colony size. All non-breeding tracks were pooled to create the non-breeder distribution[2]. As this species has a restricted range without long migration routes to over-wintering grounds, it was assumed that non-breeders during the breeding season would follow the same distribution as during the non-breeding season.
Northern Royal Albatross	Chick-rearing tracks were not separated into brood-guard and post-guard stages; these were thus pooled. Separate breeding/non-breeding grids were created for each colony and weighted by colony size. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole. All non-breeding tracks (adults and juveniles) were pooled to create the non-breeding distribution as sample sizes were small.

Short-tailed Albatross	Only post-guard tracks were available for breeding, but as these showed a very restricted breeding range, even during late chick-rearing, it was assumed that the incubation and brood-guard stages would follow a similar distribution. All non-breeding tracks (from adults and juveniles) were pooled to create the non-breeder distribution. Although there appeared to be a general west-east migration by post-breeders, it is unsure whether this applies to all non-breeders as at-sea tracking from the Aleutians was only performed after the breeding season. It was thus assumed that non-breeders during the breeding season would follow the same distribution as during the non-breeding season, except that the distribution was restricted to no further north than the South Bering Sea/Aleutian Island chain from January to April (R. Suryan, pers comm.)
Wandering Albatross	Separate breeding/non-breeding grids were created for each colony and weighted by colony size. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole. Non-breeding data from all colonies were pooled as sample sizes were small and a large proportion of the birds were of unknown provenance.
Waved Albatross	Only breeding data were available, however the breeders covered most of the range, so it was assumed that non-breeders during the breeding season would have the same distribution. Clarke *et al.* (2003), using at-sea surveys conducted within the range of the waved albatross, developed a generalized additive model which predicted high densities of albatrosses as far as 15 deg S, where the distribution of tracked breeders did not extend beyond 13 deg S. It was thus decided to use the full range to model non-breeding distribution during the non-breeding season.
White-chinned Petrel	Only tracks from the South Georgia (Islas Georgias del Sur) population were used. Chick-rearing tracks were effectively pooled as the brood-guard stage is very short. It was assumed that non-breeders (except juveniles) during the breeding season were distributed as for breeders as a whole.
Sooty Shearwater	Breeding and non-breeding GLS data from two colonies in New Zealand were available; these were pooled as tracking shows that there are no colony-specific differences in distribution (Shaffer *et al.* 2006). Chick-rearing tracks were pooled as the brood-guard period is very short. Post-breeders performed a fairly synchronous migration from the south-west Pacific to the northern and eastern Pacific in April and May, returning to the colonies in October. The birds performed an incredibly fast transit of the central Pacific, during which they did not stop to forage (Shaffer *et al.* 2006). These transit points were thus separated out by selecting all points during April, May and October with a velocity, averaged over the preceding and following 24 hours, of 22 km.hr^{-1}, which corresponds to the lower limit of the migration rate given in Shaffer *et al.* (2006). The paths of the tracked birds, outside the range of the foraging areas, were then calculated by assuming a straight line between successive points. The remaining points were used to generate kernel density distributions of foraging areas. To model the post-breeder distribution during the non-breeding season the tracking points were grouped by date. However non-breeders (juveniles, immatures and adults on sabbatical), may have a slightly different migration schedule as they are not constrained by breeding. Harrison (1989) places this species in the northern portion of its range from June to November, and in the south from September to April. Separate distributions were thus produced from the northern and eastern portion of the post-breeders' range, and also from the south-western portion, and were used to model non-breeder distribution during these two periods.

[1] Merged cells indicate where tracks from different phases were pooled
[2] Separate grids were produced for PTT and GLS data, and then combined, weighting them by the number of hours of tracking in each grid - see methods

APPENDIX 2.

Remote tracking data held in the Global Procellariiform Tracking Database for species addressed in this paper.

| Species	Site	Annual Breeding Pairs	Global popn (%)	Data submitted: Status (Number of tracks) All tracks are PTT unless otherwise specified.
Antipodean Albatross	Antipodes Is	5,148	41%	Breeding (79 tracks), non-breeding (including post-breeding and juveniles) (33 tracks)
(Gibson's Albatross)	Auckland Is	7,319	59%	Breeding (43 tracks), post-breeding (22 tracks)
Black-browed Albatross	Chile	122,870	20%	Breeding (165 tracks), post-breeding (5 GLS)
	Falkland Islands (Islas Malvinas)	380,000	62%	Breeding (206 tracks), post-breeding (1 PTT, 38 GLS), juveniles (3 tracks)
	Iles Kerguelen	4,270	1%	Breeding (26 tracks)
	Macquarie Island	182	0%	Breeding (7 tracks)
	South Georgia (Islas Georgias del Sur)	100,332	16%	Breeding (365), post-breeding (3 PTT, 49 GLS)
	At-sea deployment			Non-breeding adult (2) and juveniles (6 tracks)
Black-footed Albatross	Midway Atoll	21,830	35%	Non-breeding juvenile (10 tracks)
	Tern Island (FFS)	4,259	7%	Breeding (99), non-breeding (24 GLS, 1 PTT)
	At-sea deployment			Non-breeding adult (20) and immature (13)
Buller's Albatross	Snares Is	8,465	27%	Breeding (180) and non-breeding (including juveniles) (97 PTT, 19 GPS, all during breeding)
	Solander Is	4,800	15%	Breeding (49 tracks), non-breeding (including post-breeding) (137 tracks, all during breeding)
Chatham Albatross	Chatham Is	4,000	100%	Breeding (16 PTT, 3 GPS), non-breeding (including post-breeding and juveniles) (19)
Grey-headed Albatross	Campbell Island	6,400	6%	Breeding (5 tracks)
	Chile	16,408	15%	Breeding (67 tracks), post-breeding (1 track)
	Macquarie Island	84	0%	Breeding (9 tracks)
	Prince Edward Is	7,717	7%	Breeding (6 tracks)
	South Georgia (Islas Georgias del Sur)	61,582	58%	Breeding (299), post-breeding (4 PTT, 22 GLS)
Laysan Albatross	Isla Guadalupe	337	0%	Breeding (118 tracks)
	Tern Island (FFS)	3,226	1%	Breeding (105), non-breeding (8 PTT, 28 GLS)
	At-sea deployment			Non-breeding (18 tracks)
Northern Royal Albatross	Chatham Is	2,060	99%	Breeding (28 tracks), post-breeding (15 tracks)
	Taiaroa Head	18	1%	Breeding (3 PTT, 50 GPS), non-breeding (including post-breeding and juveniles) (16)
Short-tailed Albatross	Torishima	325	84%	Breeding (8), post-breeding (14), juvenile (1)
	at-sea deployment			Non-breeding adult (3) and juvenile (6 tracks)
Wandering Albatross	Iles Crozet	2,062	26%	Breeding (204 tracks)
	Iles Kerguelen	1,094	14%	Breeding (11 tracks)
	Prince Edward Is	2,707	34%	Breeding (20 tracks), post-breeding (3 tracks)
	South Georgia (Islas Georgias del Sur)	2,001	25%	Breeding (222 PTT, 66 GPS), post-breeding (4)
	At-sea deployment			Non-breeding (5 tracks)
Waved Albatross	Isla Española	10,475	100%	Breeding (44 PTT, 21 GPS)
White-chinned Petrel	South Georgia (Islas Georgias del Sur)	2,000,000	?%	Breeding (23 tracks), non-breeding (10 GLS)
Sooty Shearwater	New Zealand (Codfish, Mana)	?	?%	Breeding (32 GLS) non-breeding (25 GLS)
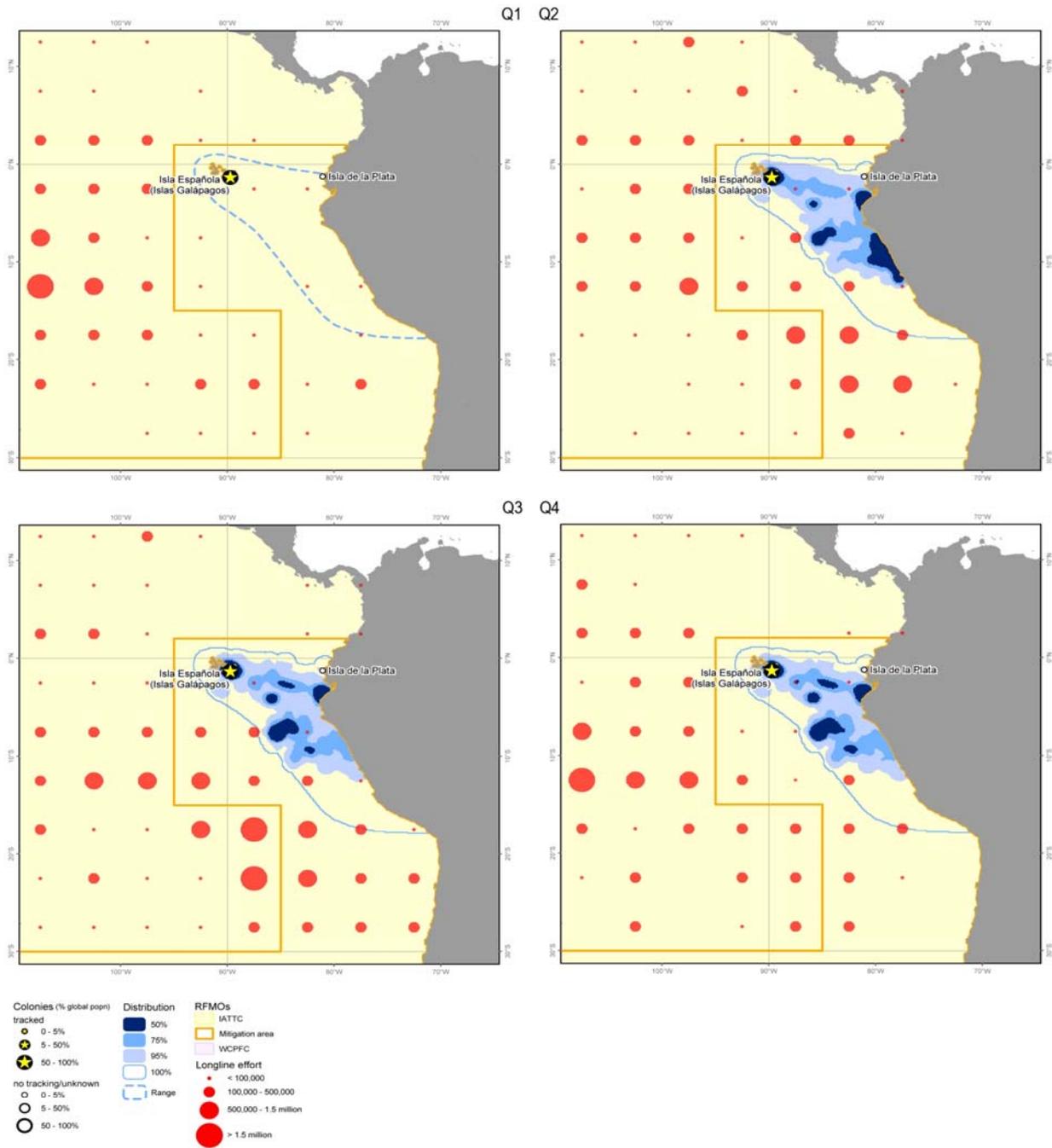
Figure 1. Waved Albatrosses distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year).
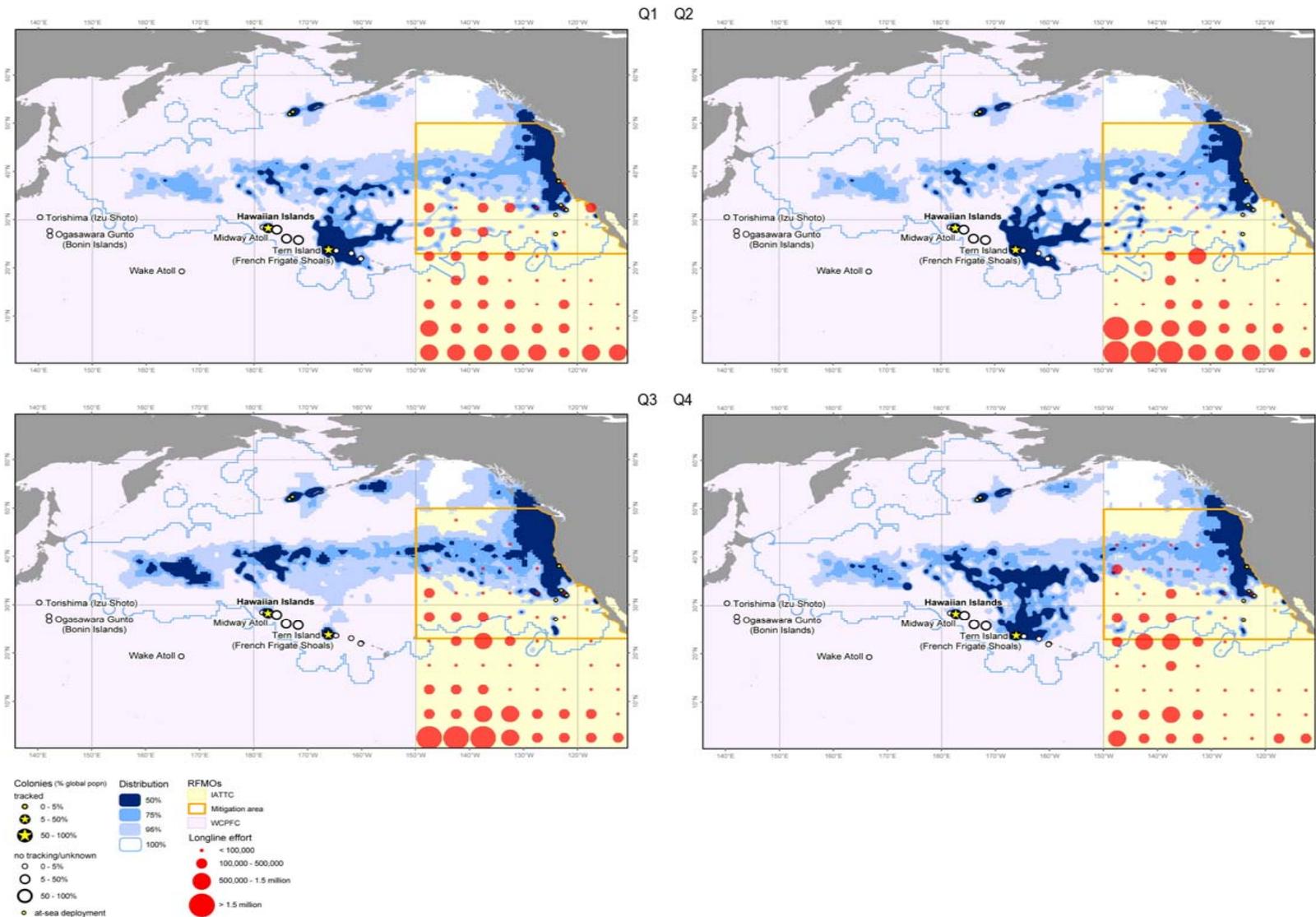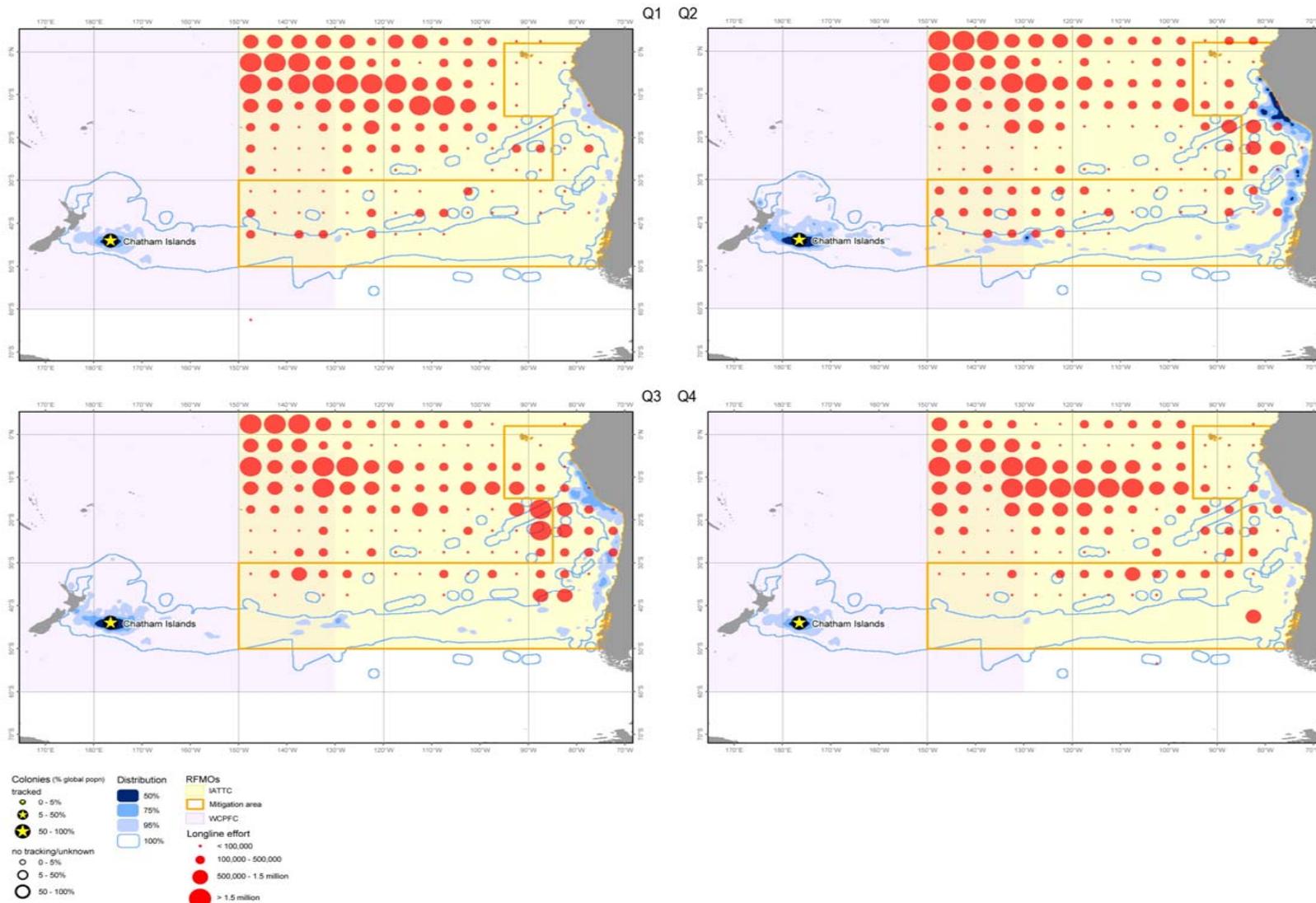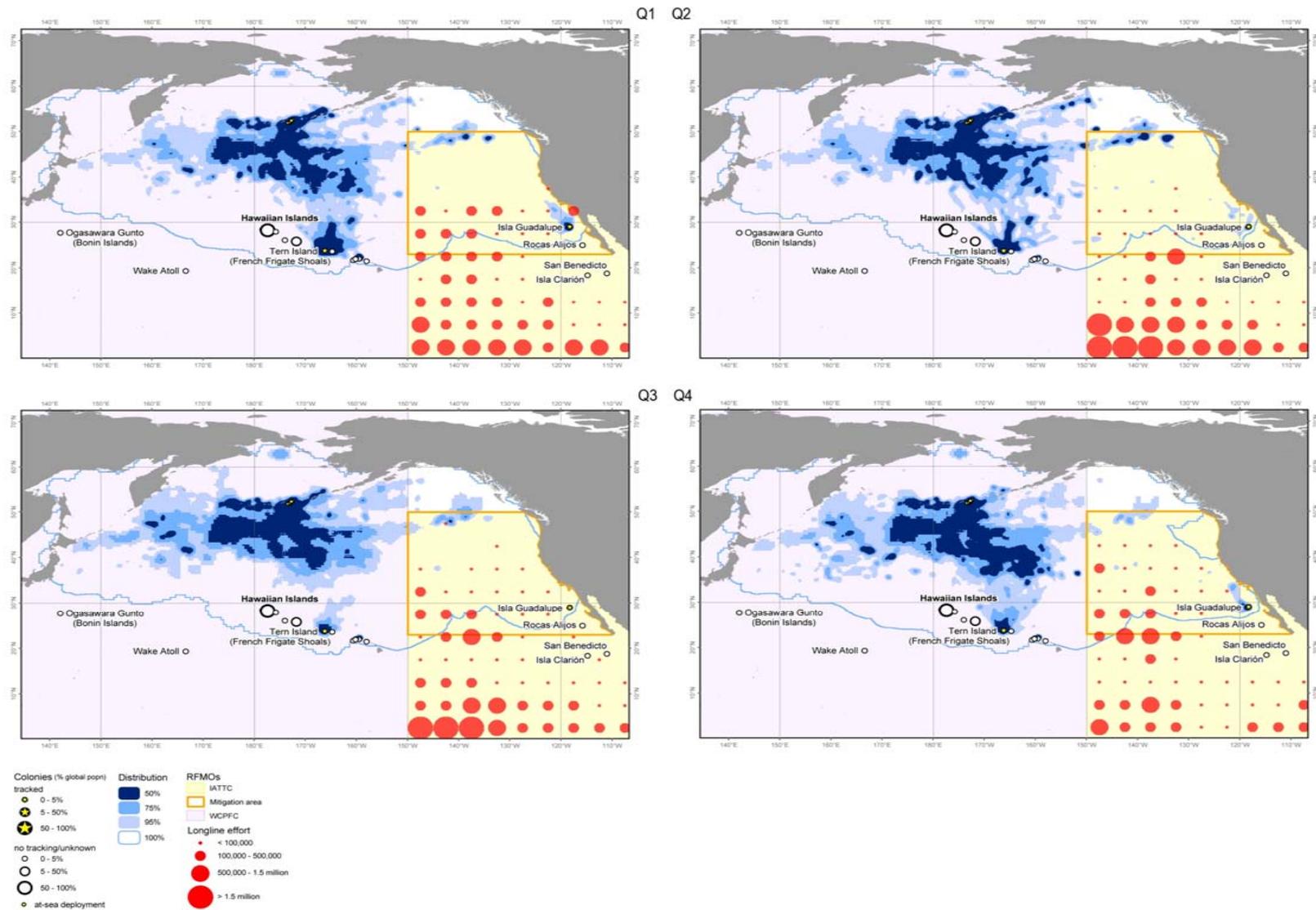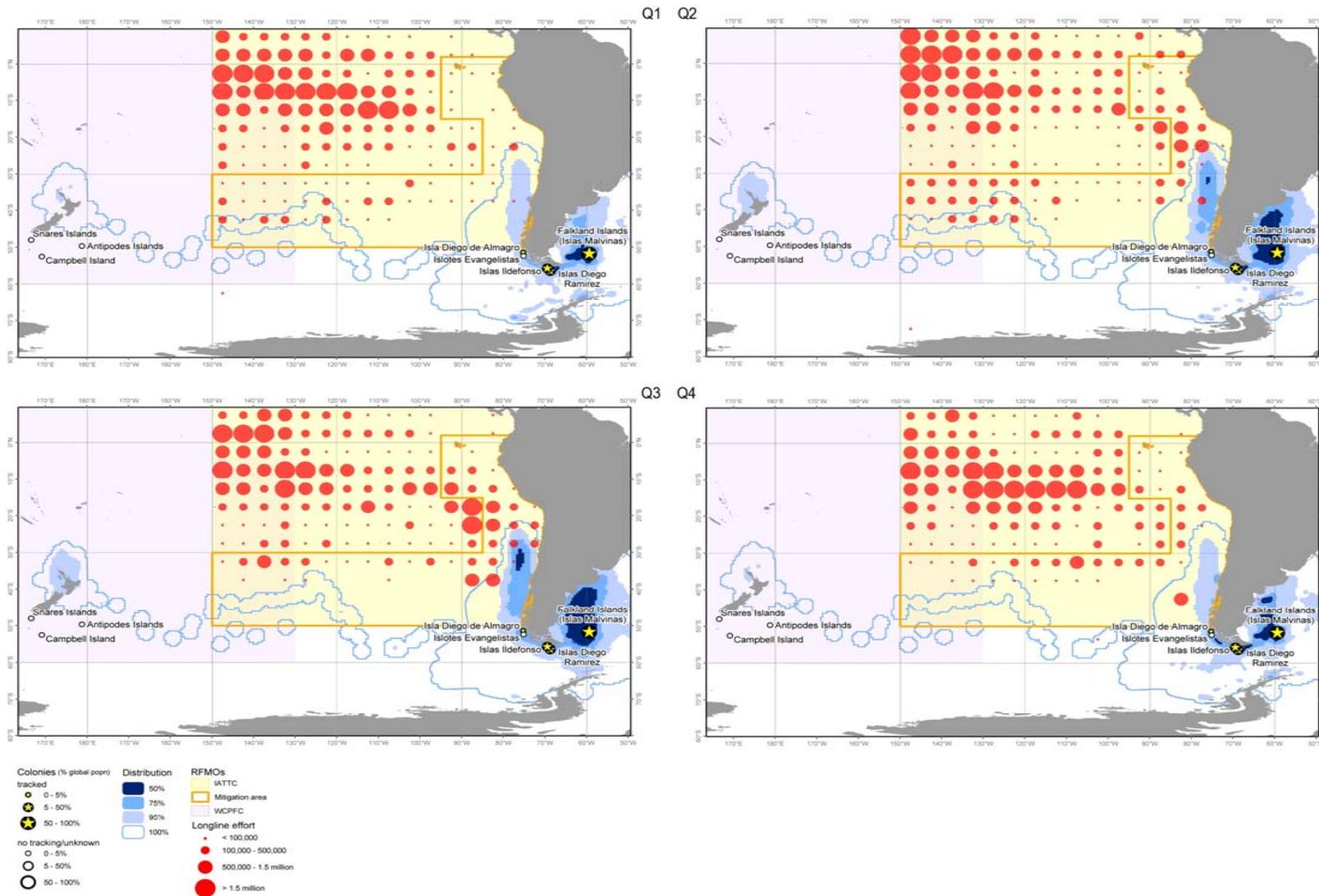
Figure 2. Black-footed Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
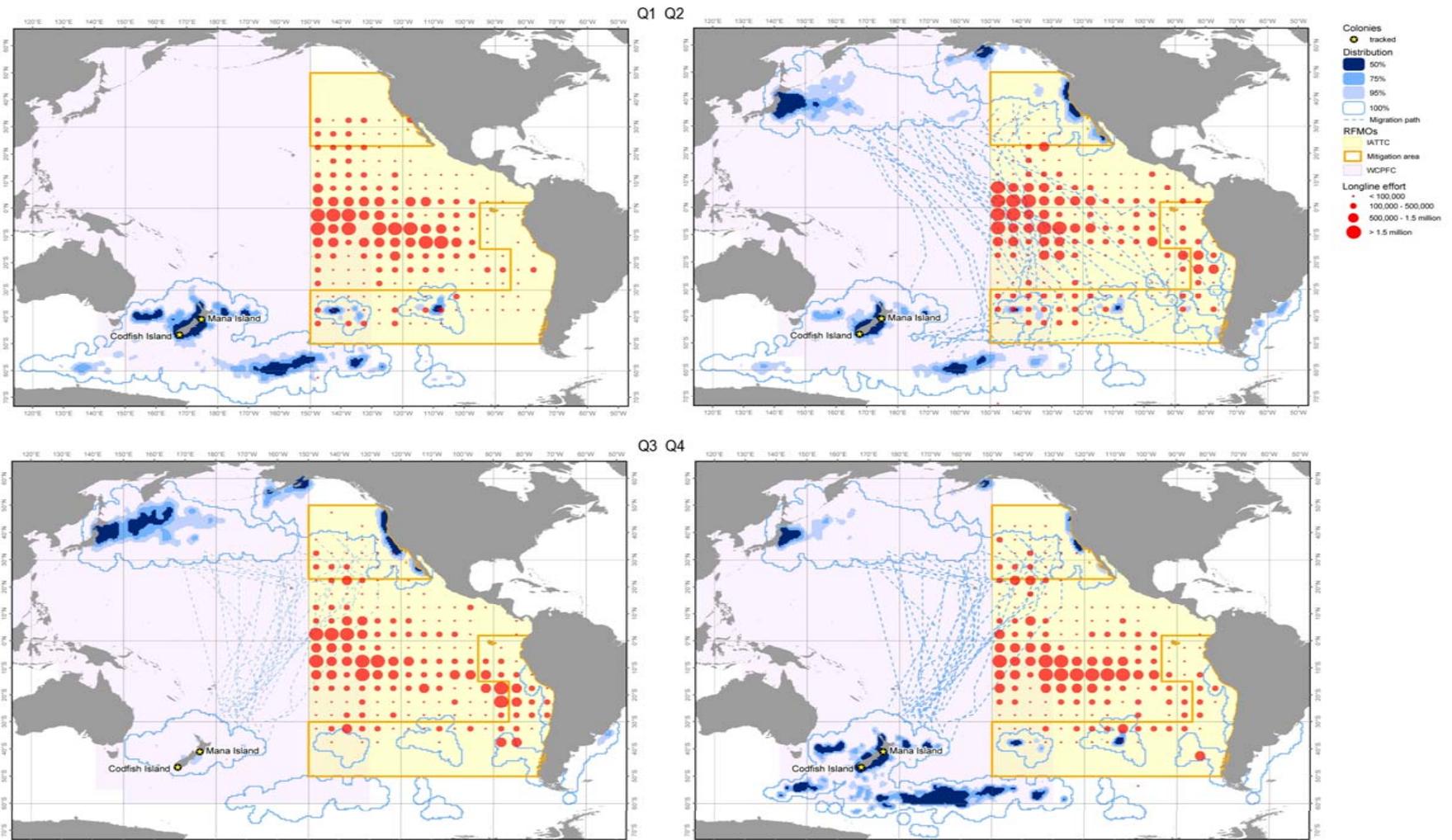
Figure 3. Chatham Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.

Figure 4. Laysan Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
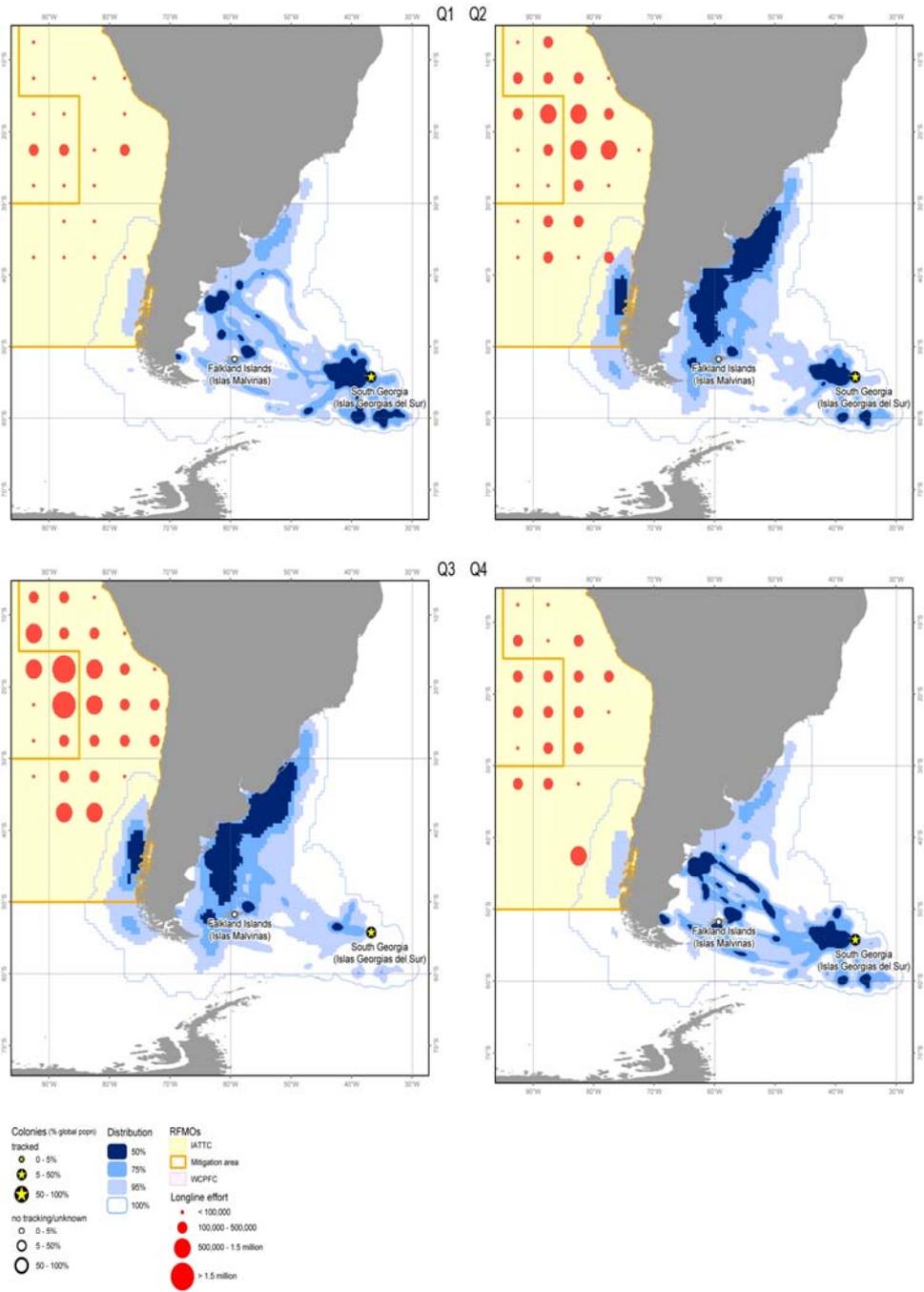
Figure 5. Black-browed Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
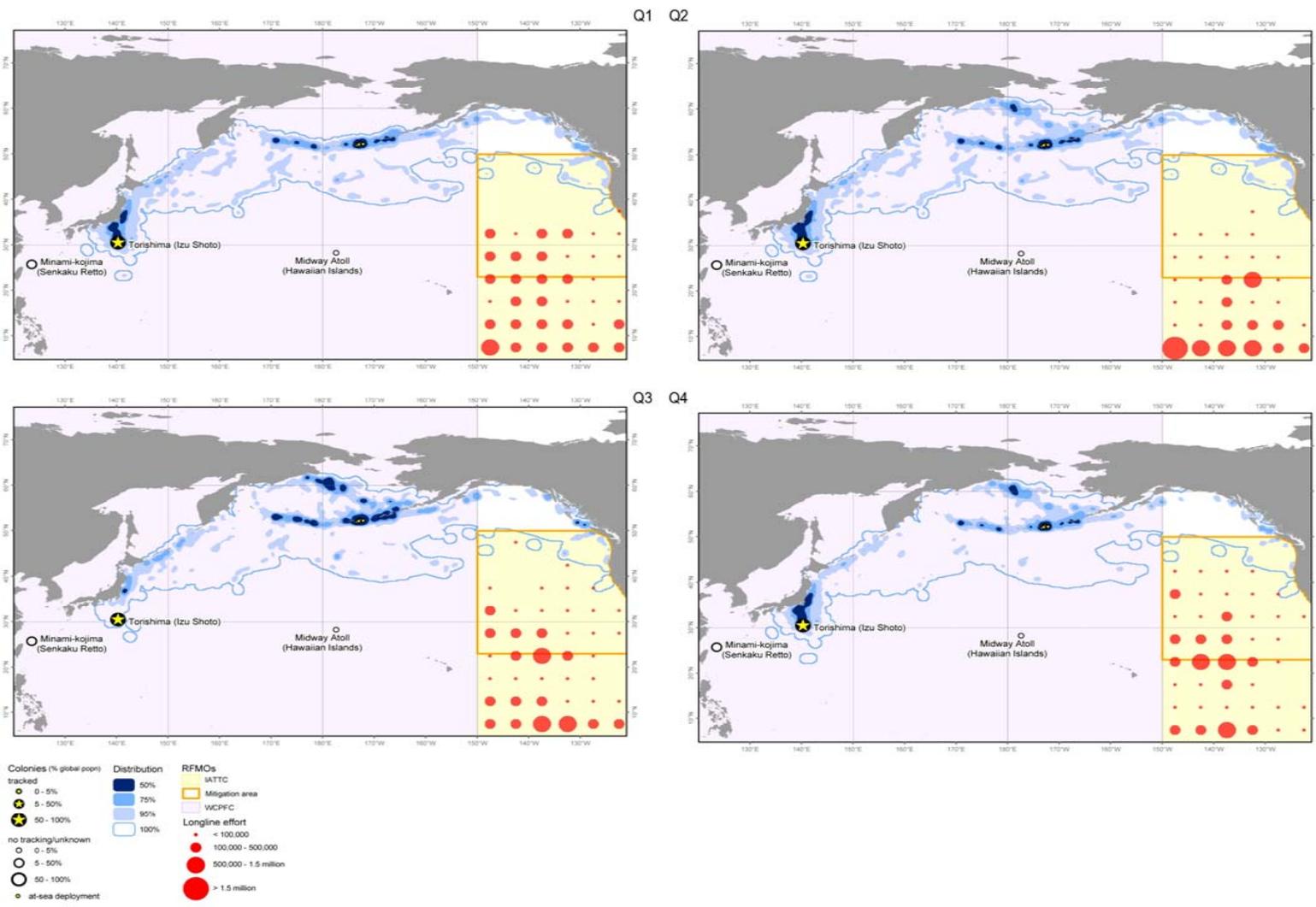
Figure 6. Sooty Shearwater distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
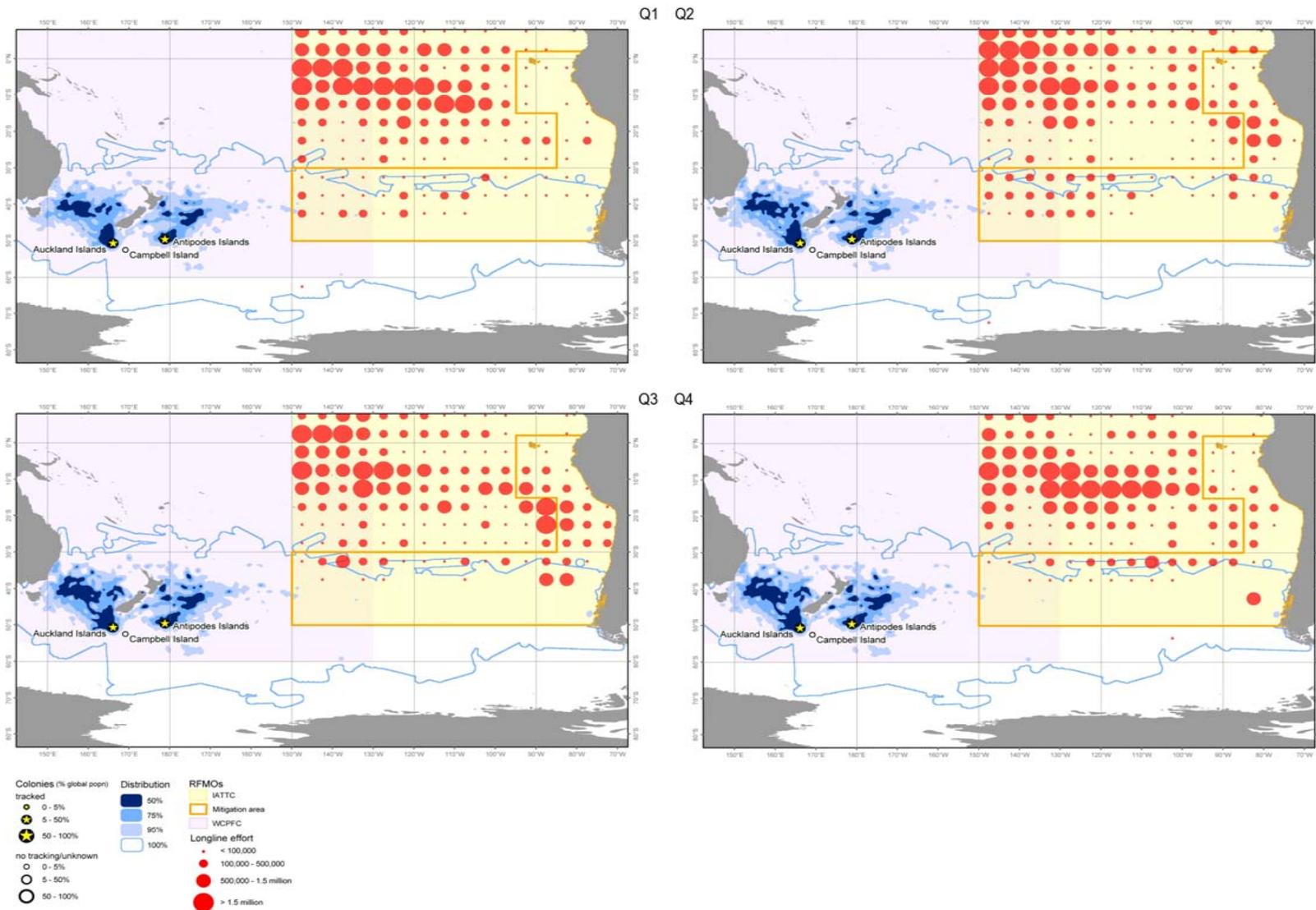
Figure 7. White-chinned Petrel distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.

Figure 8. Short-tailed Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
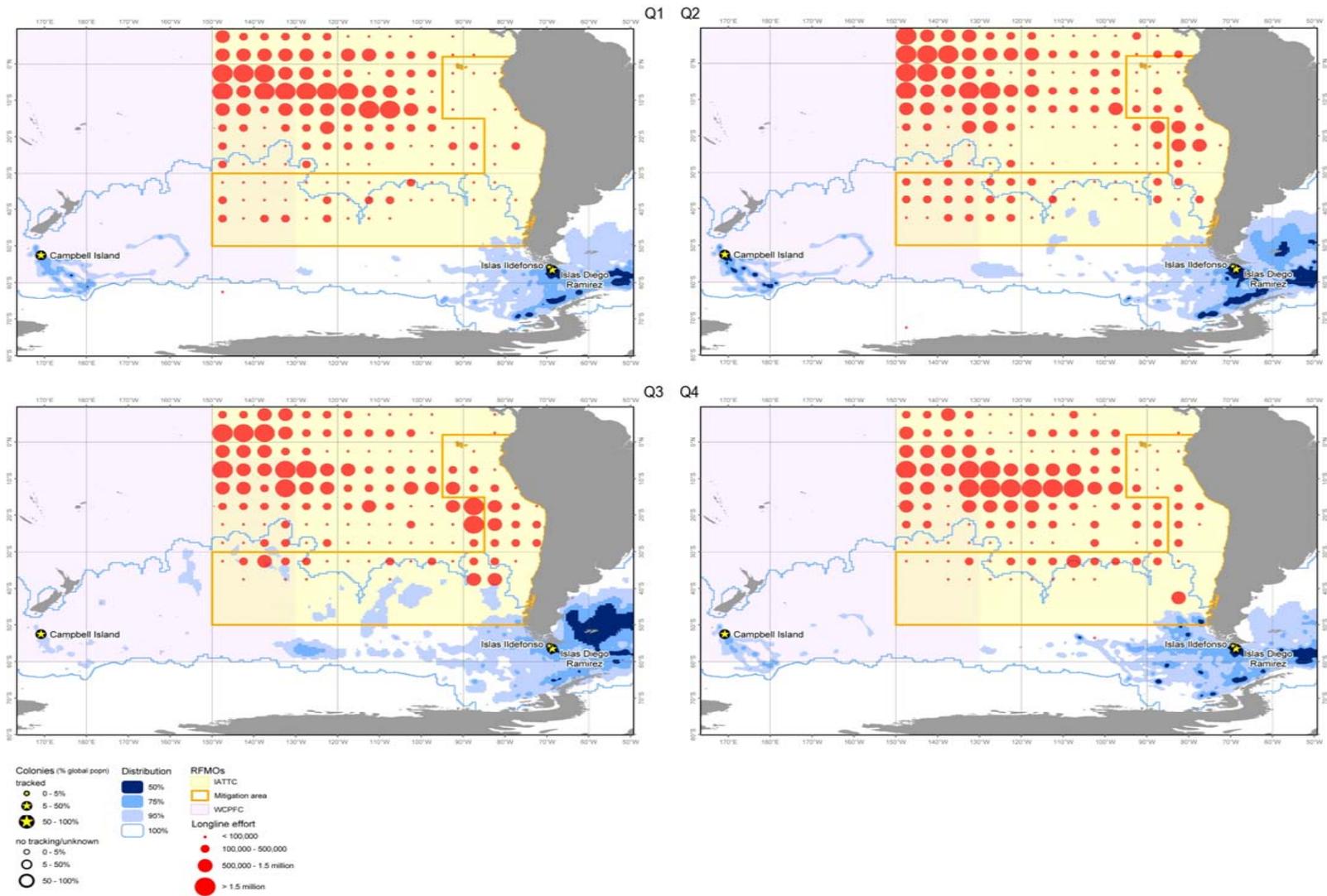
Figure 9. Antipodean Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
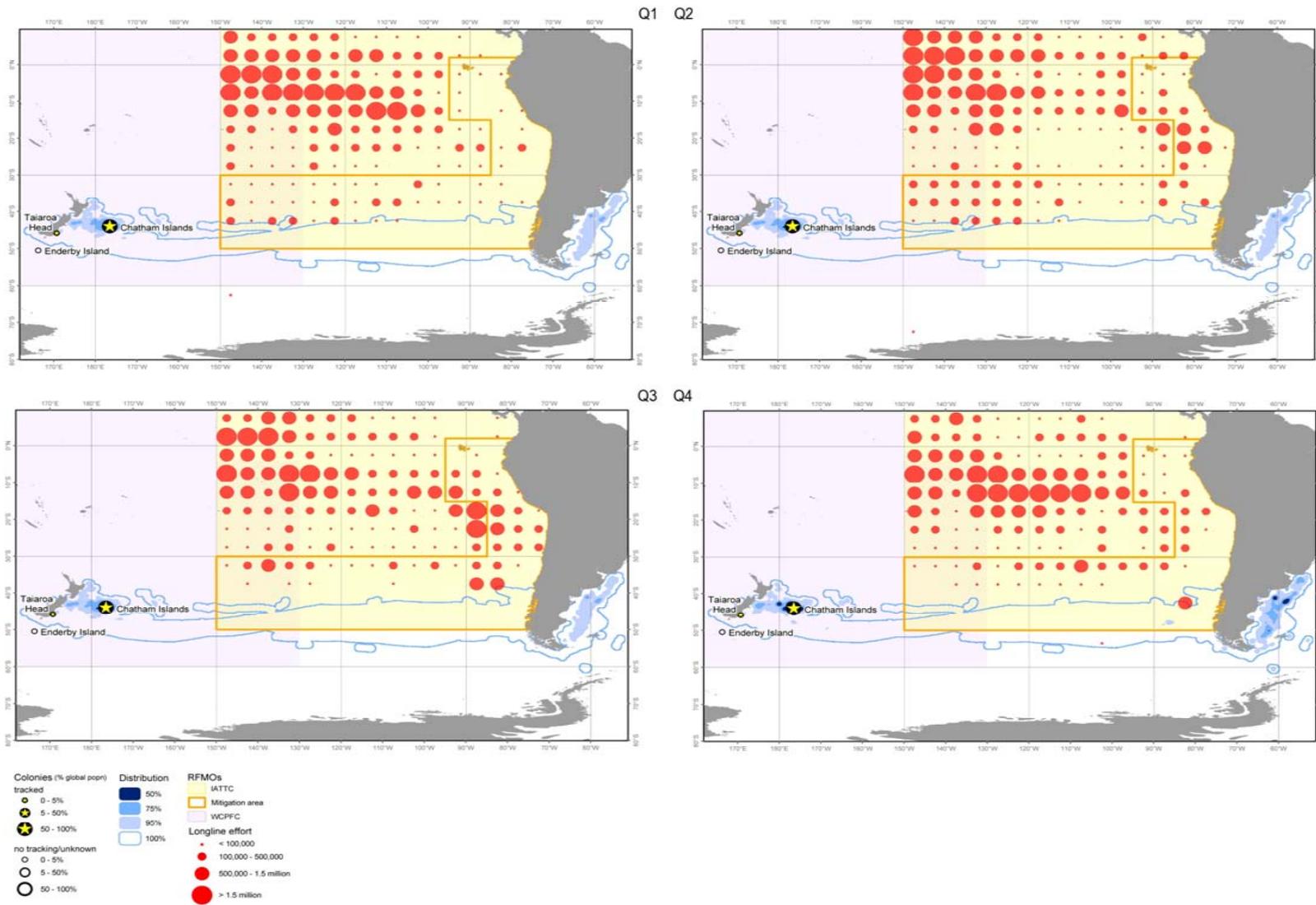
Figure 10. Grey-headed Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.

Figure 11. Northern Royal Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
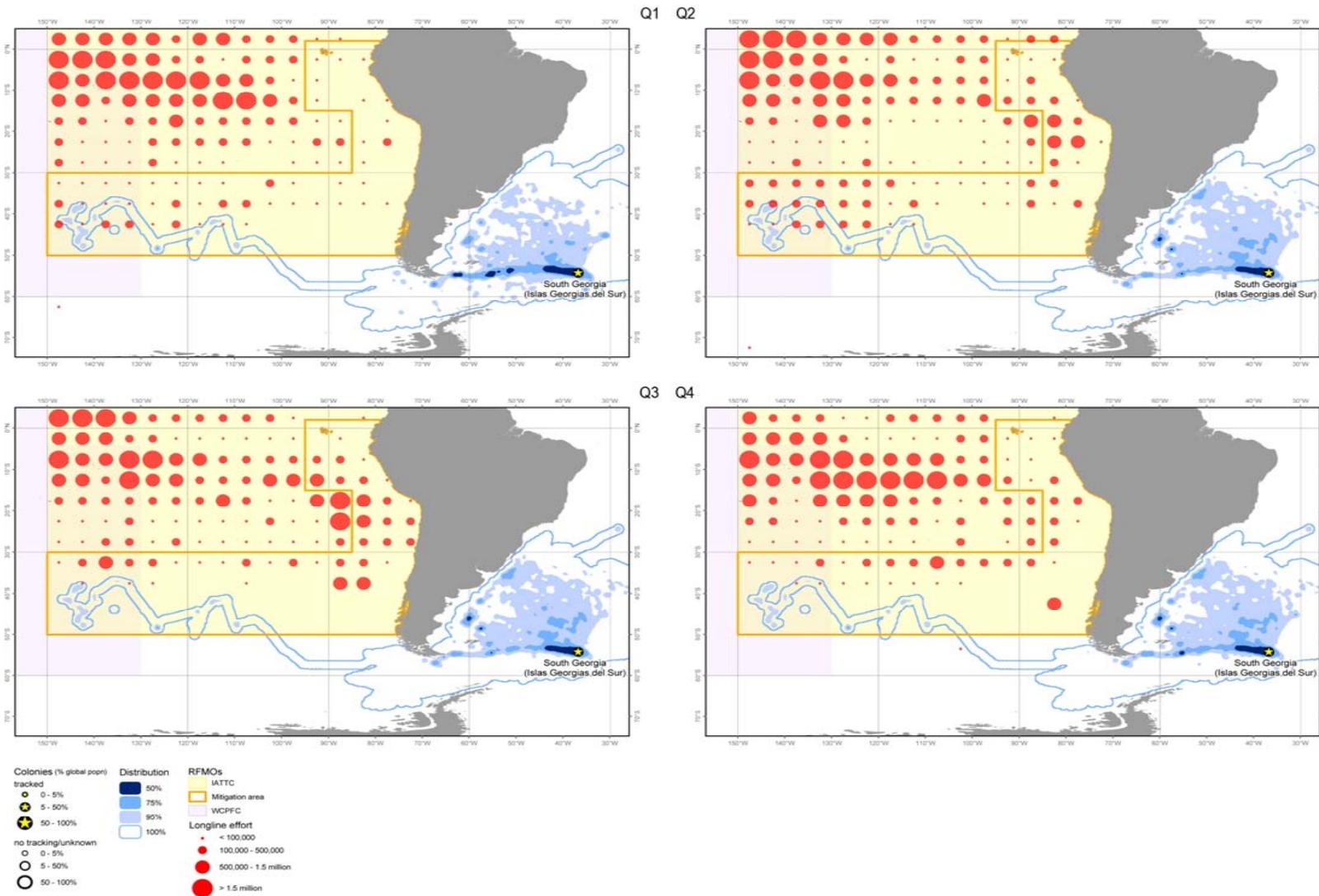
Figure 12. Wandering Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
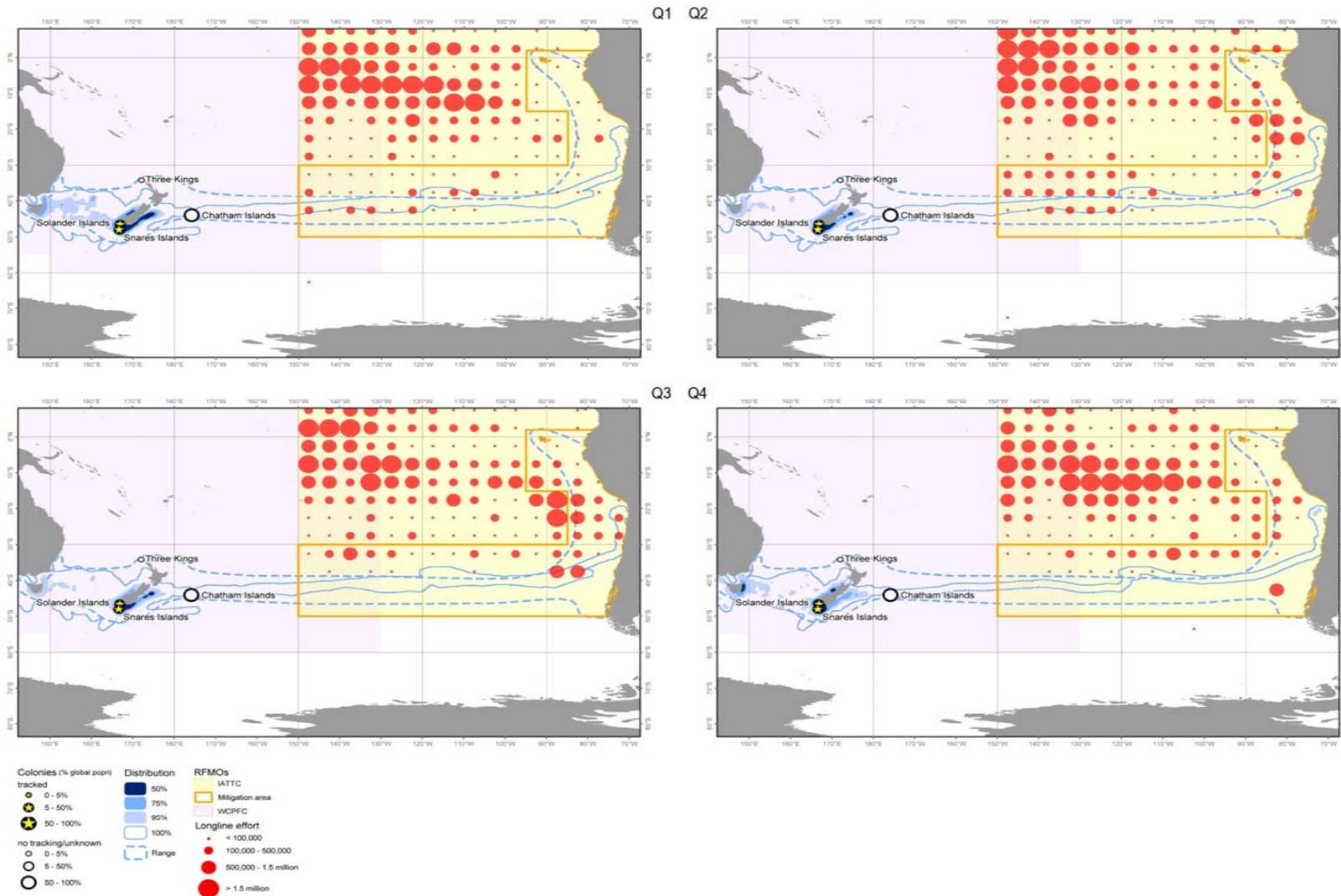
Figure 13. Buller's Albatross distribution in the IATTC area by year quarter (Q1=Jan-Mar, Q2=Apr-Jun, Q3=July-Sep, Q4=Oct-Dec), and overlap with IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per quarter per year). Highest densities of bird distribution are shown in dark blue. The 100% contour indicates the full extent of the distribution of tracked birds, and full range (estimated from other sources) is shown for comparison. The mitigation areas recommended in IATTC-75-0c are also shown.
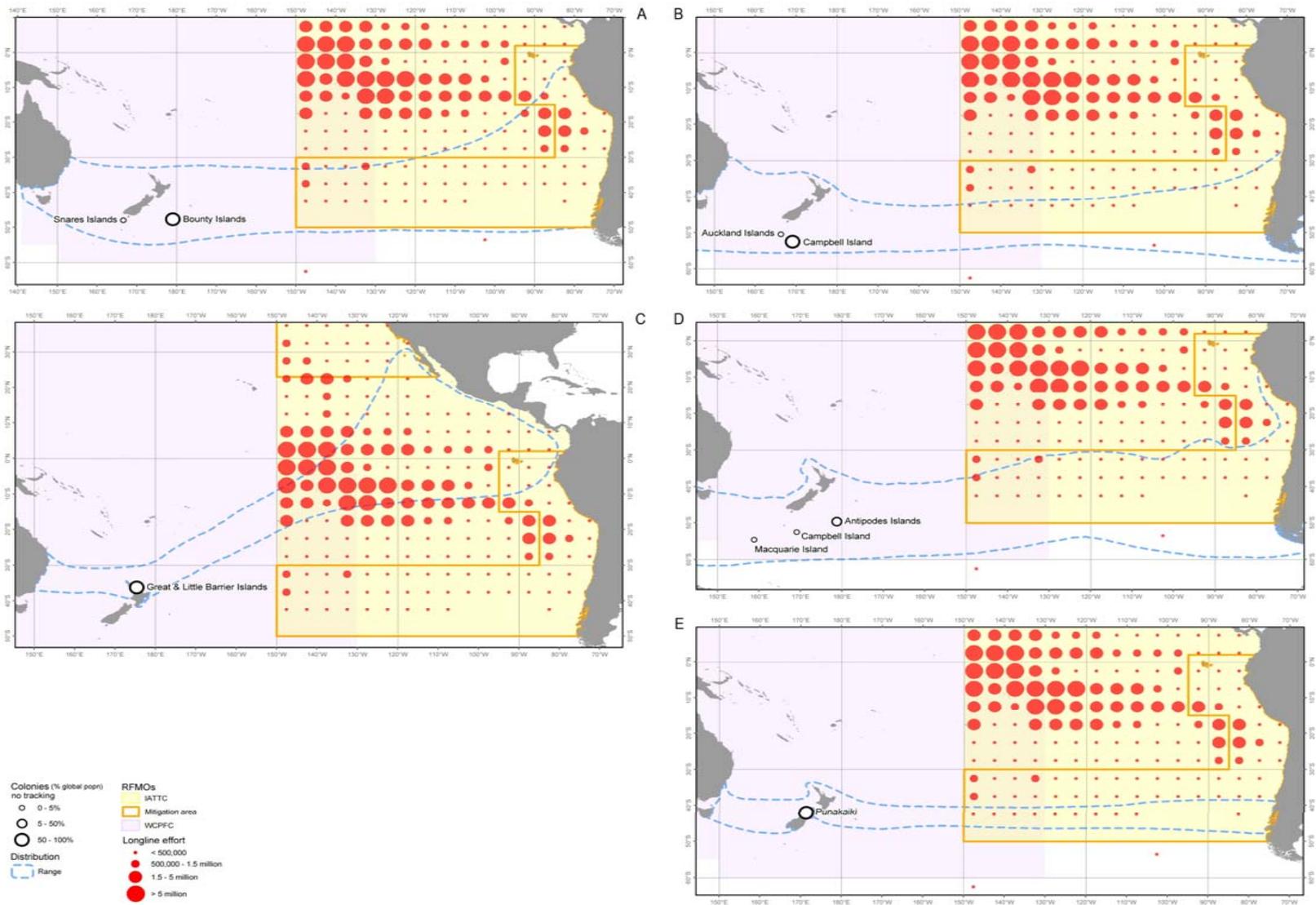
Figure 14: The range maps of species for which no relevant (i.e. non-breeding) tracking data are held in the database, and their overlap with the IATTC area and IATTC longline fishing effort 2000-2005 (average number of hooks set per 5° grid square per year). A =Salvin's Albtross, B=Southern Royal Albatross, C=Black Petrel, D=Grey Petrel and E=Westland Petrel.