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Analysis of albatross and petrel distribution and overlap with longline fishing effort within the IOTC area: results from the Global Procellariiform Tracking Database

Paper submitted on behalf of the
Agreement for the Conservation of Albatrosses and Petrels
(ACAP)
Prepared for the Third Session of the IOTC
Working Party on Ecosystems and Bycatch
Victoria, Seychelles, 11-13 July 2007

Author: BirdLife International

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ABSTRACT

This paper analyses the distribution of albatrosses and petrels in the IOTC area and the degree of overlap with IOTC longline fishing effort.

Fishing effort data indicate that IOTC longline fisheries set up to 150 million hooks per year below 30°S. Albatrosses breeding on Southern Indian Ocean Islands spent 70-100% of their foraging time within areas overlapping with IOTC longline fishing effort. Other species breeding outside the IOTC area had slight overlap.

The proximity of the Critically Endangered Amsterdam Albatross and Endangered Indian Yellow-nosed Albatross to high levels of pelagic longline effort is of particular concern. Wandering and Grey-headed Albatross also had a high overlap with fishing effort in the IOTC. There are still many tracking data gaps for non-breeding and juvenile birds. Tracking data are largely lacking for Black-browed Albatrosses and White-capped Albatrosses, but bycatch data indicate these birds are among the most frequently caught. White-chinned Petrels, caught in large numbers, showed a high overlap with IOTC longline effort although tracking data were only available from one of the three colonies.

While the pelagic longline effort for tuna was of prime importance to most species, breeding and non-breeding Shy Albatrosses showed high degrees of overlap with the swordfish longline effort (primarily Australian) in Australian waters.

Analysis of seasonal distribution was possible for two albatross species. The degree of seasonal variation will vary by species. However, for some of the albatrosses, particularly biennial breeders such as Amsterdam, Grey-headed and Wandering Albatross, birds will be distributed in the IOTC area throughout the year.

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Albatross and petrel tracking data presented in this report are from the Global *Procellariiform* Tracking Database, with additional unpublished data provided by Henri Weimerskirch, Centre d'Etudes Biologiques de Chizé. Data-holders of those data analysed in this paper are listed below. Initial results from analysis of the database have been published in *Tracking Ocean Wanderers* (BirdLife International 2004a).

Data Contributors

Satellite tracking (PTT) data contributors

Wandering, black-browed and sooty albatross and white-chinned petrel (Iles Crozet and Kerguelen), Indian yellow-nosed and Amsterdam albatross (Ile Amsterdam), Buller's albatross (Snares Islands):
Henri Weimerskirch, Centre d'Etudes Biologiques de Chizé, (CNRS UPR 1934), France.

Wandering and grey-headed albatross (Marion Island):
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Shy albatross (Tasmania), black-browed albatross (Macquarie Island):
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Wandering albatross (Australia):
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Geolocator (GLS) data contributors

Black-browed and Grey-headed albatross (South Georgia):
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Global positioning system (GPS) data contributors

Buller's albatross (New Zealand):
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1. INTRODUCTION

Albatrosses, petrels and shearwaters that forage by diving are some of the most vulnerable species to bycatch in fisheries (Wooller *et al* 1992, Brothers *et al* 1999). Nineteen of the world's 22[1] albatross species are now globally threatened with extinction (IUCN 2006, BirdLife International 2004b), and incidental catch in fisheries, especially longline fisheries, is recognised as one of the principal threats to many of these species (Robertson & Gales 1998).

The southern Indian Ocean is of global importance in relation to albatross distribution: nine of the species of albatross have breeding colonies on Indian Ocean islands. The Indian Ocean is particularly important for **Amsterdam Albatross** (Critically Endangered) and **Indian Yellow-nosed Albatross** (Endangered), which are endemic to the southern Indian Ocean, as well as **Shy Albatross** (endemic to Tasmania, and which forages in the area of overlap between IOTC and WCPFC), **Wandering Albatross** (74% global breeding pairs), **Sooty Albatross** (39% global breeding pairs), **Light-mantled Albatross** (32% global breeding pairs), **Grey-headed Albatross** (20% global breeding pairs) and **Northern and Southern Giant-petrel** (26% and 30% global breeding pairs, respectively). In addition, all but one[2] of the 18 species of southern hemisphere albatrosses forage in the Indian Ocean at some stage in their life cycle.

At the first meeting of the Working Party on Ecosystems and Bycatch (WPBy) in 2005, BirdLife International presented a paper on satellite tracking data of albatrosses and petrels (BirdLife International 2005) reporting that the IOTC area includes 21% of the global breeding distribution of albatrosses. Provisional analysis of IOTC longline fishing effort data indicated that the greatest fishing effort south of 30°S occurred in the 2nd and 3rd quarters of the year, which coincides with periods of greatest densities of non-breeding albatrosses. The meeting of the Scientific Committee in 2006 recommended that BirdLife prepare a paper examining the overlap of albatrosses and petrels with longline fisheries in more detail for presentation at the next WPBy meeting.

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, coordinated by BirdLife International. The paper explores the spatial distribution of albatrosses, petrels and shearwaters in the Indian Ocean, and the overlap with IOTC longline fishing effort. It also identifies data gaps.

2. METHODS

2.1 IOTC longline fishing effort

IOTC provided their Catch and Effort Database (CE) as well as their Nominal Catches Database (NCDB) for use in this analysis. Both databases contained complete information up to and including 2005. The analysis uses 2002-2005 data from the IOTC longline fisheries listed in Table 1, based on catch/effort data for five tuna and billfish species which make up the bulk (95%) of the nominal longline catch for the period (Table 2).

For each gear type in Table 1, effort not reported as number of hooks was converted to number of hooks using conversion factors as detailed below. The catches in the NCDB are reported by IOTC Area, defined as the Eastern (EIO) or Western (WIO) Indian Ocean, split along the 80°E line of longitude. The CE data per grid cell/year/month were raised so that the total catch in these two regions agreed with the catch reported by IOTC Area in the NCDB. For fleets which had reported effort for the period/area this was simply a matter of calculating the raising factor by dividing the nominal catch by the CE catch, and raising the effort in each grid cell/year by the calculated factor.

[1] In 2006, Shy albatross (*Thalassarche cauta*) was split into Shy albatross (*T. cauta*) and White-capped albatross (*T. steadi*), creating a total of 22 species of albatross

[2] Chatham Albatross (*Thalassarche eremita)*

Fleets for which there was no reported effort had their nominal catch assigned spatially and temporally using a proxy fleet for which there was reported effort. In most cases the fleet used to assign effort in this manner was the Taiwanese longline (LL) fleet, as this represented the most reliable effort data in the database. However in some cases other fleets, most notably the Spanish swordfish (ELL) fleet, were considered to represent the spread of the missing fleet more accurately, and were used instead. The effort of the proxy fleet was adjusted so that the CE catch matched the nominal catch for the fleet under consideration. Appendix 1 gives the raising factors and proxy fleets used for each gear type and fleet by IOTC Area and year.

The majority of the effort was reported in 5x5° grid squares; where this was not the case it was converted by totalling (in the case of 1x1° grid squares) or splitting (in the case of larger grid squares) the effort across the overlapping 5x5° squares. The average annual effort per 5x5° grid square for selected gear types and fleets was used to create kernel density distributions of longline effort. This was done using the kernel function in ArcView 8.2 with a smoothing factor (*h*) of 7.5°, chosen as it removed the grid effect without smoothing out detail. Grid squares in which no effort was reported were removed. The resultant density distributions were classified into various levels of fishing intensity for use in the calculation of effort/seabird overlap.

2.2 Albatross and petrel remote tracking data

Over 90% of existing southern hemisphere albatross and petrel tracking data have been submitted to the Global *Procellariiform* Tracking Database, representing 14 of the 18 southern albatross species, both species of giant-petrel, White-chinned Petrel, Westland Petrel, Sooty Shearwater and Short-tailed Shearwater (Table 3). The contributors of the data presented in this paper are listed on page (ii) of this report. Appendix 2 lists species names used in the text.

The satellite tracking (PTT) data were processed using standardised methods agreed among data-holders. Data points were 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 $100 km.hr^{-1}$ for all species) and an alternative latitude and longitude was provided, the filter substituted the alternative point. In an iterative process, the filter then removed the uplink with the highest velocity over *vMax*, although a point with high accuracy was 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 were then recalculated and the process repeated, until no low quality point had a velocity above *vMax* (BirdLife International 2004a).

In order to convert the PTT tracking data into density distributions, the assumption was made that birds travelled at constant speed in a straight line between uplinks. The path of the bird was then resampled at hourly intervals. If the interval between two uplinks was more than 24 hours, no resampling was conducted between these points. Bird tracks were grouped into datasets that represented unique combinations of species/colony/breeding status/breeding stage/sex, as far as data availability allowed. Kernel density distributions were derived from these datasets using the kernel function in ArcGIS 8.2, with a smoothing (*h*) parameter of 1° and a grid size of 0.1°. (The smoothing factor of 1° was selected on the basis that this was likely to be the smallest practical unit for management on the high seas.) Data points were not separated into 'commuting' or 'foraging' points. 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.

Global Positioning System (GPS) tracking data were processed in the same manner, and resampled at hourly intervals to make them comparable to the PTT data, although in most cases this reduced the number of points for kernel analysis

Data holders submitted Geolocator (GLS) data to the database in a processed form, since the variety of geolocators available made it unrealistic to develop a standardised validation routine for GLS data. GLS data did not require resampling since the locations of tracked birds are available at regular (approximately 12-hour) intervals. Kernel density distribution maps were generated as above, but with a smoothing parameter (h) of 2°, which approximated the nominal resolution of the GLS data, and a cell size of 0.5°.

The foraging ranges and distributions of albatrosses vary depending on stage of the breeding cycle, sex and colony. For each species, overall breeding distribution was calculated by weighting each dataset by the number of individuals at sea for that particular combination of colony/breeding stage/sex. Density distributions for each species were standardised to allow addition across species to create multi-species maps. Population sizes of albatross species vary greatly: there are over 500,000 annual breeding pairs of Black-browed and Laysan Albatross, whereas three albatross species have less than 1000 annual breeding pairs (Table 3). For this reason, the multi-species maps were calculated with all species weighted equally, to avoid domination of the maps by the few species with large populations. The density distributions are represented on maps by the 50, 75 and 95% utilisation distributions (UD), indicating the areas within which birds spend 50, 75 and 95% of their at-sea time. For full further details on methods for data validation and derivation of density distributions, see Tracking Ocean Wanderers (BirdLife International 2004a).

Tracking data are not available for all colonies of all species, and fewer data exist for adult non-breeding and juvenile distribution compared to distribution during the breeding season (Table 3). Care must be taken when interpreting kernel distributions where data is missing from some colonies (Table 3, and indicated on maps), and where sample sizes are small. 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 2004a). Distribution of albatrosses and petrels has also been identified as varying between years, though analysis suggests that while differences do exist, they are not as substantial as other factors, such as breeding stage (Weimerskirch *et al.* 1993, Prince *et al.* 1998, Weimerskirch 2004, Phillips *et al.* 2004).

2.3 Overlap of bird distributions with IOTC longline fishing effort

For each albatross, petrel and shearwater species, for each breeding colony from which the birds were tracked, calculations were made of the percentage at-sea time spent within the various fishing intensity levels of the selected gears/fleets. Where there was tracking data from a sufficient proportion of the species' colonies, this was also done for the global species distribution. The distributions of breeding adult birds during the breeding season were analysed separately from the post-breeding and non-breeding distributions of adults and juveniles. These latter datasets were combined as, while it is recognised that there may be differences between juvenile and post-breeding/non-breeding adult distributions, sample sizes were simply too small to allow for separate analysis. For two species (Shy and Wandering Albatross) sufficient tracking data were available to analyse distribution by season (year-quarter)

3. RESULTS

3.1 IOTC longline fishing effort

The raising exercise reported that approximately 600 million longline hooks were set in the IOTC area south of 30°S from 2002 to 2005, an average of 150 million hooks per year. Sixty-five percent of this was concentrated in the EIO and 35% in the WIO. The most effort (64%) came from pelagic longline fleets, followed by the fresh tuna fleets (32%). The swordfish fleet made up only 2.3% of the total effort south of 30°S and the combined deep, exploratory and shark effort made up the remaining 1.7%. The largest effort by a single fleet was reported by the Taiwanese (31% of the total), with the Indonesian fresh and Japanese efforts contributing 22% and 21% respectively. All other fleet efforts were below 5% of the total. The estimated effort south of 30°S is given for each gear type and fleet in Table 4.

It must be noted that the there was no effort distribution information available for the fresh tuna longline effort, two-thirds of which was contributed by the Indonesian fleet (21% of total longline effort). The Taiwanese fleet was used to estimate the effort distribution for this data set. As Indonesia fishes only in the EIO, this exaggerated the effort estimated in the area between 80 and 90°E used by the Taiwanese longline fleet. It is likely that the Indonesian effort is concentrated more to the north and north-east of the region.

The overall IOTC longline effort showed three main concentrations, one of which was below 30°S, to the north-east of Amsterdam and St. Paul between 80 and 90°E (Figure 1). Effort in this region was estimated to be above 10 million hooks set per 5° grid square annually. Another concentration was centred south of the Mozambique channel, just north of the 30°S line – effort here was estimated at 5-10 millions hooks Japanese effort was largely responsible for the western concentration, while the eastern concentration was mainly effort from the Taiwanese pelagic longline and remaining fleets. This could be misleading as the Taiwanese fleet was used to assign effort for the majority of these fleets (see Appendix 1) and so they would reinforce the Taiwanese distribution. However their combined effort makes up only 15% of the pelagic longline effort, compared with Japan's 32% and Taiwan's 49%, thus the pattern would be evident even without the use of Taiwan as a proxy fleet.

3.2 Distribution of breeding birds during the breeding season

The Global *Procellariiform* Tracking Database contains tracking data for7 of the 9 albatross species breeding on Indian Ocean Islands, and for 2 of the other albatross species breeding outside the IOTC area but likely to forage there during breeding. There are also tracking data for White-chinned Petrel and Short-tailed Shearwater.

Figure 1 shows the overlap of the combined breeding distribution of these species with the total annual longline effort estimated from the IOTC databases. There are two main regions used by the tracked breeding birds: the Prince Edward-Crozet-Kerguelen band in the south-western Indian Ocean, and the south-eastern Australian waters around Tasmania.

Adult albatrosses breeding on Indian Ocean islands spent between 70-100% of their time at-sea foraging in areas overlapping with IOTC longline fishing effort. The distributions of the seven albatross species (Amsterdam, Black-browed, Grey-headed, Indian Yellow-nosed, Shy, Sooty, Wandering albatrosses) are shown in Figures 2-8. White-chinned Petrels from Iles Crozet spent 60% of their time in areas overlapping with IOTC longline fishing effort (Figure 8).

In addition, the distribution of several species breeding on islands outside the IOTC area had some (but slight) overlap with IOTC longline fishing effort (Antipodean, Buller's albatross and Short-tailed Shearwater). Overall, the birds tracked spent 42% of their time in areas overlapping with IOTC longline fishing effort. The percentage time spent in areas overlapping with longline effort are summarised in Table 5.

In terms of distribution of albatrosses among areas of low, medium and high intensity of fishing effort, of particular note is that the two endemic albatross species (the Critically Endangered Amsterdam Albatross and the Endangered Indian Yellow-nosed Albatross) spent a large proportion of their at-sea time in areas of medium to high fishing effort (over 1 million hooks set per 5° grid square annually) (39% and 57% time respectively). The breeding distributions of Grey-headed and Wandering Albatrosses also had a high overlap with medium/high intensity fishing areas. No breeding tracking data were available for Light-mantled Albatross, Northern or Southern Giant-petrels.

3.3 Distribution of non-breeding adults and juveniles

The combined non-breeding distribution of the seven species of albatross for which non-breeding tracking data were submitted shows that their range extends further north than the distribution of breeding adults, and forms an almost continuous band from south of the African continent to the southern Australian waters (Figure 10). This more northerly extension brings the birds into a high degree of overlap with longline fishing effort. However, in addition the non-breeding range of many species extends outside the IOTC area and some species have circumpolar ranges during the non-breeding period. This decreases the percent time spent in the IOTC area.

Of the species for which tracking data were available, non-breeding Amsterdam, Shy and Wandering Albatross had a high degree of overlap with IOTC longline fishing effort. In particular, Amsterdam Albatross had a 98% overlap, 72% of which occurred in medium to high fishing intensity areas (Figure 11). This distribution was derived from three post-fledging chicks tracked for three to four months each, so the sample size is small. However, of interest is the fact that the track of one juvenile extended to the north of the 30°S line, the usual assumed northern limit of albatross distribution in the Indian Ocean. Non-breeding Wandering and Shy Albatross also had a high degree of overlap with IOTC fishing effort. The distribution of non-breeding Antipodean, Buller's, Grey-headed, Shy and Wandering Albatrosses are shown in Figures 12-16.

Only one non-breeding track was available for Indian Yellow-nosed Albatrosses (a post-breeding female tracked for three days after her nest failed) which is insufficient to allow for an analysis of the species' non-breeding distribution. However this track did lie entirely within the IOTC area and it is likely that the species as a whole would show a high overlap with the IOTC area. No non-breeding data were available from Indian-Ocean colonies of Grey-headed Albatross, Sooty Albatross, Light-mantled Albatross, White-chinned Petrel, or Northern or Southern Giant-petrels.

3.4 Seasonal Analyses of Shy Albatross and Wandering Albatross distribution

Although a seasonal analysis of albatross and petrel distribution with fishing effort is required to fully understand their potential interactions (see discussion), in most cases data simply do not exist to be able to perform these analyses adequately. Sufficient tracking data exist for only two Indian Ocean species: the Wandering and Shy Albatrosses. However, an analysis of these datasets can help to identify patterns which may become apparent in other species once sufficient data are available.

The Wandering Albatross showed high overlap with all fisheries (Table 5) and so the combined IOTC longline effort has been used in the seasonal analysis for this species. The Shy Albatross only showed overlap with the swordfish longline fishery (ELL) and so only this effort has been used to investigate seasonal changes. Breeding and non-breeding data were combined when deriving the quarterly kernel density distributions. The table below provides a summary of the overlap of both species with different levels of fishing intensity in the different periods:

Table 6. Overlap between the quarterly distribution of breeding and non-breeding albatrosses and quarterly IOTC longline fishing effort intensity. Distributions were derived from tracking data held in the Global *Procellariiform* Tracking Database. Fishing data are given as the average quarterly number of hooks set per 5° grid square from 2002 to 2005. Overlaps are given for each breeding site as well the species' global population. (blank = no overlap).

Species/Population	Jan-Mar				Apr-Jun				Jul-Sep				Oct-Dec			
ELL Millions of Hooks	< 0.05	0.05-0.1	0.1-0.5	> 0.5	< 0.05	0.05-0.1	0.1-0.5	> 0.5	< 0.05	0.05-0.1	0.1-0.5	> 0.5	< 0.05	0.05-0.1	0.1-0.5	> 0.5
Shy Albatross	75				11	1	3		3	1			48	14		
Albatross Island	47				26	2	7		6	2			14	3		
Mewstone	95												72	20		
Pedra Branca	no data								no data				51	42		
Wandering Albatross																

Global	24		49		52	2	66	
Iles Crozet	37		29	1	82	4	96	
Iles Kerguelen	no data		44		no data		no data	
Prince Edward Islands	28		89		81	2	98	

Wandering Albatrosses are biennial breeders with a breeding season lasting 11-12 months (Nel *et al.* 2002b). For much of the first quarter the breeders are incubating eggs and so still able to forage widely (Nel *et al.* 2002b) (Figure 17). Once the egg hatches, at the end of the first quarter, the birds are restricted to the immediate vicinity of the colony as the small chick needs frequent feeding (Weimerskirch *et al.* 1997). This explains the contracted distribution shown on the map for the second quarter. As the chick grows it needs less frequent provisioning and the adults' range expands until the chick fledges towards the end of the last quarter, at which stage the next season's breeders are already laying eggs. The overlap in different quarters varied between the colonies, with the Crozet colony overlapping most fishing effort in the last two quarters, while the Prince Edward birds showed high overlap in all but the first, but especially the last quarter. Overall however, the results highlight the presence of Wandering Albatrosses in the IOTC area throughout the year.

In contrast to Wanderers, Adult Shy Albatrosses are relatively sedentary (Baker *et al.* 2007), and remain in the Tasmanian waters year-round. Shy Albatrosses are also annual breeders and so have more distinct breeding and non-breeding seasons. The adults commence breeding at the end of the third quarter, and most of the last quarter is spent incubating the egg, which hatches towards the end of the year (Baker *et al.* 2007). During the first quarter the birds are provisioning chicks (Baker *et al.* 2007), thus their range is restricted to the region surrounding the colony until early in the second quarter when the chicks fledge (Figure 18). However, the non-breeding Shy Albatross tracks included three juveniles which undertook a migration to the south-western Australian waters in the second and third quarters.
Because the adults remain close to the colonies year-round, they are always at risk from fishing effort in that area. However the highest overlap with IOTC longline effort targeting swordfish was shown in the first quarter, when chicks are being raised. The migration undertaken by the juveniles in the second, and to a lesser extent the third, quarters put them at risk from higher fishing intensity extending down the western Australian coast during this period.

4. DISCUSSION

4.1 Seabird distribution data gaps

The coverage of remote tracking data for breeding albatrosses and petrels is reasonable in IOTC area, with data from the Critically Endangered Amsterdam Albatross, Endangered Indian Yellow-nosed Albatross and all of the Vulnerable Wandering Albatross colonies. However, data gaps remain for some species and sites. In particular, the lack of breeding distribution data for Light-mantled Albatross, Northern and Southern Giant-petrels is a significant omission in this analysis (31%, 26% and 23% of their respective global populations breed on Indian Ocean islands). In addition, breeding tracks were missing from key colonies such as Indian Yellow-nosed, Grey-headed and Sooty Albatrosses. These populations are likely to have distributions that include either the medium/high intensity fishing areas around Southern Africa or the high intensity effort region between 80 and 90°E.

In addition, many data gaps remain for tracking data of non-breeding and juvenile birds, in part due to practical difficulties in collecting such data. Non-breeding birds typically have wider ranges than breeding birds since they don't have the necessity to make periodic returns to the breeding sites to brood or feed chicks. The analysis presented here must be considered an underestimate of true distribution. Key gaps to fill are on the non-breeding distribution of non-breeding and juvenile Indian Yellow-nosed, Grey-headed, Light-mantled and Sooty Albatrosses, and adult Amsterdam

Albatrosses. Data are also required on the non-breeding distributions of adult and juvenile Northern and Southern Giant-petrels and White-chinned Petrels.

4.2 Overlap with longline effort

The majority of effort encountered by birds was from pelagic longline fleets. The exception was Shy Albatrosses, as their restricted breeding range lies largely over the Australian swordfish effort around Tasmania (Figure 6). Two species, Amsterdam and Indian Yellow-nosed Albatrosses, were particularly concentrated in the area of highest fishing intensity north-east of Amsterdam and St Paul (Figures 2 and 5). Non-breeding birds also used the area south-east of Southern Africa. Grey-headed and Wandering Albatrosses had a high degree of overlap with longline fishing effort, and many data gaps remain for the non-breeders and juveniles of other albatross species.

The ranges of non-breeding birds extended north of those of breeding birds, bringing them into high overlap with IOTC longline fishing effort. However, the ranges of non-breeding birds also extend outside the IOTC area. Many gaps remain, and the estimation of non-breeding distribution and overlap with IOTC longline fishing effort must be considered an underestimate.

No tracking data yet exist for non-breeding the White-capped, Black-browed (except South Georgia population) or Indian Yellow-nosed Albatross or White-chinned Petrels that forage in the IOTC area, and yet these are the principle species recorded as bycatch in the observer programme of the South African pelagic longline fishery (Brothers *et al.* 1999, Gales *et al.* 1998, Petersen *et al.* unpublished MS). The South African pelagic longline fishery targets mainly swordfish (South African vessels) and tuna (mainly Japanese and Taiwanese vessels). Overall, bycatch rates were high (0.44 birds/1000 hooks). Wandering, Grey-headed and Northern Royal Albatrosses and both species of giant-petrel were caught in lesser numbers. Data from the Japanese Southern Bluefin Tuna longline fishery operating in the Australian Fishing Zone indicates catches of Black-browed, Shy, Grey-headed, Indian Yellow-nosed and Wandering Albatrosses, as well as fewer numbers of White-chinned Petrels (Gales *et al.* 1998). Catch rates here were 0.15 birds/1000 hooks. Australia's western swordfish fisheries showed low bycatch rates of 0.02 birds/1000 hooks, with no reports of albatrosses caught during 2002-2004, probably because of night-setting (Baker *et al.* 2007).

While rarer species such as Wandering Albatrosses may form only a small proportion of the seabird bycatch, such species will be impacted by even low bycatch rates due to their small population size (6,000 pairs breeding annually in the Indian Ocean, equivalent to a total of 10,500 pairs in this biennially breeding species). The growth of the Southern Bluefin Tuna longline fishery until the 1980s and subsequent development of the Patagonian Toothfish longline fishery coincided with the steady decline of Wandering Albatross populations at Crozet, Kerguelen and Marion Island (Weimerskirch *et al.* 1997, Nel *et al.* 2002a). These colonies still show a high overlap with fisheries in the region (Figure 8, Table 5). An additional concern is that high mortality due to bycatch in one colony could create a metapopulation sink for the entire region as it would be preferentially colonised by juveniles from other colonies because of the lower density of breeding birds (Inchausti & Weimerskirch 2002).

The critically endangered Amsterdam Albatross has not been reported as bycatch in any of these studies, but its extremely low population numbers and proximity to areas of high fishing effort indicate potential risk. Inchausti and Weimerskirch (2001) suggest that the particularly high levels of Southern Bluefin longline effort close to Amsterdam from the 1960s to the 1980s could have been a factor in the decline of the population to its present low numbers.

4.3 Seasonal variation
Fishing effort and albatross distribution can vary between seasons and this can affect rates and risk of bycatch. During some parts of the breeding cycle, especially early chick-rearing, adults are much more restricted to the area surrounding the colony. Three Indian Ocean islands holding major colonies of breeding albatrosses (Prince Edward, Crozet and Amsterdam) lie within 300km of regions of medium to high longline fishing effort (over 1 million hooks set annually per 5° grid square) (Figure 1). An increase in longline effort close to the colony during the chick-rearing period can be expected to have a higher impact on albatross mortality as more birds will encounter the fleet (Weimerskirch *et al.* 1997, Nel *et al.* 2002b). In the Australian Fishing Zone more birds were killed by the Japanese Southern Bluefin longline fleet during the summer breeding season even though fishing effort was higher during the winter (Gales *et al.* 1998). The region in which these vessels were operating is in the proximity of the major albatross breeding colonies of Australia and New Zealand. Conversely, bycatch rates in the South African pelagic longline fishery are higher during winter, when the most hooks are set, as this region is primarily used by non-breeding birds (Petersen *et al.* unpubl ms). From this study it is evident that overlaps of albatross and petrel distributions and longline effort change from the breeding to the non-breeding season (Figures 1 and 10 and Table 5).

SUMMARY
This analysis has highlighted the importance of the IOTC area for albatross and petrel distribution, and the high degree of overlap between IOTC longline fishing effort and the distribution of albatrosses, particularly those breeding on islands in the Southern Indian Ocean. The Critically Endangered Amsterdam Albatross and Endangered Indian Yellow-nosed Albatross are endemic to the IOTC area, and both forage almost exclusively in the areas fished by longline IOTC fleets, close to the area of highest longline effort south of 30°S. Grey-headed, Wandering and Shy Albatrosses also have a high degree of overlap with IOTC longline fishing effort.

The addition of tracking data from other colonies of Grey-headed Albatross in the Indian Ocean would probably increase the overlap identified, especially with the region of high-intensity longline effort between 80 and 90°E. Non-breeding Black-browed and White-capped Albatrosses are caught in large numbers by longline fisheries in the region, but tracking data area lacking. Other key data gaps include tracking data for Northern and Southern Giant-petrels, both of which form part of the bycatch reported for the region and have substantial breeding colonies in the Indian Ocean, as well as non-breeding data for White-chinned Petrels and Indian Yellow-nosed and Grey-headed Albatrosses.

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Table 1. IOTC longline gear types

Gear	Description	Notes	Hooks per Set/Day
ELL	Longline (targeting swordfish)		1,600
FLL	Longline Fresh	no effort data available	1,200
LL	Longline		2,750
LLCO	Coastal Longline	not included in this analysis	2,750
LLD	Longline (Deep)		2,750
LLEX	Longline (exploratory fishing)		2,750
SLL	Longline (targeting shark species)		1,600
TLL	Longline (targeting tuna or tuna-like species)	included in gear type LL	2,750

Table 2. Tuna and billfish species used to estimate longline effort in the IOTC area.

Species	Common Name	Scientific Name	% of catch[1]
YFT	Yellowfin tuna	*Thunnus albacares*	37%
BET	Bigeye tuna	*Thunnus obesus*	36%
SWO	Swordfish	*Xiphias gladius*	11%
ALB	Albacore	*Thunnus alalunga*	9%
SBF	Southern bluefin tuna	*Thunnus maccoyii*	2%

[1] percentage (by weight) of the total nominal longline catch for the period 2002-2005.

Table 3. Remote tracking data of southern-hemisphere species held in the Global *Procellariiform* Tracking Database.

pecies	Site	Annual breeding pairs	Global popn (%)	Dataset: Status (Number of tracks) All tracks are PTT unless otherwise specified. Blank cells indicate no tracking data.
Amsterdam	Ile Amsterdam	17	100%	Breeding (15 tracks) and non-breeding (3 tracks[2])
Antipodean	Antipodes Is	5,148	41%	Breeding (79 tracks[1]) and non-breeding (including post-breeding and juveniles) (28 tracks)
	Campbell Island	6	0%	
Antipodean (Gibson's)	Auckland Is	7,319	59%	Breeding (43 tracks[1]) and post-breeding (29 tracks[1])
Atlantic Yellow-nosed	Gough Island	7,500	23%	
	Tristan da Cunha Is	25,750	77%	
Black-browed	Antipodes Is	115	0%	
	Campbell Island	16	0%	
	Chile	122,870	20%	Breeding (165 tracks) and breeding to post-breeding GLS (5 tracks)
	Falkland Is (Malvinas)	380,000	62%	Breeding (198 tracks) and post-breeding (1 track), breeding to post-breeding GLS (191 tracks)
	Heard & McDonald Is	729	0%	
	Iles Crozet	880	0%	
	Iles Kerguelen	4,270	1%	Breeding (26 tracks)
	Macquarie Island	182	0%	Breeding (7 tracks)
	Snares Is	1	0%	
	South Georgia	100,332	16%	Breeding (365 tracks[1]) and post-breeding (3 tracks[1]), breeding to post-breeding GLS (49 tracks)
Buller's	Chatham Is	18,150	58%	
	Three Kings	20	0%	
	Snares Is	8,465	27%	Breeding (180 tracks) and non-breeding (including juveniles) (97 tracks, all during breeding season, and 18 GPS tracks[1])
	Solander Is	4,800	15%	Breeding (49 tracks), non-breeding (including post-breeding) (137 tracks, all during breeding season)
Campbell	Campbell Island	26,000	100%	Breeding (10 tracks[1])
Chatham	Chatham Is	4,000	100%	Breeding (16 tracks, 3 GPS tracks[1]), non-breeding (including post-breeding and juveniles) (19 tracks)
Grey-headed	Campbell Island	6,400	6%	Breeding (5 tracks)
	Chile	16,408	15%	Breeding (67 tracks) and post-breeding (1 track)
	Iles Crozet	5,940	6%	
	Iles Kerguelen	7,905	7%	
	Macquarie Island	84	0%	Breeding (9 tracks)
	Prince Edward Is	7,717	7%	Breeding (6 tracks)
	South Georgia	61,582	58%	Breeding (299 tracks[1]) and post-breeding (4 tracks), breeding to post-breeding GLS (22 tracks)
Indian Yellow-nosed	Ile Amsterdam	25,000	70%	Breeding (62 tracks[2]) and post-breeding (1 track)
	Ile St. Paul	12	0%	
	Iles Crozet	4,430	12%	
	Iles Kerguelen	50	0%	
	Prince Edward Is	6,000	17%	
Light-mantled	Antipodes Is	169	1%	
	Auckland Is	5,000	23%	
	Campbell Island	1,600	7%	
	Heard & McDonald Is	350	2%	
	Iles Crozet	2,421	11%	
	Iles Kerguelen	4,000	18%	
	Macquarie Island	2,000	9%	Breeding (10 tracks)
	Prince Edward Is	241	1%	
	South Georgia	6,250	28%	Breeding (42 tracks[1])
Northern Royal	Chatham Is	2,060	99%	Breeding (28 tracks) and post-breeding (15 tracks)
	Taiaroa Head	18	1%	Breeding (3 tracks, 50 GPS tracks[1]), non-breeding (including post-breeding and juveniles) (16 tracks)
Salvin's	Bounty Is	76,352	99%	
	Iles Crozet	4	0%	
	Snares Is	587	1%	
Shy	Tasmania	12,250	100%	Breeding (64 tracks) and non-breeding (including post-breeding and juveniles) (8 tracks)

[1] some or all tracks added since the publication of Tracking Ocean Wanderers (BirdLife International 2004a)

[2] data submitted for use in this report only

peciesaa	Site	Annual breeding pairs	Global popn (%)	Dataset: Status (Number of tracks) All tracks are PTT unless otherwise specified. Blank cells indicate no tracking data.
Sooty	Gough Island	5,000	38%	
	Ile Amsterdam	350	3%	
	Ile St. Paul	20	0%	
	Iles Crozet	2,248	17%	Breeding (26 tracks)
	Iles Kerguelen	4	0%	
	Prince Edward Is	2,755	21%	
	Tristan da Cunha Is	2,747	21%	
Southern Royal	Auckland Is	72	1%	
	Campbell Island	7,800	99%	Breeding (7 tracks)
Tristan	Gough Island	798	100%	Breeding (128 tracks)
	Tristan da Cunha Is	3	0%	
Wandering	Iles Crozet	2,062	26%	Breeding (204 tracks) and non-breeding (including post-breeding and juveniles) (14 tracks[2])
	Iles Kerguelen	1,094	14%	Breeding (11 tracks)
	Macquarie Island	10	0%	
	Prince Edward Is	2,707	34%	Breeding (20 tracks) and non-breeding (including post-breeding) (3 tracks)
	South Georgia	2,001	25%	Breeding (207 tracks) and post-breeding (4 tracks)
	Unknown			Non-breeding (5 tracks)
White-capped	Antipodes Is	18	0%	
	Auckland Is	72,233	100%	
	Chatham Is	1	0%	
Northern Giant-petrel	Antipodes Is	300	3%	
	Auckland Is	100	1%	
	Campbell Island	240	2%	
	Chatham Is	2,150	19%	
	Iles Crozet	1,060	9%	
	Iles Kerguelen	1,400	12%	
	Macquarie Island	1,110	10%	
	Prince Edward Is	540	5%	
	South Georgia	4,310	38%	Breeding (18 tracks)
Southern Giant-petrel	Antarctic Continent	290	1%	
	Antarctic Peninsula	6,500	21%	
	Argentina	1,350	4%	Breeding (16 tracks[1]) and non-breeding (including juveniles) (10 tracks[1])
	Chile	290	1%	
	Falkland Is (Malvinas)	3,100	10%	
	Gough Island	50	0%	
	Heard & McDonald Is	4,400	14%	
	Iles Crozet	1,060	3%	
	Iles Kerguelen	4	0%	
	Macquarie Island	2,300	7%	
	Prince Edward Is	1,790	6%	
	South Georgia	4,650	15%	Breeding (11 tracks)
	South Orkney Is	3,400	11%	
	South Sandwich Is	1,550	5%	
White-chinned Petrel	Antipodes Is	50,000	?%	
	Auckland Is	50,000	?%	
	Campbell Island	?	?%	
	Iles Crozet	50,000	?%	Breeding (16 tracks)
	Iles Kerguelen	200,000	?%	
	Falkland Is (Malvinas)	?	?%	
	Macquarie Island	?	?%	
	Prince Edward Is	?	?%	
	South Georgia	2,000,000	?%	Breeding (23 tracks[1]), non-breeding GLS (10 tracks)
Westland Petrel	Punakaiki	2,000	100%	Breeding (20 tracks[1])
Short-tailed Shearwater	SE Australia (French, Montague.)	?	?%	Breeding (3 tracks[1]) and post-breeding (1 track[1])
Sooty Shearwater	New Zealand (Codfish, Mana)	?	?%	Breeding GLS (19 tracks[1]) non-breeding GLS (19 tracks[1])

[1] some or all tracks added since the publication of Tracking Ocean Wanderers (BirdLife International 2004a)
[2] data submitted for use in this report only

Table 4. Total estimated longline effort south of 30°S, per fleet and IOTC Area, for the period 2002-2005, given as millions of hooks set. (Blanks indicate no hooks set.)

Gear	Fleet	Name	EIO	WIO	Total	% of total
Swordfish (ELL)						
	AUS	Australia	5.3		5.3	0.9%
	ESP	Spain	0.9	3.8	4.7	0.8%
	FRA-REU	France-Reunion		0.0	0.0	0.0%
	FRAT	France-Territories		0.0	0.0	0.0%
	GIN	Guinea		1.4	1.4	0.2%
	KEN	Kenya	0.0	0.0	0.1	0.0%
	NEI[1]-DFRZ	NEI-Deep-freezing	0.5	1.6	2.1	0.3%
	SEN	Senegal	0.1		0.1	0.0%
	Total		6.8	6.8	13.7	2.3%
Fresh (FLL)						
	IDN	Indonesia	131.0		131.0	21.7%
	IND	India	0.6	0.0	0.6	0.1%
	MDV	Maldives		0.1	0.1	0.0%
	MYS	Malaysia	2.8		2.8	0.5%
	NEI[1]-ICE	NEI-Fresh Tuna	6.4	0.1	6.5	1.1%
	OMN	Oman		0.2	0.2	0.0%
	TWN	Taiwan	49.2	4.0	53.1	8.8%
	Total		189.9	4.3	194.2	32.1%
Longline (LL, includes TLL)						
	BLZ	Belize	1.9	2.3	4.2	0.7%
	GBR	UK-Territories	0.1	0.1	0.2	0.0%
	IND	India	0.0	0.0	0.0	0.0%
	IRN	Iran		0.1	0.1	0.0%
	JPN	Japan	49.7	74.0	123.7	20.5%
	KOR	Korea	4.5	9.7	14.2	2.3%
	MUS	Mauritius	0.3	0.8	1.1	0.2%
	NEI[1]-DFRZ	NEI-Deep-freezing	9.3	8.3	17.6	2.9%
	PHL	Philippines	6.8	21.1	27.9	4.6%
	PRT	Portugal		0.6	0.6	0.1%
	SYC	Seychelles	1.1	4.7	5.8	1.0%
	THA	Thailand	0.4	0.4	0.9	0.1%
	TWN	Taiwan	123.8	64.2	188.0	31.1%
	ZAF	South Africa		1.5	1.5	0.3%
	Total		197.9	187.9	385.8	63.9%
Deep (LLD)						
	PRT	Portugal		0.9	0.9	0.1%
	Total			0.9	0.9	0.1%
Exploratory (LLEX)						
	ESP	Spain	0.2		0.2	0.0%
	Total		0.2		0.2	0.0%
Shark (SLL)						
	PRT	Portugal		9.0	9.0	1.5%
	ZAF	South Africa		0.3	0.3	0.1%
	Total			9.4	9.4	1.5%
TOTAL			394.8	209.3	604.1	

[1] Not Elsewhere Included

Table 5. Overlap between the distribution of (a) breeding and (b) non-breeding albatrosses, petrels and shearwaters and IOTC fishing effort intensity. Distributions were derived from tracking data held in the Global *Procellariiform* Tracking Database. Fishing data are given as the average annual number of hooks set per 5° grid square from 2002 to 2005. Overlaps are given for each breeding site as well the species' global population where sufficient data exists. Overlap is expressed as the percentage of time spent in regions with varying degrees of longline effort. The combined maps were created giving each species equal weighting.

Species/Population	**Global Population (%)**	**Overlap (percentage of time) Annual effort per grid square (millions of hooks)**			
(a) Breeding		**< 1**	**1-5**	**5-10**	**> 10**
Combined (11 species)		29	10	1	1
Amsterdam Albatross (Amsterdam)	100	61	32	4	3
Antipodean (Gibson's) Albatross					
Auckland Islands	59	1			
Black-browed Albatross		1			
Iles Kerguelen	1	87	1		
Macquarie Island	<1	1			
Heard & MacDonald[1]	<1				
Iles Crozet[1]	<1				
Buller's Albatross		2			
Solander Islands	15	1			
Snares Islands	27	2			
Grey-headed Albatross		5	2		
Prince Edward Islands	7	51	19		
Iles Crozet[1]	6				
Iles Kerguelen[1]	7				
Indian Yellow-nosed Albatross[1]					
Ile Amsterdam	70	43	43	10	4
Ile St. Paul[1]	<1				
Iles Crozet[1]	12				
Iles Kerguelen[1]	<1				
Prince Edward Island[1]	17				
Light-mantled albatross[1]					
Shy Albatross (Tasmania)	100	67			
Sooty Albatross[1]					
Iles Crozet	17	74	13		
Ile Amsterdam[1]	3				
Ile St. Paul[1]	<1				
Iles Kerguelen[1]	<1				
Prince Edward Island[1]	21				
Wandering Albatross		59	16		
Iles Crozet	26	73	20		
Iles Kerguelen	14	92	4		
Prince Edward Islands	34	67	28		
Northern Giant Petrel[1]					
Southern Giant Petrel[1]					
White-chinned Petrel[1]					
Iles Crozet	?	44	16		
Iles Kerguelen[1]	?				
Prince Edward Island[1]	?				
Short-tailed Shearwater[1]					
Australia	?	3			

[1] Insufficient or no tracking data available in the Global *Procellariiform* Tracking Database

Table 5 (continued)

Species/Population **(n) Non-breeding**	**Global Population (%)**	**Overlap (percentage of time) Annual effort per grid square (millions of hooks)**			
		< 1	**1-5**	**5-10**	**> 10**
Combined (7 species)		23	13	1	1
Amsterdam Albatross (Amsterdam)	100	26	60	7	5
Antipodean (Gibson's) Albatross		9			
Antipodes Islands	41	3			
Auckland Islands	59	13			
Black-browed Albatross[1]					
South Georgia (GLS data)	16	1	2		
Heard & MacDonald Islands[1]	<1				
Iles Crozet[1]	<1				
Iles Kerguelen[1]	1				
Buller's Albatross		13			
Solander Islands	15	9			
Snares Islands	27	15			
Grey-headed Albatross[1]					
South Georgia (GLS data)	58	10	6		
Iles Crozet[1]	6				
Iles Kerguelen[1]	7				
Prince Edward Island[1]	7				
Indian Yellow-nosed Albatross[1]					
Light-mantled albatross[1]					
Northern Royal Albatross		2	1		
Chatham Islands	99	2	1		
Taiaroa Head	1	1			
Shy Albatross (Tasmania)	100	71	1		
Sooty Albatross[1]					
Southern Royal Albatross[1]					
Wandering Albatross		33	24	2	
White-Capped Albatross[1]					
Northern Giant Petrel[1]					
Southern Giant Petrel[1]					
White-chinned Petrel[1]					
Westland Petrel[1]					
Short-tailed Shearwater[1]					

[1] Insufficient or no tracking data available in the Global *Procellariiform* Tracking Database