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New information on distribution of albatrosses and petrels breeding in the Indian Ocean and assessment of potential overlap with the IOTC fisheries

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ABSTRACT

We present the results from a large scale project designed to study the at-sea distribution of 10 threatened seabirds breeding in the French Southern Territories: Crozet, Kerguelen and Amsterdam (6 albatrosses species: Amsterdam albatross, wandering albatross, light-mantled albatross, sooty albatross, black-browed albatross, yellow-nosed albatross; 4 petrels species: northern giant petrel, southern giant petrel, white-chinned petrel, grey petrel). The main objective is to determine the at-sea distribution of non-breeding adults and juveniles, and to estimate the degree of overlap with fisheries, especially bycatch hotspots zones for Taiwanese and Japanese fisheries, within the IOTC (Indian Ocean Tuna Commission). We show that extensive overlap exists between bycatch hotspots for IOTC longliners and albatrosses and petrels from Indian Ocean, especially with naïve juvenile, young immature and non-breeding birds. We also demonstrate that the degree of overlap is variable according to species, population of origin and season. We suggest that the bycatch occurring in the IOTC Convention area probably could drive part of the declines observed.

ALBATROSS AND PETREL DISTRIBUTION

The Southern Indian Ocean is an important area for albatrosses and petrels (Catard et al. 2000, IOTC-2005-WPBy-05, Pinaud and Weimerskirch 2007, Péron et al. 2010).

Recent trends analyses showed a decline for at least half of the species involved in our project (Barbraud et al. 2008, Delord et al. 2008, CEBC-CNRS Unpublished data). Recent demographic analysis highlighted that the declining trend was not only due to increased adult mortality, but is partly due to a recruitment problem in the population (Barbraud et al. 2008), underlining the necessity to obtain information on juveniles and immatures birds in addition to adults during non-breeding period. Up to date information on the distribution of albatrosses and petrels in the IOTC convention area is presented, focusing here on 4 species of albatrosses and a petrel.

MATERIAL AND METHOD

The study was carried out in the French Southern Territories (Amsterdam, Crozet and Kerguelen Islands) located in subantarctic or subtropical area of the Southern Indian Ocean. We tracked 10 species of seabirds between 1989 and 2010 with a total of 1084 individual tracking data: 10 species of albatrosses and petrels (Tables 1 & 2).

<table>
<tr><th>Island</th><th>Amsterdam albatross

Diomedea amsterdamensis (CR)*</th><th>Wandering albatross

Diomedea exulans (VU)*</th><th>Black-browed albatross

Thalassarche melanophrys (EN)*</th><th>Light-mantled albatross

Phoebetria palpebrata (NT)*</th><th>Sooty albatross

Phoebetria fusca (EN)*</th><th>Indian yellow-nosed albatross

Thalassarche carteri (EN)*</th></tr>
<tr><td>Amsterdam</td><td>26</td><td>-</td><td>-</td><td>-</td><td rowspan="3">77</td><td>124</td></tr>
<tr><td>Kerguelen</td><td>-</td><td rowspan="2">416</td><td>207</td><td rowspan="2">43</td><td>-</td></tr>
<tr><td>Crozet</td><td>-</td><td>-</td><td>-</td></tr>
</table>

** IUCN Red List Category: CR-Critically Endangered, EN- Endangered, VU- Vulnerable, NT-Near Threatened, LC-Least Concern. IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 29 July 2011.*

Table 1 Individual tracking data (rough data of number of individual equipped) available by species and island for albatross (CEBC-CNRS database)

<table>
<tr><th>Island</th><th>Northern giant petrel

Macronectes halli (LC)*</th><th>Southern giant petrel

Macronectes giganteus (LC)*</th><th>White-chinned petrel

Procellaria aequinoctialis (VU)*</th><th>Grey petrel

Procellaria cinerea (NT)*</th></tr>
<tr><td>Amsterdam</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Kerguelen</td><td>50</td><td>-</td><td rowspan="2">91</td><td>21</td></tr>
<tr><td>Crozet</td><td></td><td>29</td><td></td></tr>
</table>

** IUCN Red List Category: CR-Critically Endangered, EN- Endangered, VU- Vulnerable, NT-Near Threatened, LC-Least Concern. IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 29 July 2011.*

Table 2 Individual tracking data (rough data of number of individual equipped) available by species and island for petrels (CEBC-CNRS database)

1. Albatross and petrel remote tracking data

Birds were captured when leaving the nest for a foraging trip (adults or immatures) or before fledging (juveniles) and electronic tracking devices were attached.

Breeding adults were tracked during breeding period (summer for most of the species or winter for grey petrel), immature and adults during non period breeding all over the year (especially in winter) and juveniles during the post fledging (2-6 month). See (Weimerskirch et al. 1993, Weimerskirch & Robertson 1994, Weimerskirch et al. 1999, Bailleul et al. 2007) for details of the procedures, dates and type of transmitter used.

1.1 Tracking with geolocators

For the large scale study of movements (adult non-breeding period) we used Global Location Sensing (GLS) loggers that allow estimates of latitudes and longitude from light measurements (Wilson et al. 1992) and provide low accuracy locations (Phillips et al. 2004).

The GLS were attached to a plastic ring on the leg of the individuals and were recovered during the following breeding seasons. The light data were then downloaded and decompressed (Phillips et al. 2004).

a. Preparation of geolocation data and filtering procedure

Light data for geolocation were then processed. First we checked each estimated times of 'sunset' and 'sunrise' (transitions) and a confidence index inserted if there was any obvious interference (ground-truthing data, timing apparently affected by >30 min., timing apparently affected by > 30 min., minor interference that probably did not affect timing, period around the equinoxes (5 days, 10 days and 20 days), without interference). All locations were then examined in the GIS to identify those that were apparently erroneous, and coded accordingly (not applicable (bird at colony or before/after deployment), excluded because of light level interference, excluded because around equinox, excluded because outside likely range, retained fixes, ground-truthing data). Unrealistic positions were then filtered following (Phillips et al.2004).

Once each file is processed, we identified start/end of track (excluding locations on ground) and spatial analyses should obviously only be carried out on locations (retained fixes), but the 'invalid' locations should always be retained as they are useful for deriving information on timing.

1.2. Satellite tracking.

Tracking using Argos satellite platform transmitter terminals (PTTs) or Global Positioning System (GPS) of adults, immatures or juveniles provide more detailed data on distribution and habitat associations during the breeding or dispersal period. PTTs were attached to the back feathers using waterproof Tesa® tape or glued with cyanoacrylate glue. From 1989 to 2003, all birds were equipped with PTTs transmitting continuously every 60-

90s. After 2003, GPS were used for black-browed albatross, wandering albatrosses, and yellow nosed albatrosses and duty-cycle GPS/Argos PTT (setting at 10h on and 24h off) for wandering albatrosses and petrels. The GPS necessitated the recovery of the equipped individual while returning to the nest to download the data.

a. Preparation of satellite data and filtering procedure

We identified start/end of each track (excluding locations on ground). Unrealistic positions were then filtered using the sda (speed–distance–angle) filter developed by (Freitas et al. 2008), without constraint on turning angle and with a maximum mean velocity of 25m.s-1 for albatrosses (Jouventin & Weimerskirch 1990; Pinaud & Weimerskirch 2007; Prince et al. 1992) or 20 m s-1 for petrels (Catard et al.2000).

RESULTS

We focus here on 4 species of albatrosses and white chinned petrels. We report the distribution of several species in relation to recent information made available by Taiwanese and Japanese fisheries where high rates of by-catch occur (Inoue et al 2011, Wang & Liu 2010). These studies have reported zones of high by-catch for several species, considered as hotspots of bycatch.

1. Indian yellow-nosed albatross

During the non-breeding period the areas important for the adults of Indian yellow-nosed breeding on Amsterdam Island (Endangered IUCN) were revealed by the analysis of GLS data. Similarly to others species of albatross they largely distribute during the non-breeding period (Figures 1 & 2) and were poorly known until recently (only via recovery/resighting data of ringed birds).

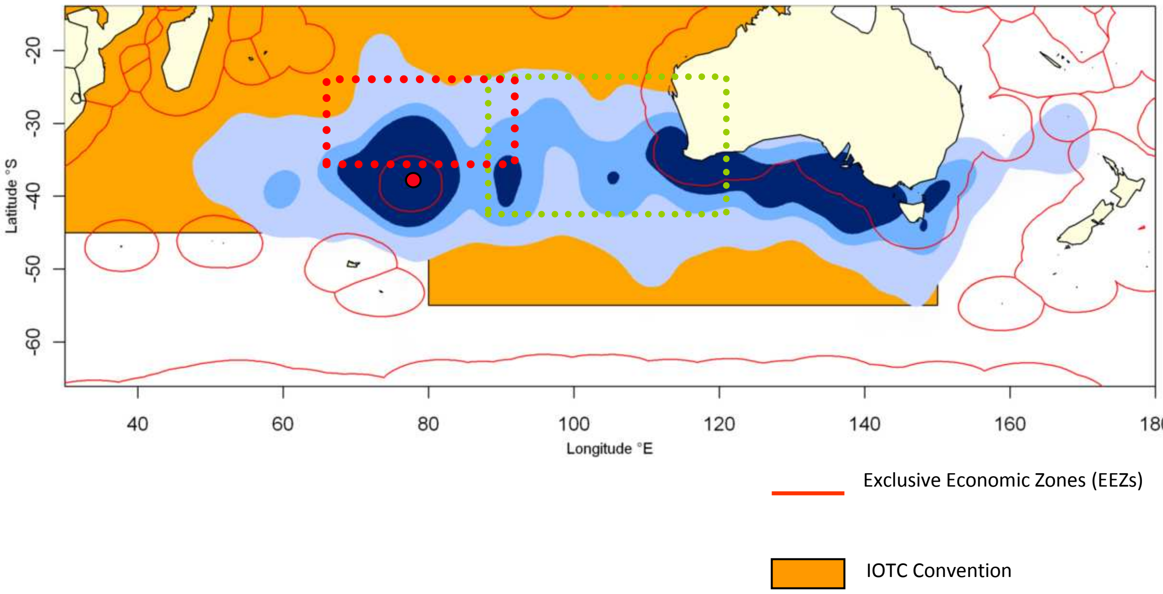

Figure 1. Map of important areas in the Southern Indian Ocean for adults of Indian yellow-nosed albatross *Thalassarche carteri* from Amsterdam Island during the non-breeding period of 2008 (blue: Kernel utilization distribution (UD: 50%, 75% & 90%)). Breeding colony-Amsterdam Island (red dot), Exclusive Economic Zones (EEZs; red lines), IOTC Convention areas (orange) and hotspots of bycatch (of yellow-nosed albatross in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

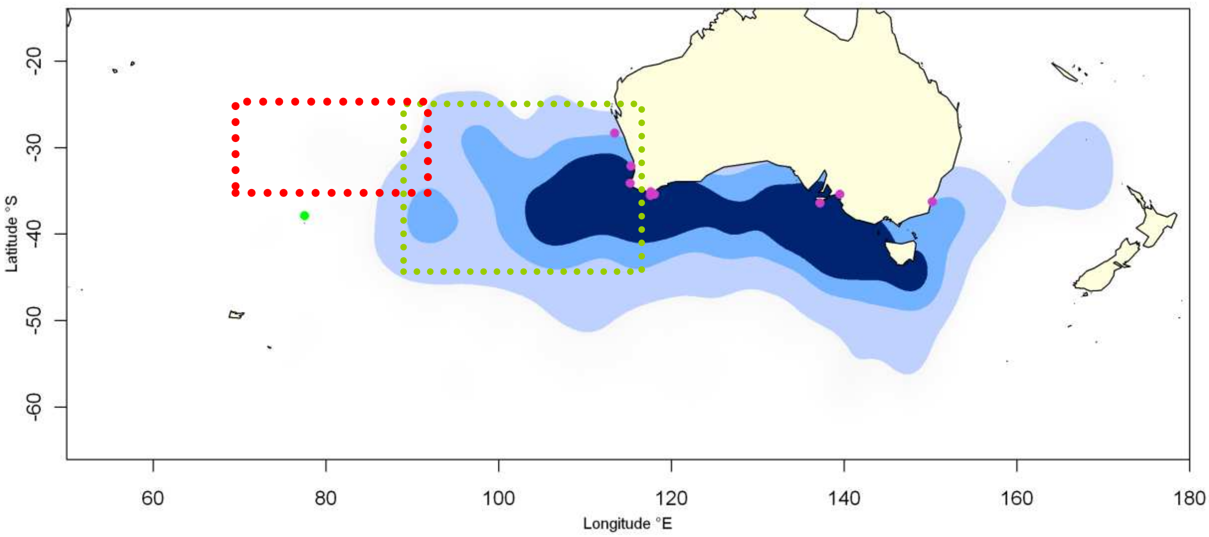

Figure 2. Map of important areas in the Southern Indian Ocean for adults of Indian yellow-nosed albatross *Thalassarche carteri* from Amsterdam Island during the non-breeding period of 2008 (blue: Kernel utilization distribution (UD: 50%, 75% & 90%)) and locations of recapture/resighting of adults ringed on Amsterdam Island (purple dot), (green dot: breeding colony-Amsterdam Island) and hotspots of bycatch of (of yellow-nosed albatross in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

These data emphasized the importance of subtropical waters during non-breeding period and post-fledging period (Figure 3) particularly international waters in the IOTC Convention area and the Australian EEZ in the survival of the population breeding in the Southern Indian Ocean.

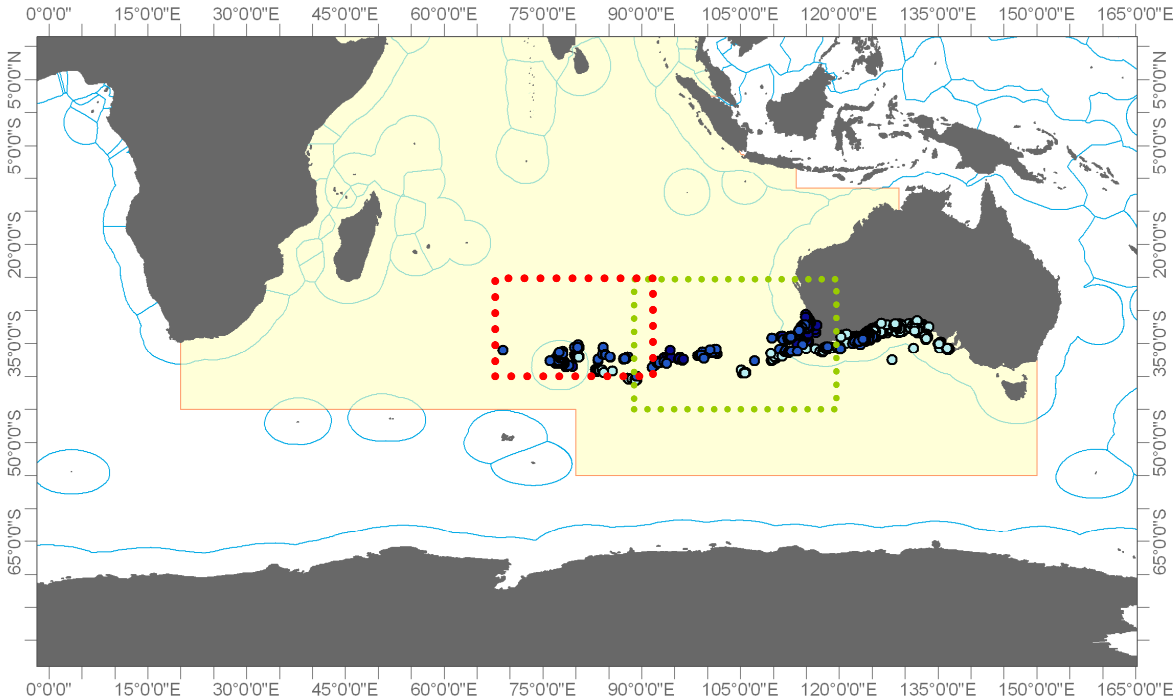

Figure 3. Map of tracking location of juveniles of Indian yellow-nosed albatross *Thalassarche carteri* from Amsterdam Island during post fledging period in 2011 (4 individuals). Limits of IOTC Convention Area (yellow), of EEZs (blue) and hotspots of bycatch (of yellow-nosed albatross in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

Similarly to the Amsterdam albatross, the areas of importance for the Indian yellow-nosed albatross during non-breeding period and post-fledging period overlapped largely with the areas of hotspots of seabirds bycatch recently presented for the Japanese and Taiwanese fleet (Inoue et al. 2011, Huang & Liu 2010).

2. Black-browed albatross

The analysis of GLS data for two consecutives annual cycles revealed the areas important (breeding/non-breeding period) for the adults of black-browed albatross breeding on Kerguelen Island (Endangered IUCN). Similarly to Indian yellow-nosed albatross they foraged around the colony during breeding period and then migrated eastward to winter around Australia. These two consecutive wintering periods showed high consistency in the area used mainly continental shelf in the Australian EEZ (Bass Detroit).

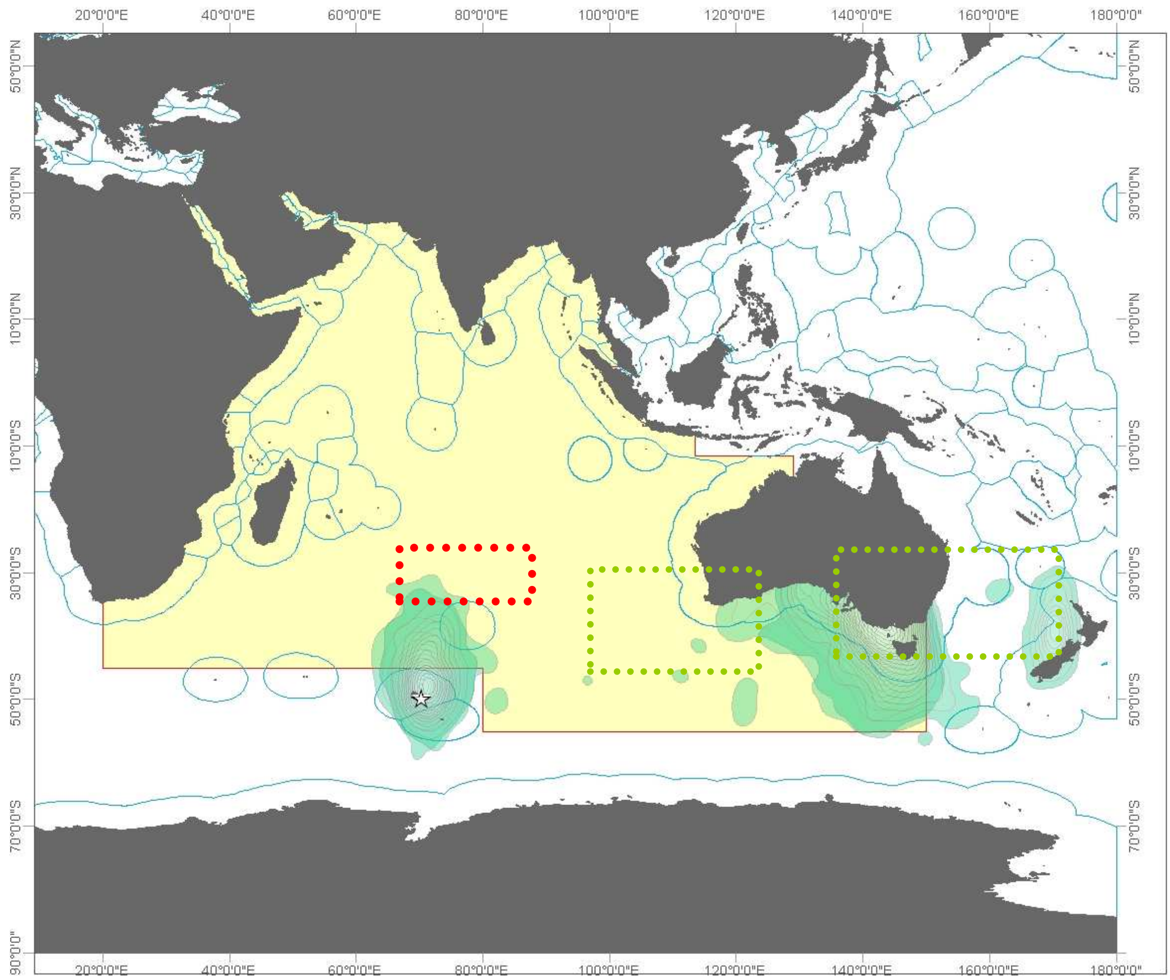

Figure 4. Map of important areas for adults of black-browed albatross *Thalassarche melanophrys* (42 individuals) for two consecutives annual cycles (breeding and non-breeding periods in 2007 and 2008) (green: Kernel utilization distribution (UD), higher UD in lighter green; white star: breeding colony at Canyon des Sourcils Noirs-Kerguelen Island; limits of IOTC Convention Area (yellow) and of EEZs (blue)) and hotspots of bycatch (of black-browed albatross in Japanese fleet - green squares (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

It is noteworthy that black-browed albatross from Kerguelen used mainly EEZs (French & Australian) during breeding and non-breeding period and international waters remains largely important during migratory periods.

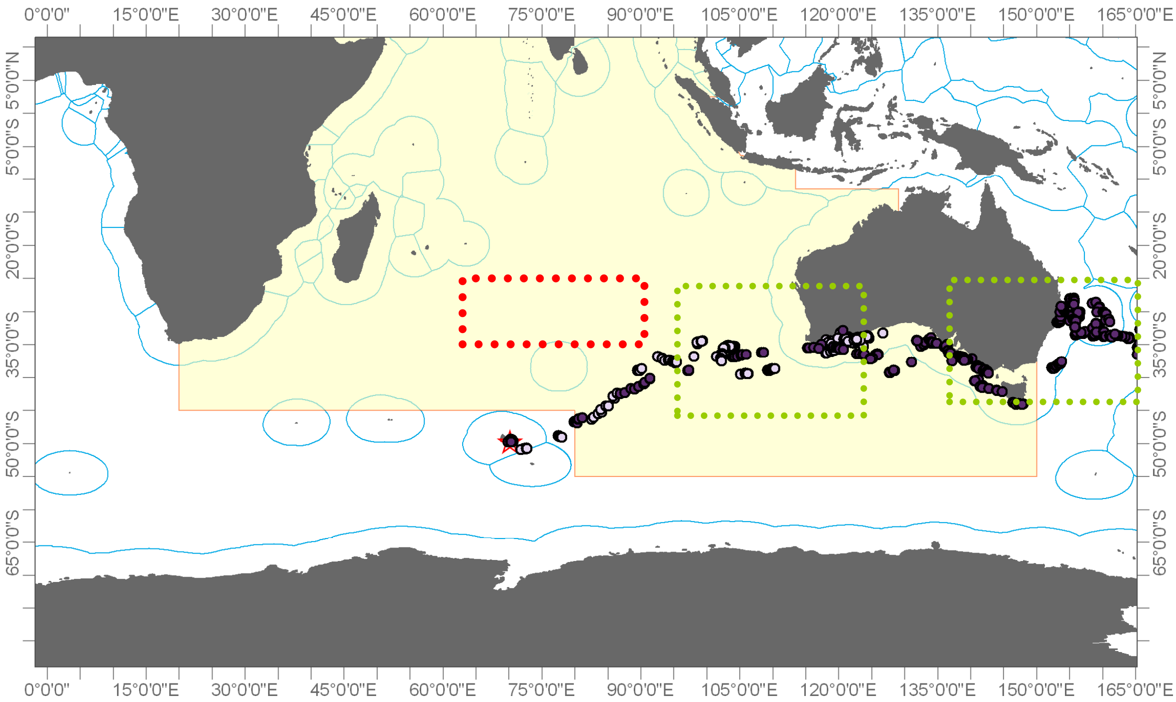

Figure 5. Map of tracking location of juveniles of black-browed albatross *Thalassarche melanophrys* from Kerguelen Island during post fledging period in 2011 (2 individuals). Limits of IOTC Convention Area (yellow), of EEZs (blue) and hotspots of bycatch (of black-browed albatross in Japanese fleet - green squares (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

The tracking of juveniles of black-browed albatross after fledging highlight that they migrate eastward through international waters in the IOTC Convention area in the same manner as adults do, but tended to distribute more northward. Important areas for black-browed albatross, whatever the stage, overlapped largely with the hotspots areas of bycatch of this species recently reported for the Japanese fleet (Inoue et al. 2011), especially during the 2nd quarter.

3. Sooty albatross

The analysis of GLS data for two populations of Southern Indian Ocean revealed the important areas (breeding/non-breeding periods) for the adults of sooty albatross breeding at Amsterdam Island and Crozet Island (Endangered IUCN).

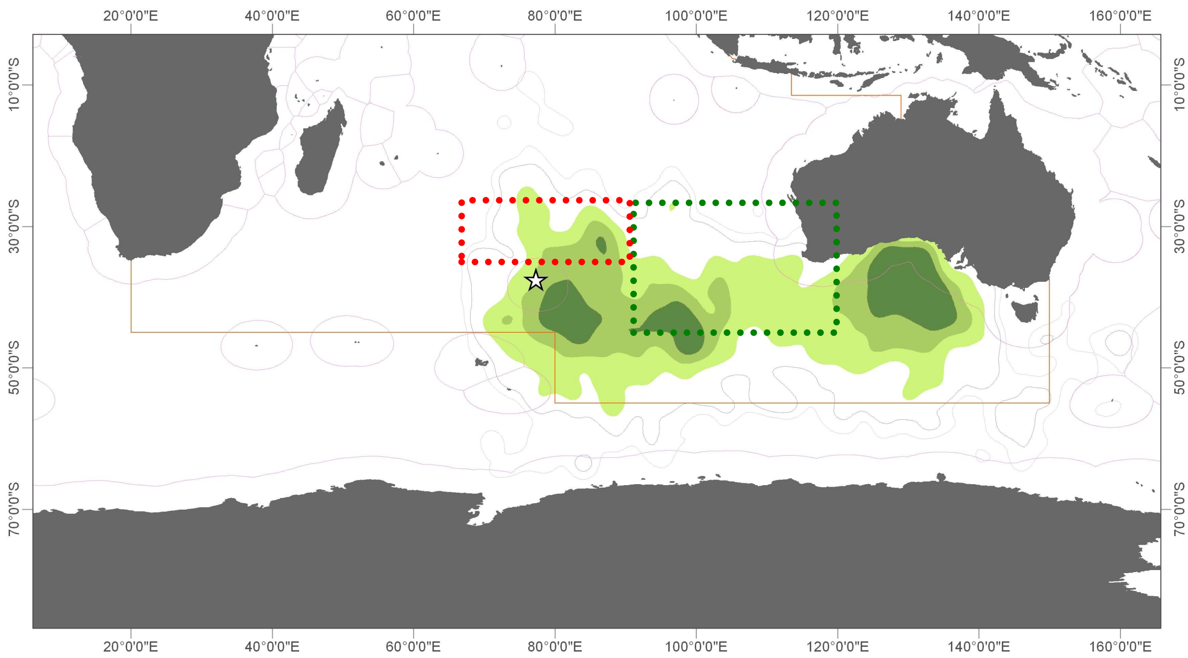

Figure 6. Map of important areas for adults of sooty albatross *Phoebetria fusca* breeding at Amsterdam Island in the Southern Indian Ocean during breeding/non-breeding periods Kernel utilization distribution (UDs, 25%, 50%, 75%), breeding colony at-Amsterdam Island (white star), limits of IOTC Convention Area (yellow) and of EEZs (blue) and hotspots of bycatch of seabirds (sooty albatross in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

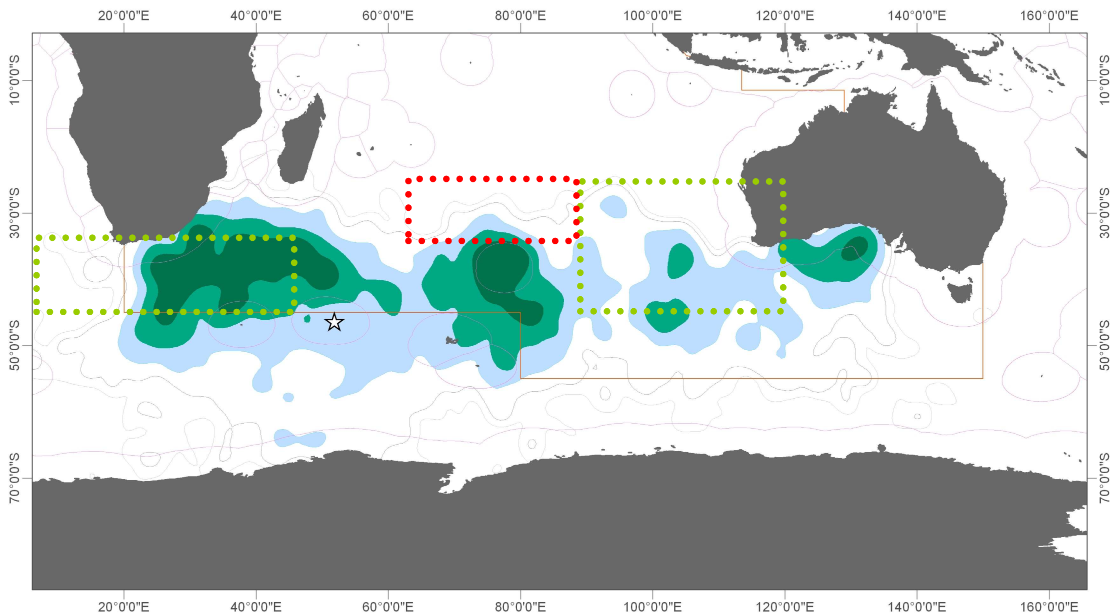

Figure 7. Map of important areas for adults of sooty albatross *P. fusca* breeding at Crozet Island in the Southern Indian Ocean during breeding/non-breeding periods Kernel utilization distribution (UDs, 25%, 50%, 75%), breeding colony at-Amsterdam Island (white star), limits of IOTC Convention Area (yellow) and of EEZs (blue) and hotspots of bycatch of seabirds (sooty albatross in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

The important areas for adults during non-breeding period (sabbatical period) overlapped with the IOTC convention area, mainly with international waters the rest being in Exclusive Economic Zones (France, South Africa for Crozet population and Australia for both populations).

Adults of sooty albatross breeding at Crozet Island tended to spend sabbatical period mostly in the eastern part, while those breeding at Amsterdam tended to distribute in the western part of the Southern Indian Ocean. This pattern leads to different overlap with bycatch hotspots, mainly with Japanese fleet (Figures 6 &7), depending on the breeding colony.

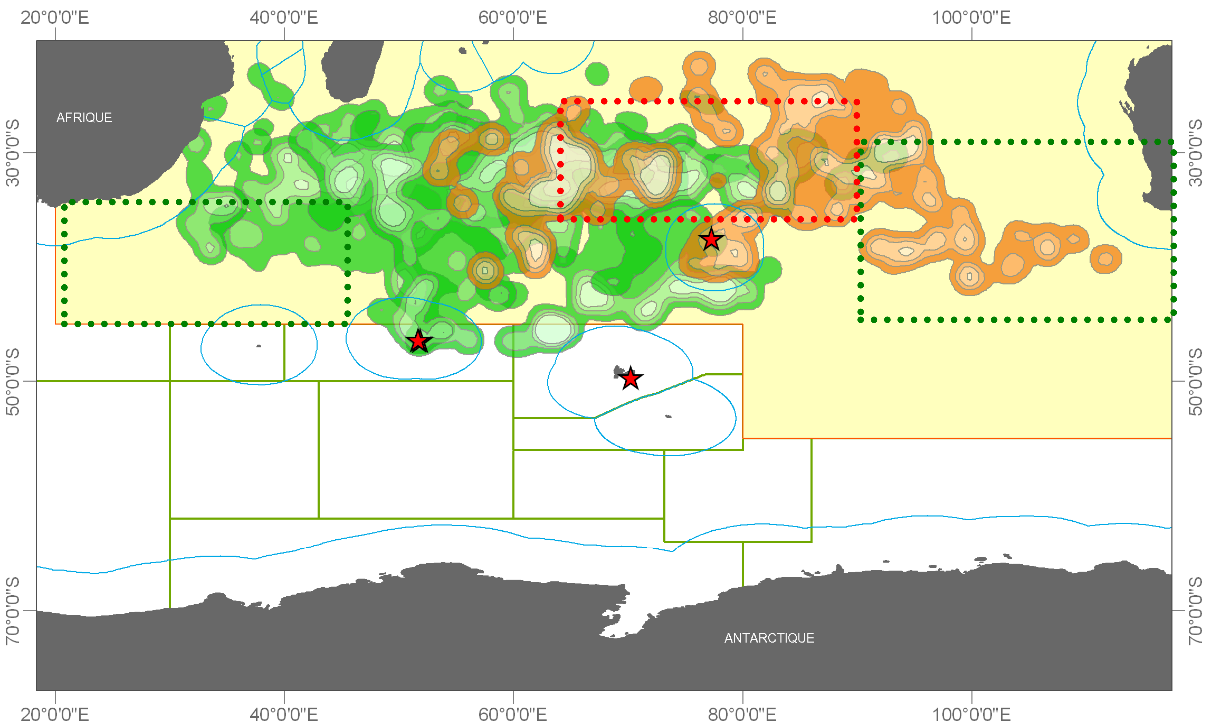

Figure 8. Map of important areas for juveniles of sooty albatross *P. fusca* from Crozet and Amsterdam Islands in the Southern Indian Ocean. Are reported Kernel utilization distribution (UDs, 25%, 50%, 75% and 95 %. green: Crozet in 2008 and 2009, orange: Amsterdam in 2009), breeding colonies (red stars), limits of IOTC Convention Area (orange) and of EEZs (blue). Hotspots of bycatch of seabirds (white-chinned petrel in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

This emphasizes the significance of subtropical and tropical during the juvenile's period (post-fledging; Figure 11). Juveniles of sooty albatross tended to distribute during post fledging period more northerly (up to 25°S) than adults do, being more at-risk of bycatch due to extended overlap with the hotspots of bycatch by both Japanese and Tawainese fleet (Inoue et al. 2011, Huang & Liu 2010).

4. Wandering albatross

The important areas used by this vulnerable species (IUCN Red List) during the sabbatical period (non-breeding period) are widely distributed across the Southern Ocean whatever their origin (Crozet -Figure 9- or Kerguelen -Figure 10- Islands).

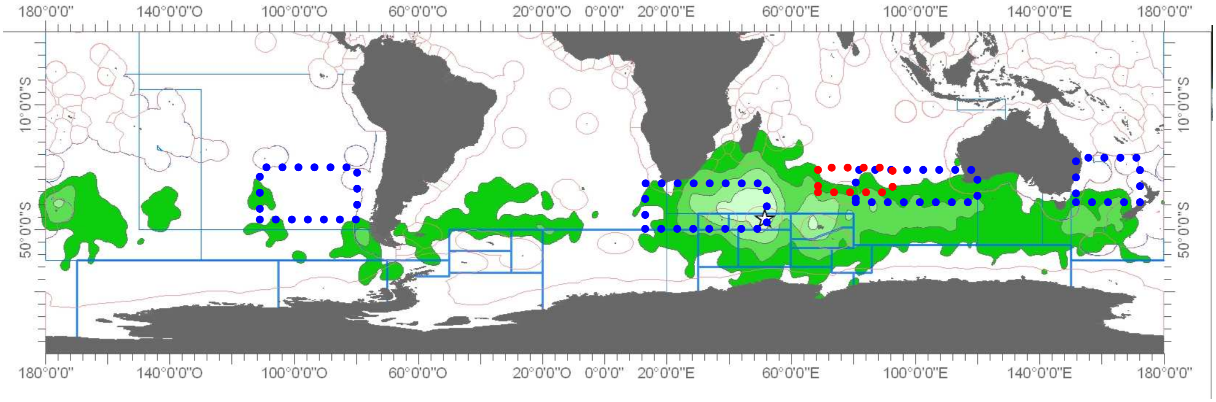

Figure 9. Map of important areas for wandering albatross *Diomedea exulans* of Crozet Island. GLS data analysed for adults (23 individuals) during sabbatical period following successful breeding in 2007/2008. Kernel utilization distribution -UD: 25%, 50%, 75% and 95%, breeding colony at Crozet (white star), limits of RFMOs, of EEZs (blue lines) and hotspots of bycatch (of wandering albatross in Japanese fleet - blue squares (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

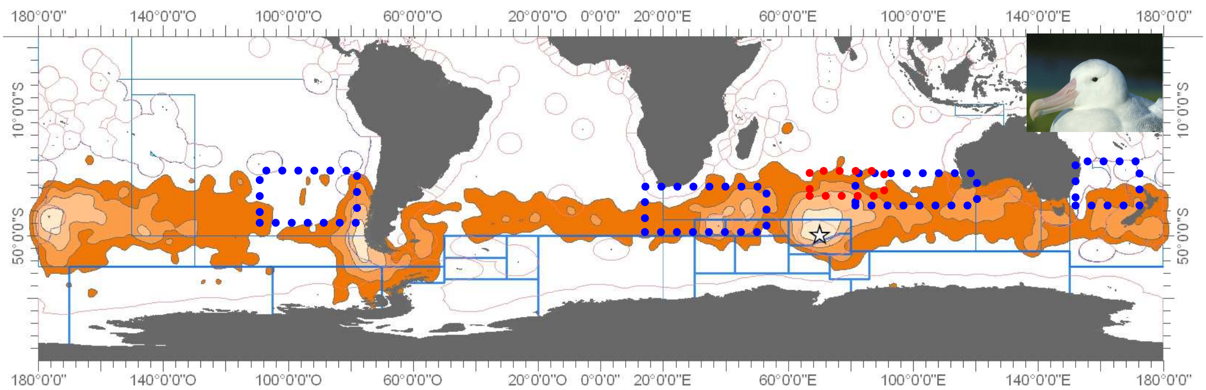

Figure 10. Map of important areas for wandering albatross *D. exulans* of Kerguelen Island. GLS data analysed for adults (17 individuals) during sabbatical period following successful breeding in 2007/2008. Kernel utilization distribution -UD: 25%, 50%, 75% and 95%, breeding colony at Kerguelen (white star), limits of RFMOs, of EEZs (blue lines) and hotspots of bycatch (of wandering albatross in Japanese fleet - blue squares (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

The areas of importance overlapped mainly with international waters the rest being in several Exclusive Economic Zones. Nonetheless, the IOTC Convention area appeared to play a more important role for the population of Crozet that tended to spend almost all the sabbatical period in the Southern Indian Ocean (Figures 9 & 10).

The important areas for wandering albatross, whatever the breeding colony, during non-breeding period overlapped largely with the areas of hotspots of bycatch of wandering albatross recently reported for the Japanese and Taiwanese fleet (Inoue et al. 2011, Huang & Liu 2010). Nonetheless, the population of Crozet can be more at risk of incidental bycatch by Japanese fleet.

5. White-chinned petrel

The analysis of GLS data for two populations of Southern Indian Ocean revealed the areas important (breeding/non-breeding periods) for the adults of white-chinned petrel breeding on Kerguelen Island and Crozet Island (Vulnerable IUCN). They alternated foraging at long distance from the colony and around the colony while breeding and then migrated westward to winter in the Benguela Current System (off Namibia and South Africa).

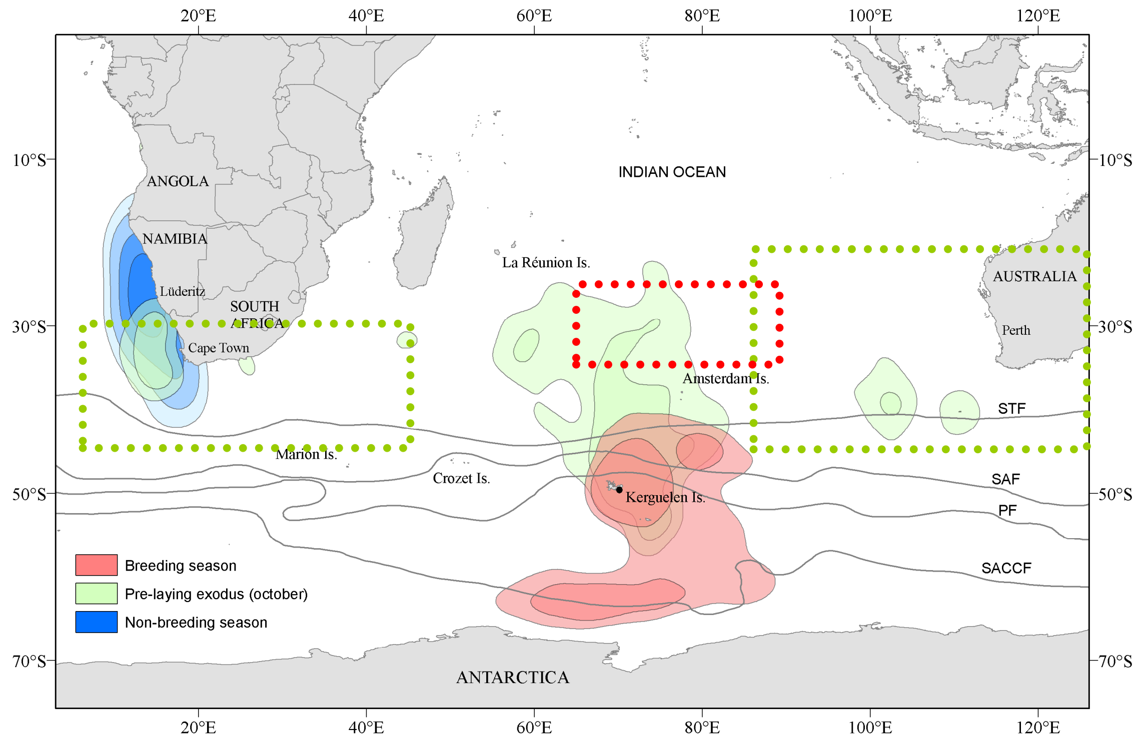

Figure 11. Map of important areas for adults of white-chinned petrel *Procellaria aequinoctialis* form Kerguelen Island in the Southern Indian Ocean (GLS data) during breeding/non-breeding periods. Kernel utilization distribution (UDs, 25-90% during non-breeding; 25-50% during breeding) and hotspots of bycatch of seabirds (white-chinned petrel in Japanese fleet - green squares (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported. Frontal structures: Subtropical Front (STF), Subantarctic Front (SAF), Polar Front (PF) and Southern Antarctic Circumpolar Current Front (SACCF) are represented (*from Péron et al. 2010*).

The areas of importance of adults overlapped mainly with international waters the rest being in Exclusive Economic Zones (namely South African, Namibian and French). Nonetheless, the IOTC Convention area appeared to play an important role for both the populations of Crozet and Kerguelen mainly during breeding period and migration (Figures 14 & 15).

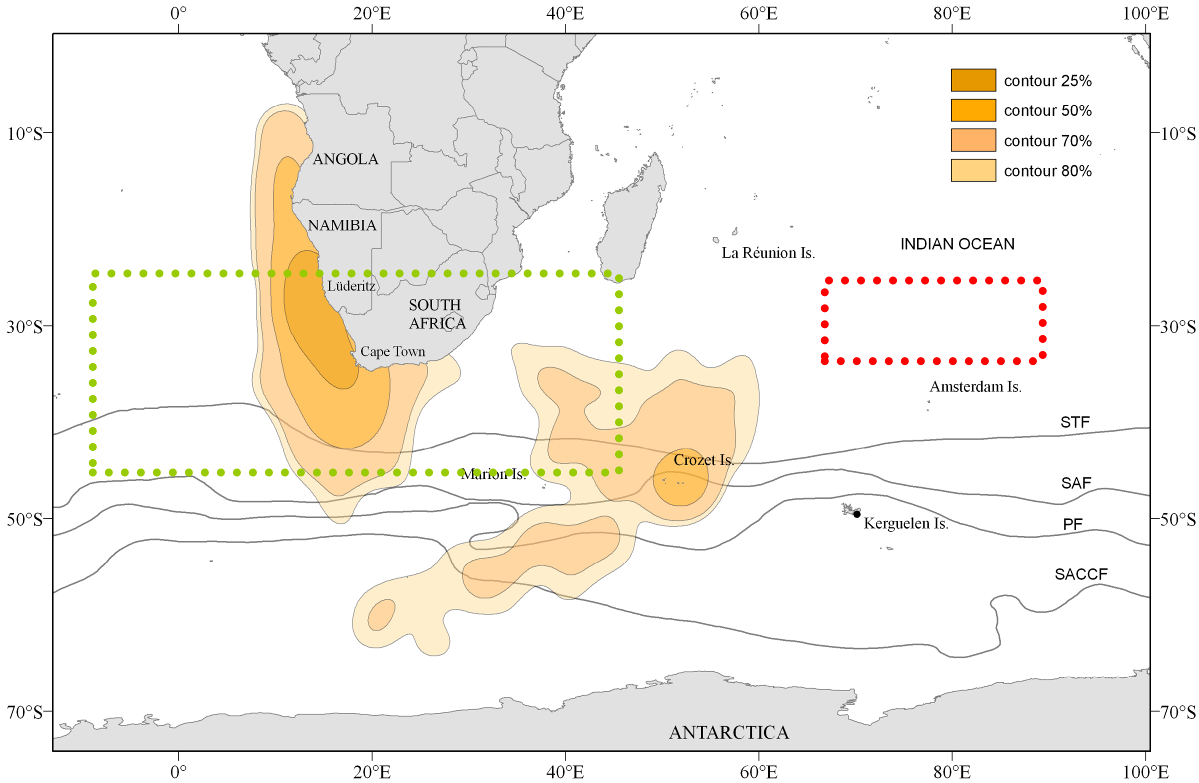

Figure 12. Map of important areas for adults of white-chinned petrel *P. aequinoctialis* form Crozet Island in the Southern Indian Ocean (GLS data) during breeding/non-breeding periods. Kernel utilization distribution (UDs, 25-80%) and hotspots of bycatch of seabirds (white-chinned petrel in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported. Frontal structures: Subtropical Front (STF), Subantarctic Front (SAF), Polar Front (PF) and Southern Antarctic Circumpolar Current Front (SACCF) are represented (*from Péron et al. 2010*).

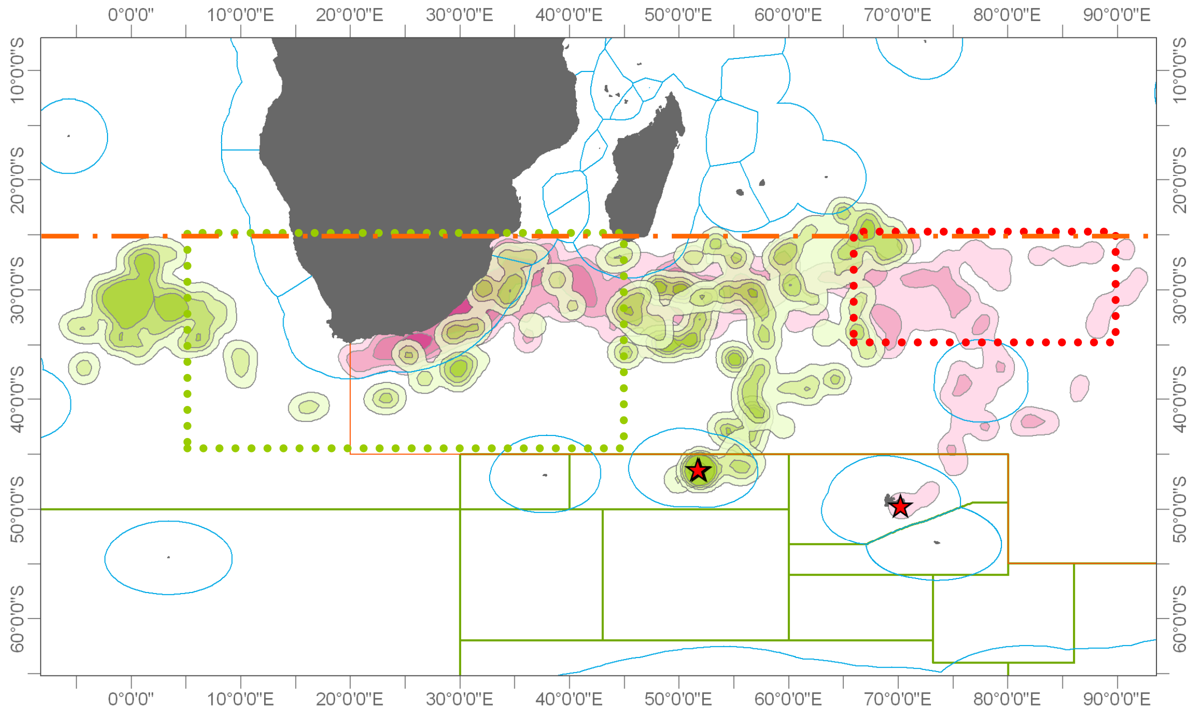

Figure 13. Map of important areas for juveniles of white-chinned petrel *P. aequinoctialis* from Crozet and Kerguelen Islands, Southern Indian Ocean. Are reported Kernel utilization distribution (UDs, 25%, 50%, 75% and 95 %. green: Crozet in 2008 and 2009, pink: Kerguelen in 2009), breeding colonies (red stars), limits of IOTC Convention Area (orange) and of EEZs (blue). Hotspots of bycatch of seabirds (white-chinned petrel in Japanese fleet - green square (Inoue et al. 2011); all species in Taiwanese fleet - red square (Huang & Liu 2010)) are also reported.

Juveniles of white-chinned petrel migrate after fledging northward (up to 25°S) of their breeding colony and then migrate eastward to the Agulha Current System (for Kerguelen) up to South Atlantic (for Crozet).

The important areas for juveniles, whatever the breeding colony, overlapped largely with the areas of hotspots of bycatch of white-chinned recently reported for the Japanese and Taiwanese fleet (Inoue et al. 2011, Huang & Liu 2010).

CONCLUSION

The results presented showed the overlap between bycatch hotspots recently reported for the IOTC Convention area (Inoue et al. 2011, Huang & Liu 2010) and the distribution of albatrosses 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 targeted by longline IOTC fleets, south of 20°S. These species, the juveniles particularly, are highly at risk of incidental bycatch because they overlap with areas of high bycatch levels.

In addition, the IOTC area is of great importance to wandering albatross, black-browed albatross, sooty albatross and white-chinned petrel during non-breeding and juvenile periods.

These results on locations data show that seabirds are largely distributed on the southern part of the Indian Ocean from the tropics to the Antarctica. They overlap with numerous Exclusive Economic Zones (belonging to France, Australia, South Africa, Namibia and New Zealand) and high sea waters covered by six RFMOs (CCAMLR, IOTC, Commission for the Conservation of Southern Bluefin Tuna-CCSBT, Southern Indian Ocean Fisheries Agreement-SIOFA, International Commission for the Conservation of Atlantic Tunas-ICCAT, South East Atlantic Fisheries Organization-SEAFO) suggesting the importance of collaboration for the conservation of seabirds.

Our results highlight the crucial need to have access to fishery data of quality and to bycatch estimates (by fleet, by specific areas and with species composition, the recoveries data) as well as band recoveries in order to enable effective management of fisheries and seabird populations.

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