Atlas of top predators from French Southern Territories in the Southern Indian Ocean

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Based on the tracking data base PELAGIS, data owners:

C-A Bost: penguins

C Guinet : seals

H Weimerskirch: albatrosses, petrels, skuas

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Executive Abstract

Penguins, albatrosses, petrels, elephant seals and fur seals are marine top predators that have to come on land to reproduce. Therefore, they are the only marine top predators that can be studied from land base sites, making them the most accessible convenient models to study marine ecosystems. Indeed, seabirds and seals are considered as good indicators of changes in ecosystems at differential spatial and temporal scales. However, current conservation measures, which comprise relatively few impact mitigation actions and restricted protection of the sole coastal areas, are insufficient, especially for the oceanic realm. Today, there is an urgent need to identify and protect the open sea environments where seabirds and marine mammals forage.

The first stage of most conservation planning is to identify areas that warrant protection (including areas that are already protected). The main criteria used to identify such areas are biological diversity (species richness), rarity, population abundance, environmental representativeness and site area. Where distribution data are both comprehensive and accurate, it is possible to identify areas of high species richness (hotspots), focusing on threat level (endangered species).

This *Atlas of top predators from the French Southern Territories in the Southern Indian Ocean* is a summary of information on the use of the southern Indian Ocean by 22 seabirds and seals species: king penguin, gentoo penguin, Adélie penguin, eastern rockhopper penguin, northern rockhopper penguin, macaroni penguin, Amsterdam albatross, wandering albatross, black-browed albatross, Indian yellow-nosed albatross, light-mantled albatross, sooty albatross, southern giant petrel, northern giant petrel, southern fulmar, Cape petrel, snow petrel, white-chinned petrel, grey petrel, brown skua, southern elephant seal and Antarctic fur seal.

The distribution map of each species was obtained by the use of tracking methods that allow identifying important areas in the southern Indian Ocean. The determination of zones of high species richness suggests several important areas for top predators. First the *breeding colonies and surrounding zones*: Amsterdam and Saint Paul Islands, Marion and Prince Edward islands and the Del Cano Rise, Crozet Islands, Kerguelen Plateau and East Antarctica (Adélie Land sector). Second, the *upwelling-current zones*: Benguela and Agulhas Currents Systems and third several the *oceanic zones*: the Southwest Indian Ridge (East Bouvetøya and the North Subtropical Front), the Mid-Indian Ridge (North of Kerguelen and the Eastern Indian Ocean, the Southeast Indian Ridge (Great Australian Bight and Tasmania, Ob and Lena Banks, and East Antarctica (Prydz Bay - Queen Maud Land sectors, Adélie Land sector).

The analysis of distribution indicates that some pelagic species have a much wider foraging range outside the breeding season than during the breeding season (some disperse over very large areas, i.e. wandering albatross). This highlights the urgent need to strengthen collaborations, namely between conservation and management organisms such as CCAMLR and the fisheries organisations (RFMOs), to ensure the protection of these species and the conservation of the ecosystem that will also be beneficial for many other species.

In conclusion, although this inventory of areas of key importance is preliminary because of the lack of data on several keystone species such as burrowing petrels which could not be studied in this work, **the results presented here show an unprecedented improvement in the identification of priority areas within the Southern Indian Ocean, which should be the primary targets of site-based conservation efforts in the near future.** The Southern Indian Ocean is not pristine. The most serious threats are linked to industrial fishing activities, including fishery discards, bycatch of seabirds and marine mammals, as well as, in a lesser extent, degradation of marine environments through global

and local pollution. On land, alien introductions and diseases are now the main threats. Despite much improvement in the conservation measures taken by several fisheries, especially in the southern part of the Indian Ocean, fisheries continue to exert an important negative influence on several seabirds, especially on the high seas. However climate change is now increasingly considered to have a negative impact on seabirds at some Antarctic and sub-Antarctic localities.

Contenu

The *Atlas* and the Conservation of the Southern Indian Ocean

Seabirds and seals are marine predators that have to come on land to reproduce. Therefore, they are the only marine predators that can be studied from land base sites, making them the most accessible convenient models to study marine ecosystems. Indeed, seabirds and seals are considered as good indicators of changes in ecosystems at differential spatial and temporal scales (Piatt and Sydeman, 2007). The presence of diverse and abundant top predators is indicative of other taxa, such as their prey (Wilson et al., 1994); (Benoit-Bird et al., 2011) or other top predators with which they associate for feeding (Ballance et al., 1997). In addition, top predators tend to congregate in highly productive areas and habitats, such as shelf slopes, seamounts and upwelling systems (Hunt et al., 1999) (Lascelles et al., 2012;Nur et al., 2010).
Seabirds and seals are widely represented across ecosystems, and their global distribution makes them especially suitable to identify import areas that cover a variety of marine ecosystems. Many of these species are highly migratory and tracking data may reveal connectivity between sites. Seabirds and seals are readily surveyed, and therefore data issued from the monitoring of these top predators are often the most abundant or even the only biological data available for some open-ocean ecosystems.

The present *Atlas* focuses on seabirds and seals which breed in the French Southern Territories and Adélie Land and forage in the entire Southern Indian Ocean. It represents the first comprehensive summary of information on how some species or communities of top predators of the Southern Indian Ocean use the habitats of this immense area.

INTRODUCTION

The present *Atlas* presents the distribution of 22 species of seabirds and seals that breed in the French Southern Territories and Adélie Land and forage in the entire Southern Indian Ocean. The aim of this work is to build a comprehensive document with the most recent information available for the 22 species in the section of the Southern Ocean located between 0° and 180°E.

For each species, information concerning the area of interest is given for the following sections: i) **Taxonomy** ; ii) **Breeding cycle**, identifies breeding and non-breeding periods; iii) **Conservation status**, refers to BirdLife International 2012 –IUCN Red List of Threatened Species (see Sources section); **Regional Breeding Sites**, presents breeding sites and estimates of breeding populations in the area; **Population trends**, gives information on populations trends at the present time (most up-to-date available data); iv) **Diet and stable isotopes**, describes the food and feeding ecology by conventional means and by stable isotopes ; v) **Marine distribution**, presents maps of distribution for all species based on remote tracking data, *important areas*, and outputs from models of *habitat selection*; vi) **Threats**, synthesizes threats faced by species in the marine environment and vii) **Gaps and Stakes**.

For the species of albatrosses and petrels listed in the ACAP (Agreement on the Conservation of Albatrosses and Petrels) the following sections *Regional Breeding Sites*, *Population trends*, *Threats*, *Gaps and Stakes* are based on the documents produced by ACAP (see references listed in Sources section).

The GIS Dataset

The *Atlas* is based on remote tracking data of key top predator species of the Southern Indian Ocean, such as albatrosses, petrels, brown skua, penguins, Antarctic fur seals and southern elephant seals. Thanks to technological developments over the last 20 years, unforeseen aspects of the behaviour of individuals at sea, such as migrations, dives and selection of habitats, can now been successfully investigated.

Three types of instruments are used in the tracking of animals: recorders for global positioning systems (GPS), satellite transmitters (Platform Terminal Transmitters, PTT) and geolocators (GLS). GPS instruments are satellite linked loggers that can record information on the position of individuals at programmable intervals down to seconds and with accuracies of metres. PTT instruments allow up to 20 localisations per day according to the locality, which are transmitted to satellites of the Argos system, with a degree of accuracy of just a 100m to a few kilometres. GLS loggers measure changes in the level of atmospheric light, and allow estimating times of sunrise and sunset and thus the duration of the day. These data are used to calculate latitude and longitude twice per day with a low accuracy (a median error of 180 km), but at low cost and long viability. For further information on remote tracking devices see Annex I: Methodological Notes.

To date (January 2013), the GIS database of the CEBC-CNRS Chizé contains more than 500 000 locations of 800 individuals tracked for 22 species of seabirds and marine mammals (Table 3). Most of these data were obtained by satellite transmitters, although GLS and GPS instruments were also deployed. The majority of the locations are within the Southern Indian Ocean, with some species distributing more widely over other Ocean basins of the Southern Ocean (e.g. wandering albatrosses from Kerguelen Island during the inter-nesting period circumnavigate Antarctica, migrating eastward over the Pacific and Atlantic, with most important areas off our area of interest in the *Atlas*; see Map 31). It is noteworthy to stress that several important species (e.g. diving petrels, prions, storm-petrels, *Pterodroma* spp. and the subantarctic fur seal *Arctocephalus tropicalis*) are lacking in the *Atlas*. For most of these species, distribution data are not available since tracking devices are still inadequate given the small body size of the species.

The *Atlas* is based on tracking data from adult individuals from a limited number of breeding colonies (cf Table 1, 2, 3; Annex II Table A1, A2).

Table 1. Species of seabirds and seals breeding in the French Southern Territories (Subantarctic and subtropical islands and Adélie Land in Antarctica) and availability of data on at-sea distribution (individual tracking), diet and isotopic signature. Coloured cells indicate that the species breeds at the site (green; Amsterdam-Saint Paul, Crozet, Kerguelen or Adélie Land) and the availability of distribution data (blue) for the *Atlas*. The availability of diet and isotopic data is indicated for each species/site (Ams: Amsterdam, St Paul: Saint Paul, Cro: Crozet, Ker: Kerguelen, TA: Adélie Land).

Species	**Amsterdam - St Paul**	**Crozet**	**Kerguelen**	**Adélie Land**	**Distribution data**	**Diet data**	**Isotopic data**
Eaton's pintail *Anas eatoni*					NA	Cro	Ker
King penguin *Aptenodytes patagonicus*					Cro, Ker	Cro, Ker	Cro, Ker
Emperor penguin *Aptenodytes forsteri*					NA[1]	TA	TA
Gentoo penguin *Pygoscelis papua papua*					Ker	Cro, Ker	Cro, Ker
Adelie penguin *Pygoscelis adeliae*					TA	TA	TA
Eastern rockhopper penguin *Eudyptes chrysocome filholi*					Cro, Ker	Cro, Ker	Cro, Ker
Northern rockhopper penguin *Eudyptes moseleyi*					Ams	Ams	Ams
Royal penguin *Eudyptes schlegeli*					NA		
Macaroni penguin *Eudyptes chrysolophus*					Cro, Ker	Cro, Ker	Cro, Ker
Wandering albatross *Diomedea exulans*					Cro, Ker	Cro, Ker	Cro, Ker
Amsterdam albatross *Diomedea amsterdamensis*					Ams		Ams
Black-browed albatross *Thalassarche melanophrys*					Ker	Cro, Ker	Ker
Salvin albatross *Thalassarche cauta salvini*					NA		

Grey-headed albatross *Thalassarche chrysostoma*	NA	Cro, Ker	
Indian yellow-nosed albatross *Thalassarche carteri*	Ams	Ams, Cro, Ker	Ams
Sooty albatross *Phoebetria fusca*	Cro, Ams	Ams, Cro	Ams, Cro
Light-mantled albatross *Phoebetria palpebrata*	Cro, Ker	Cro, Ker	Cro, Ker
Southern giant petrel *Macronectes giganteus*	Cro, Ker	Cro	Cro
Northern giant petrel *Macronectes halli*	Cro, Ker	Cro	Cro, Ker
Southern fulmar *Fulmarus glacialoides*	TA	TA	TA
Cape petrel *Daption capense*	TA	Cro, TA	TA
Snow petrel *Pagodroma nivea*	TA	TA	TA
Great-winged petrel *Pterodroma macroptera*	NA	Cro	Ker, St Paul
White-headed petrel *Pterodroma lessonii*	NA[2]	Cro, Ker	Ker
Soft-plumaged petrel *Pterodroma mollis*	NA	Cro, Ker	Ker
Kerguelen petrel *Aphrodroma brevirostris*	NA	Cro	Ker
Blue petrel *Halobaena caerulea*	NA[2]	Cro, Ker	Ker
Salvin prion *Pachyptila salvini*	NA	Cro	
Macgillivray prion *Pachyptila macgillivrayi*	NA		St Paul
Antarctic prion *Pachyptila desolata*	NA[2]	Ker	Ker

Thin-billed prion *Pachyptila belcheri*	NA[2]	Ker	Ker
Fairy prion *Pachyptila turtur*	NA	Cro	
White-chinned petrel *Procellaria aequinoctialis*	Cro, Ker	Cro, Ker	Cro, Ker
Grey petrel *Procellaria cinerea*	Ker	Cro, Ker	Ker
Flesh-footed shearwater *Puffinus carneipes*	NA		St Paul
Little shearwater *Puffinus assimilis*	NA		
Wilson's storm-petrel *Oceanites oceanicus*	NA	Cro, TA	Ker, TA
Grey-backed storm-petrel *Garrodia nereis*	NA	Cro	Ker
Black-bellied storm-petrel *Fregetta tropica*	NA	Cro	Ker
White-bellied storm-petrel *Fregetta grallaria*	NA		
South Georgia diving-petrel *Pelecanoides georgicus*	NA	Cro, Ker	Ker
Common diving-petrel *Pelecanoides urinatrix*	NA	Cro, Ker	Ker
Crozet shag *Phalacrocorax melanogenis*	NA	Cro	
Kerguelen shag *Phalacrocorax verrucosus*	NA	Ker	Ker
Black-faced sheathbill *Chionis minor*	NA		Ker
Kelp gull *Larus dominicanus judithae*	NA	Cro	Ker
Antarctic tern *Sterna vittata*	NA	Cro	

Kerguelen tern *Sterna virgata*	NA	Cro	
Brown skua *Catharacta antarctica lonnbergi*	Ker	Cro, Ker	Ams, Cro, Ker
South polar skua *Catharacta maccormicki*	NA[1]	TA	TA
Southern elephant seal *Mirounga leonina*	Ker		Cro, Ker
Antarctic fur seal *Arctocephalus gazella*	Ams	Cro, Ker	Cro, Ker
Subantarctic fur seal *Arctocephalus tropicalis*	NA	Ams, Cro	Ams, Cro

[1] Data not included in the analysis of distribution due to the range of the location (off the area of interest for South Polar Skua) or concerning only juveniles (Emperor Penguin); [2] Data under analysis (NA[2]) or not available (NA)

Table 2. Species included in the *Atlas*

Noms des espèces Species names Français	 English	Noms scientifiques Scientific names
Manchots	**Penguins**	
Manchot royal	King penguin	*Aptenodytes patagonicus*
Manchot papou	Gentoo penguin	*Pygoscelis papua papua*
Manchot Adélie	Adélie penguin	*Pygoscelis adeliae*
Gorfou sauteur de l'Est	Eastern rockhopper penguin	*Eudyptes chrysocome filholi*
Gorfou sauteur du Nord	Northern rockhopper penguin	*Eudyptes moseleyi*
Gorfou macaroni	Macaroni penguin	*Eudyptes chrysolophus*
Albatros	**Albatrosses**	
Albatros d'Amsterdam	Amsterdam albatross	*Diomedea amsterdamensis*
Grand albatros	Wandering albatross	*Diomedea exulans*
Albatros à sourcils noirs	Black-browed albatross	*Thalassarche melanophrys*
Albatros à bec jaune de l'Océan Indien	Indian yellow-nosed albatross	*Thalassarche carteri*
Albatros fuligineux à dos clair	Light-mantled albatross	*Phoebetria palpebrata*
Albatros fuligineux à dos sombre	Sooty albatross	*Phoebetria fusca*
Pétrels	**Petrels**	
Pétrel géant antarctique	Southern giant petrel	*Macronectes giganteus*
Pétrel géant subantarctique	Northern giant petrel	*Macronectes halli*
Fulmar antarctique	Southern fulmar	*Fulmarus glacialoides*
Damier du Cap	Cape petrel	*Daption capense*
Pétrel des neiges	Snow petrel	*Pagodroma nivea*
Pétrel à menton blanc	White-chinned petrel	*Procellaria aequinoctialis*
Pétrel gris	Grey petrel	*Procellaria cinerea*
Skuas		
Skua subantarctique	Brown skua	*Catharacta antarctica lonnbergi*
Pinnipèdes	**Pinnipeds**	
Eléphant de mer du Sud	Southern elephant seal	*Mirounga leonina*
Otarie à fourrure de Kerguelen	Antarctic fur seal	*Arctocephalus gazella*

Table 3. Species included in the *Atlas*: conservation status and international listing

Species names	Noms scientifiques Scientific names	IUCN[1]	CITES[2]	ACAP[3]
Penguins				
King penguin	*Aptenodytes patagonicus*	**LC**		
Gentoo penguin	*Pygoscelis papua papua*	**NT**		
Adélie penguin	*Pygoscelis adeliae*	**NT**		
Eastern rockhopper penguin	*Eudyptes chrysocome filholi*	**VU**		
Northern rockhopper penguin	*Eudyptes moseleyi*	**EN**		
Macaroni penguin	*Eudyptes chrysolophus*	**VU**		
Albatrosses				
Amsterdam albatross	*Diomedea amsterdamensis*	**CR**		γ
Wandering albatross	*Diomedea exulans*	**VU**		γ
Black-browed albatross	*Thalassarche melanophrys*	**EN**		γ
Indian yellow-nosed albatross	*Thalassarche carteri*	**EN**		γ
Light-mantled albatross	*Phoebetria palpebrata*	**NT**		γ
Sooty albatross	*Phoebetria fusca*	**EN**		γ
Petrels				
Southern giant petrel	*Macronectes giganteus*	**LC**		γ
Northern giant petrel	*Macronectes halli*	**LC**		γ
Southern fulmar	*Fulmarus glacialoides*	**LC**		
Cape petrel	*Daption capense*	**LC**		
Snow petrel	*Pagodroma nivea*	**LC**		
White-chinned petrel	*Procellaria aequinoctialis*	**VU**		γ
Grey petrel	*Procellaria cinerea*	**NT**		γ
Skuas				
Brown skua	*Catharacta antarctica lonnbergi*	**LC**		
Pinnipeds				
Southern elephant seal	*Mirounga leonina*	**LC**	**Annexe II**	
Antarctic fur seal	*Arctocephalus gazella*	**LC**	**Annexe II**	

[1] IUCN - International Union for Conservation of Nature- Red List Category: CR-Critically Endangered, EN- Endangered, VU-Vulnerable, NT-Near Threatened, LC- Least Concern IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Downloaded on 29 January 2013.

[2] CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora. <http://www.cites.org/index.php>. Downloaded on 29 January 2013.

[3] ACAP - Agreement on the Conservation of Albatrosses and Petrels. <http://www.acap.aq/>. Downloaded on 29 January 2013.

Breeding cycle of the Species in the *Atlas*

The breeding cycle of each species is presented as below (Table 5). Breeding period (orange) and inter-breeding period (green) - or non-breeding period, are presented separately. Penguins and seals have to come on land to moult and this period is indicated (shaded orange). The availability of tracking data is indicated by a blue arrow for the corresponding period. Some species of albatrosses that fledged a chick take a sabbatical year of one year before starting a new breeding season.

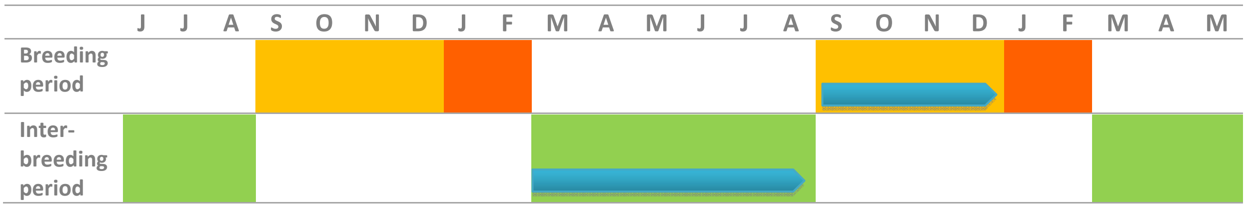


Table 4. *Breeding cycle and availability of tracking data (blue arrow) of* M. leonina. Shaded cells (dark orange) indicates moulting period on land.

Breeding Sites of the Species in the *Atlas*

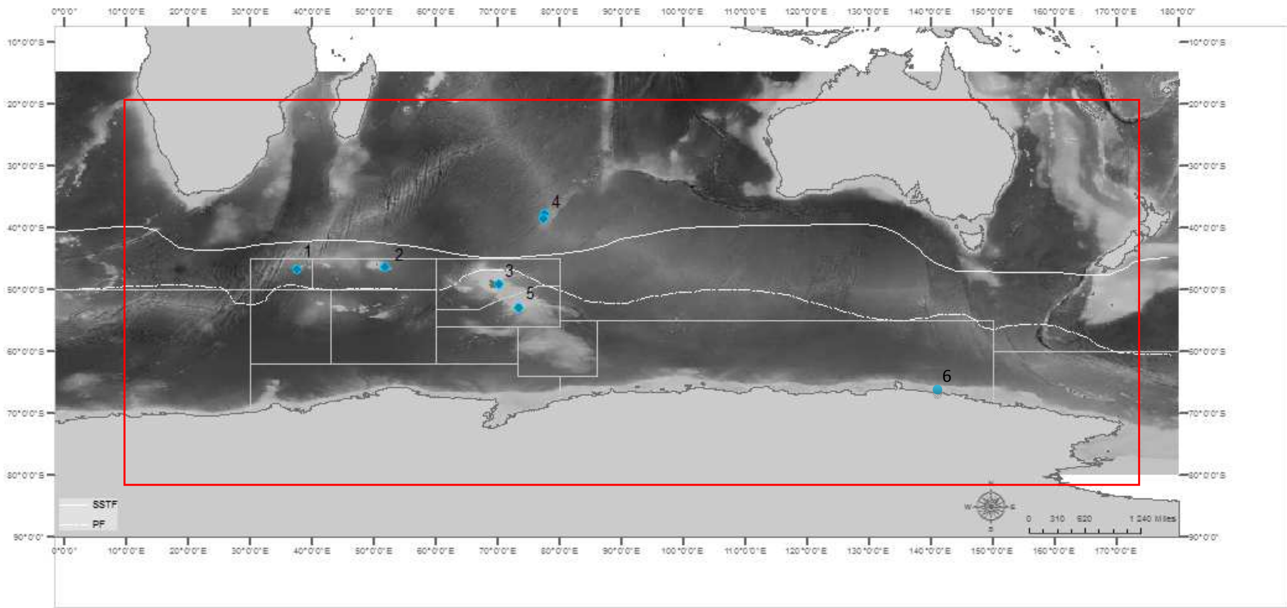
The *Atlas* includes data on 22 species of marine top predators from 4 breeding localities in the French Southern Territories and Antarctica (Amsterdam, Crozet, Kerguelen and Adélie Land).

All the colonies are located within the targeted area defined as the Southern Indian Ocean (Map 1, Table 5), and including Amsterdam, Crozet, Kerguelen and Adélie Land.

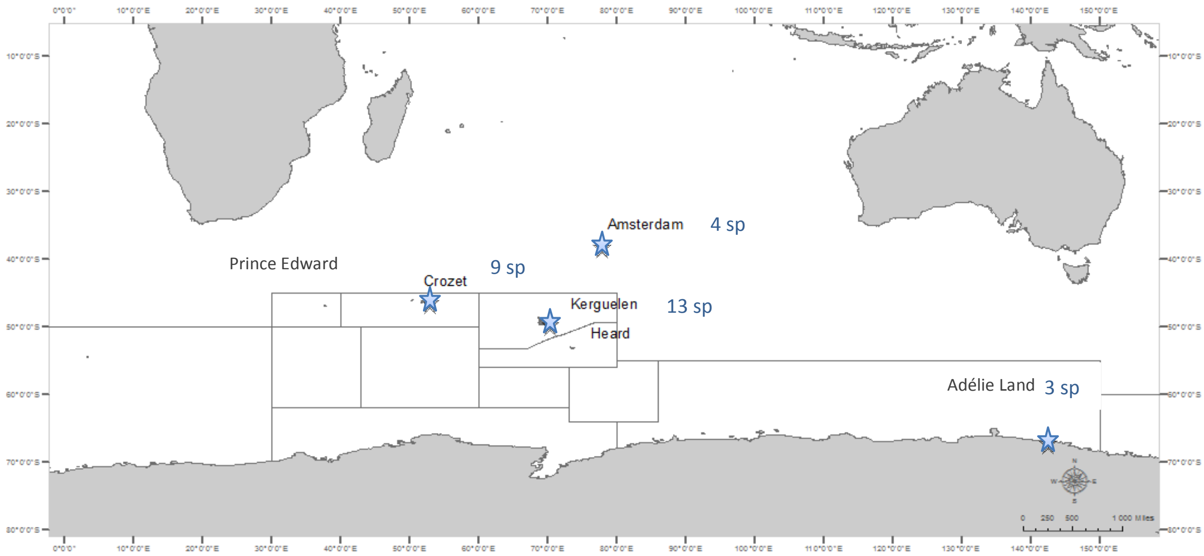
Table 5. Breeding localities in the Southern Indian Ocean (see references in Map 1)

1- I. Marion - Prince Edward	**4- I. Amsterdam - Saint Paul**
2- I. Crozet	**5- I. Heard - McDonald**
3- I. Kerguelen	**6- Adélie Land, Antarctica**

Breeding localities are located all along a latitudinal gradient, from subtropical islands (Amsterdam – Saint Paul), subantarctic islands (Crozet and Kerguelen) to polar site (Adélie Land).



Map 1. Breeding localities in the Southern Indian Ocean (see references in Table 5). Oceanographic frontal structures delimit 3 distinct biogeographic domains: subtropical waters north of the South Subtropical Front (SSTF), Subantarctic waters between the SSTF and the Polar Front (PF) and Antarctic waters south of the PF (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996); updated 2003. The area of interest is shown (red box)



Map 2. Number of species tracked per breeding locality used in the Atlas (see references in Annex II Table A1 & 2).

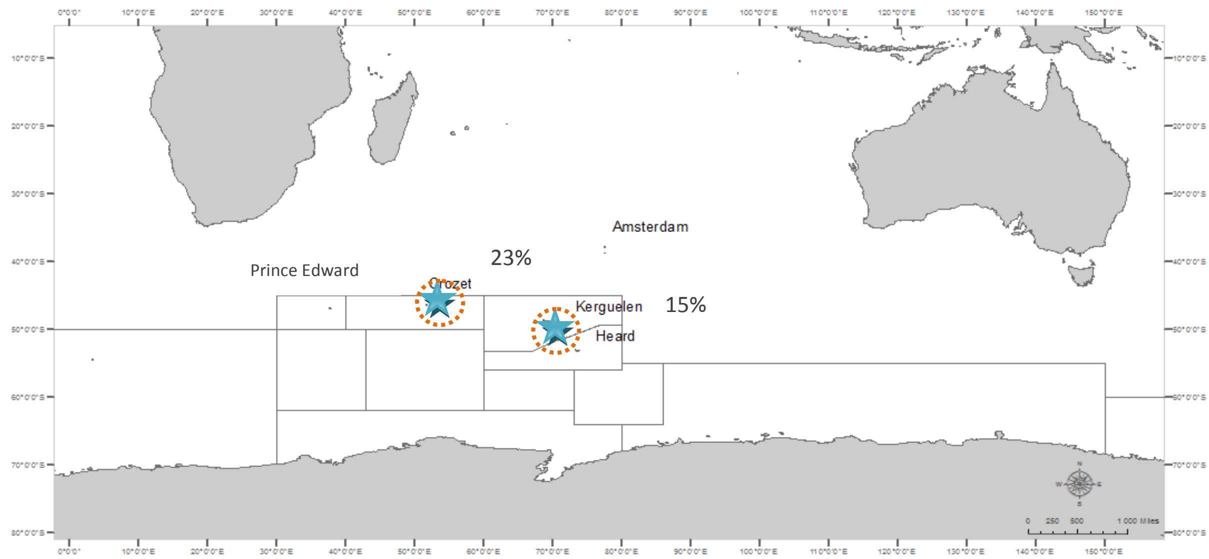
Interpreting the maps in the *Atlas*

Breeding localities in the French Southern Territories and Adélie Land

The location of breeding sites of seabirds and seals in the French Southern Territories is provided at the beginning of each species sheet (example: Map 3). The breeding sites situated in the area of interest but outside the French Southern Territories are not indicated. These maps show only the breeding sites (blue star) for the species included in the *Atlas*, and the percentage of the world population that each site represents.

A blue star and orange circle represents breeding sites from where individuals where tracked

The maps were generated by using the geographic coordinate system WGS 1984 (World Geodetic System of 1984).



Map 3. Breeding localities of the wandering albatross in the French Southern Territories. The area of interest is shown (red box). The breeding sites (blue star) for the species at French Southern Territories included in the *Atlas*, and the percentage of the world population that each site represents are reported. An orange circle represents breeding sites from where individuals where tracked.

Use of the Southern Indian Ocean by seabirds and seals from French Southern Territories

The first stage of most conservation planning is to identify areas that warrant protection (including areas that are already protected). The main criteria used to identify such areas are biological diversity (species richness), rarity, population abundance, environmental representativeness and site area (Prendergast et al., 1999). Where distribution data are both comprehensive and accurate, it is possible to identify areas of high species richness (hotspots), focusing on threat level (endangered species). The simplicity of the species richness approach to reserve selection is both its strength and its weakness.

In a first step, we present in the *Atlas*, the distribution maps for each species and then the important areas identified using the species richness approach.

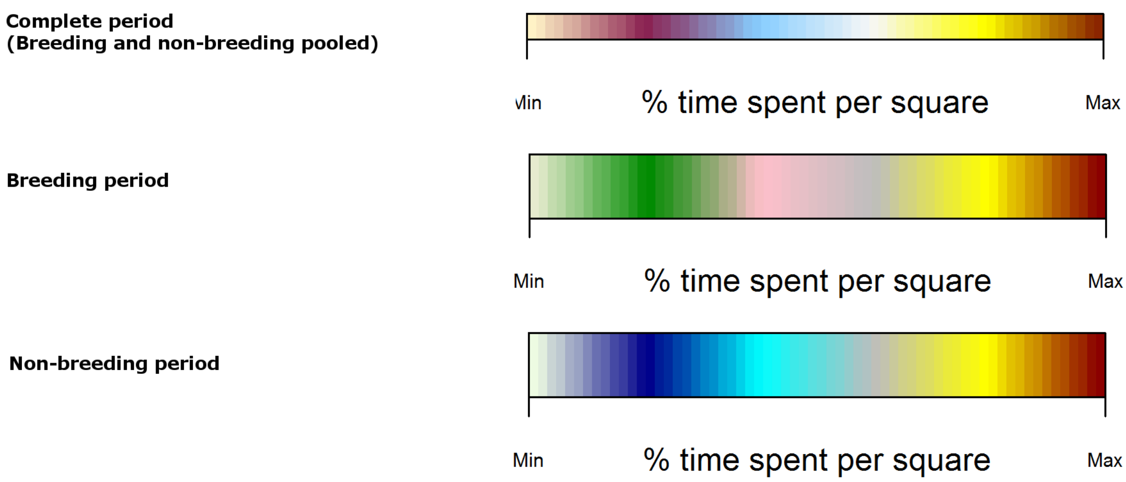
Distribution maps

The methodology used for creating the species distribution maps is briefly explained here. Details are given in Annex I: Methodological Notes.

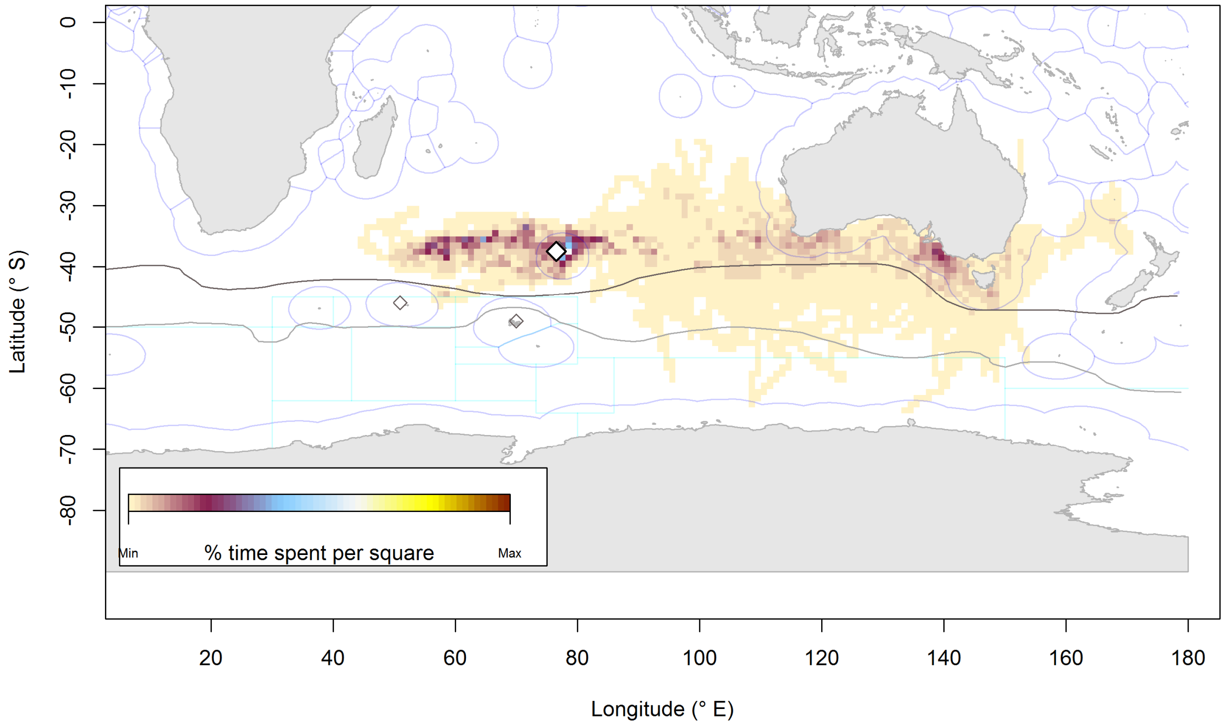
First, the tracking data were standardised and validated. Second, using location data, the residence time was defined as the proportion of time spent by each individual within a 1° × 1° cell in the area of interest (10°E-180°E, 20°S-90°S). Then, the mean residence time spent per square was calculated by species. Residence time was calculated using the *tripGrid* function (trip package) in R, which resamples each individual track at a higher temporal resolution by linear interpolation and calculates the time spent in each spatial unit. The corresponding percentage of time spent in relation to the total trip duration was then calculated to obtain the area distribution (Map 4). The area distribution was calculated for the breeding period, the inter-breeding period and for both periods combined when sufficient data were available. The 1° cell size was chosen according to the tracking devices with the lowest accuracy of geolocators.

The most commonly used areas do not necessarily indicate the zones where individuals feed, but do indicate areas of intense use, which are therefore important for the species.

It is possible to quantify the amount of relative time that the tracked individuals stayed in each cell visited, and to identify the areas where the animals remained for the longest time. In all the distribution maps presented in the *Atlas*, the darkest areas (dark red) identify the zones where individuals spend most of the time (see for example Map 4). The legend used for each of the three periods (*complete*: breeding and non-breeding, *breeding* and *non-breeding*) were as follow.



Diamonds mark the breeding localities of seabirds and seals for which distribution data are shown (see Map 4).



Map 4. *Yellow-nosed albatross, Amsterdam Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding and inter-breeding periods pooled). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The spatial distribution values of residence time are normalized at each step (values between 0 and 1) such as to compare between stages, breeding localities and species.

We deduced from residence time data, the presence/pseudo-absence data (or occurrence data) for each species and stage. Top predators diversity was then evaluated across the Southern Indian Ocean at a 1° latitude-longitude grid cell scale. These cells are not proposed as the unit of conservation, but rather that important sites might, in principle, be identified within such an area.

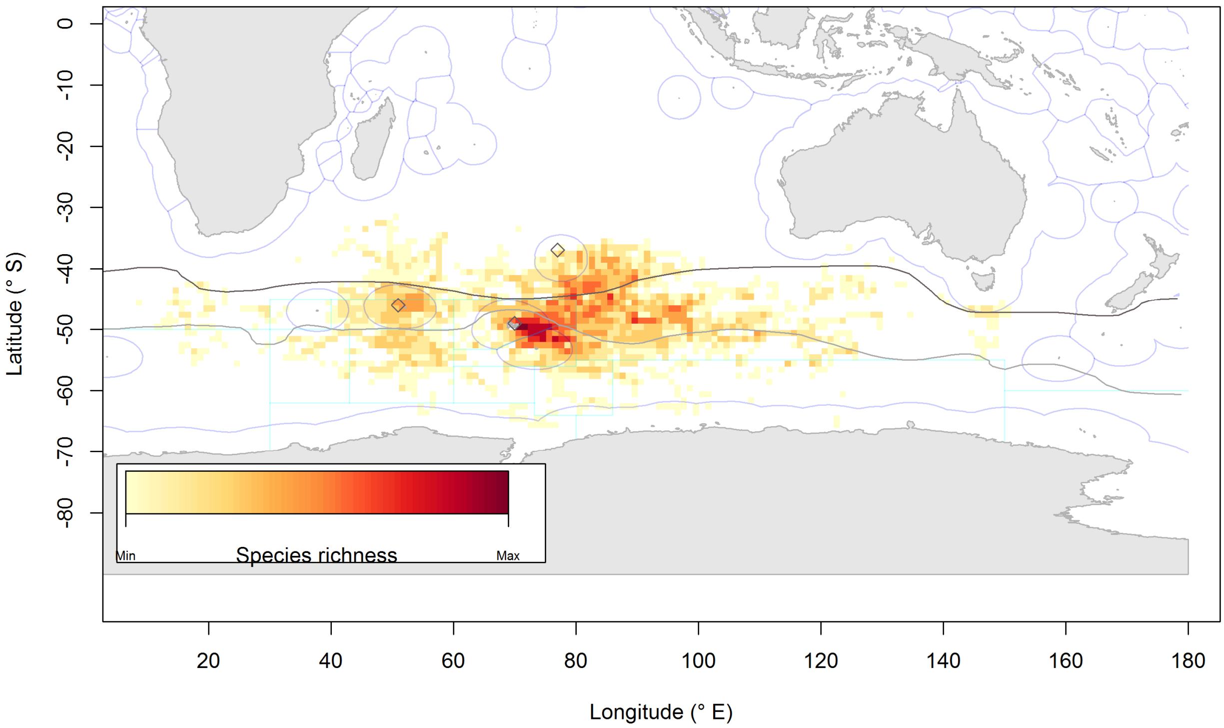
Hotspots identification

Biological diversity can be evaluated on the basis of single or multiple criterion indices. In this analysis of area evaluation, following (Hacker et al., 1998), four indices (*species richness, rarity-weighted richness, threatened species richness, conservation-weighted rarity richness*), two of each type, are used.

The first single-criterion index is "*species richness*". It is directly deduced from the occurrence data of the species. Two alternative approaches can be used in multiple-criterion evaluation (e.g. (Williams, 1997)). The first is to devise an index which combines two or more single-criterion indices, where for

example species richness is weighted by the spatial range size of the species present to determine the "*rarity-weighted richness*" of an area. Range size is a common measure of rarity (Gaston, 1994). The *rarity-weighted richness* is calculated as the sum of rarity scores for all species present in a grid cell, where the rarity score for each species is the reciprocal of the number of cells in which it occurs (e.g. (Williams and Humphries, 1996); the cells with highest score value are therefore those which have a large number of restricted-range species.
The second approach to multiple-criterion indices is that of sequential filtering. This is used in an index in which species richness is combined with endangerment by discarding all the species which are not classified as threatened (following Stevenson et al. 1992; CR: Critically Endangered, EN: Endangered, VU: Vulnerable; Table 4), and then evaluating species richness for the remaining database of threatened species. This measure is called "*threatened species richness*". Finally, we considered a weight score for the IUCN status (i.e. Critically Endangered: 5, Endangered: 4 and so on) which was combined to the *threatened species richness* to produce a final index called "*conservation-weighted rarity richness*".

Hotspots were identified by overlapping the top-scoring 10% and 5% of grid cells (Prendergast et al., 1993) for *species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness* (example shown in Map 5).



Map 5. ***Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell, top-scoring 5% of grid cells) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

For all indices, grid cells with maximum values are shown in dark red and grid cells with minimum values are shown in yellow.

Diet and stable isotopes

Each species sheet includes a short description of the food and feeding ecology including the main prey species and the trophic niche based on stable isotope analysis.

Diet
In birds, dietary analyses are restricted to the chick-rearing period, because adult birds return to the colony with significant amount of food in their proventriculus at that time only. Hence, prey items correspond to chick food, and not to the prey caught by the parent birds when they feed for themselves. Noticeable is the lack of dietary information on breeding adults during incubation, non-breeding adults during the breeding season, and on adults during the inter-breeding period. Analysis of stomach contents followed (Cherel et al., 2000b), meaning that special care was made to not pool fresh and accumulated items (Table 6). The dietary habits of Antarctic fur seals were determined from scat analysis (Cherel et al., 1997).

Stable isotopes
Measurement of stable isotopes is a powerful tool to complement the conventional ways to investigate the food and feeding ecology of consumers (e.g. stomach content and scat analysis, and bio-logging). The isotopic niche is used as a proxy of the ecological niche, with $\delta^{13}C$ and $\delta^{15}N$ values reflecting the foraging habitats and trophic levels of the animals (Newsome et al., 2007). In birds, whole blood and feathers are the two most commonly targeted tissues, because they can be sampled easily in the field. Metabolically active blood represents a period of days to a few months before sampling, depending on animal size, whereas the metabolically inactive feathers reflect the diet at the time they were grown. Hence, blood and feathers from large chicks provide information on the foraging habits of parent birds during the breeding period. In contrast, adult feathers reflect the previous non-breeding period, because adult moult occurs primarily at that time. Here, we focused on feathers from chicks and adults of flying birds, and on blood of penguins and pinnipeds.

The southern Indian Ocean is marked by a well-defined latitudinal (not longitudinal) baseline carbon isoscape that is reflected in the tissue of consumers (Cherel and Hobson, 2007;Jaeger et al., 2010b). Our isotopic seabird database allowed estimating the carbon position of the main oceanic fronts, and thus to delineate robust isoscapes of the main foraging zones for top predators, depending on the targeted tissues. Based on blood (feather) $\delta^{13}C$ isoscapes, values less than -22.9 ‰ (-21.2‰), -22.9 to -20.1 ‰ (-21.2 to -18.3 ‰), and greater than -20.1 ‰ (-18.3 ‰) were considered to correspond to the Antarctic, Subantarctic and Subtropical Zones, respectively (Jaeger et al., 2010b).

Table 6. Relative importance by mass of broad prey classes in the diets of seabirds and pinnipeds during the breeding period. +, from 1 to 10%; ++, from 10 to 40%, +++, >40% by mass.

Species	Localities	Crustaceans	Cephalopods	Fish	Others
Penguins					
King penguin	Crozet		+	+++	
	Kerguelen		+	+++	
Gentoo penguin	Kerguelen (closed sea)	+++		++	+
	Kerguelen (open sea)	++	+	+++	++
Adelie penguin	Adelie Land	+++	+	++	
Eastern rockhopper penguin	Crozet	+++	++	++	
	Kerguelen	+++	+	++	
Northern rockhopper penguin	Amsterdam	++	++	++	
Macaroni penguin	Crozet	+++	+	++	
	Kerguelen	+++		+++	
Albatrosses					
Amsterdam albatross	Amsterdam	no data	no data	no data	no data

Wandering albatross	Crozet		+++	++	+
	Kerguelen		++	++	+
Black-browed albatross	Kerguelen		+	+++	++
Indian yellow-nosed albatross	Amsterdam	+	++	+++	+
Light-mantled sooty albatross	Crozet	++	+++	++	++
	Kerguelen	no data	no data	no data	no data
Sooty albatross	Amsterdam		++	+++	
	Crozet	+	+++	+	+++
Petrels					
Southern giant petrel	Crozet		+	+	+++
Northern giant petrel	Crozet		+		+++
	Kerguelen	no data	no data	no data	no data
Antarctic fulmar	Adélie Land	+++		++	+++
Cape petrel	Adélie Land	+++		++	
Snow petrel	Adélie Land	+	+	+++	+

White-chinned petrel	Crozet	++	++	+++	+
	Kerguelen	++	++	+++	+
Grey petrel	Kerguelen	+	++	+++	+
Skuas					
Brown skua	Kerguelen				+++
Pinnipeds					
Southern elephant seal	Kerguelen	no data	no data	no data	no data
Antarctic fur seal (females)	Kerguelen		+	+++	

Threats to Biodiversity

Exploitation of marine ressources is not usually sustainable, which means that some anthropogenic activities induce actual threats to biodiversity (Pauly et al., 2002). The Southern Indian Ocean is not pristine. The most serious threats are linked to industrial fishing activities, including fishery discards, bycatch of seabirds and marine mammals, as well as degradation of marine environments through global and local pollution (Lewison et al., 2004;Lewison et al., 2005). On land, alien introductions and diseases are now the main threats.

Incidental bycatch. Every year thousands of seabirds and marine mammals die in commercial fishing operations in the southern Indian Ocean (Brothers, 1991;Croxall et al., 2012;Lewison et al., 2004;Lewison et al., 2005). Longline fisheries (using baited hooks) are largely responsible for the historical and current reduction in many albatross and petrel populations. Birds are attracted by baited hooks, caught on hooks and drown when the lines sink. Seabirds and marine mammals are also attracted by fishing vessels to feed on fishing discards, being thus at the risk of being caught in nets and hooks (BirdLife International, 2013). Most species of albatrosses and some petrels in the world are badly threatened with incidental bycatch and ghost fishing (drifting nets) representing major problems to the birds (Barbraud et al., 2012).

@P.Tixier

Entanglement. This threat to the life of many seabirds and marine mammals is a consequence of the interaction with fishing vessels and drifting fishing wastes. Fur seals and southern elephant seals have been recorded entangled in fishing gear.

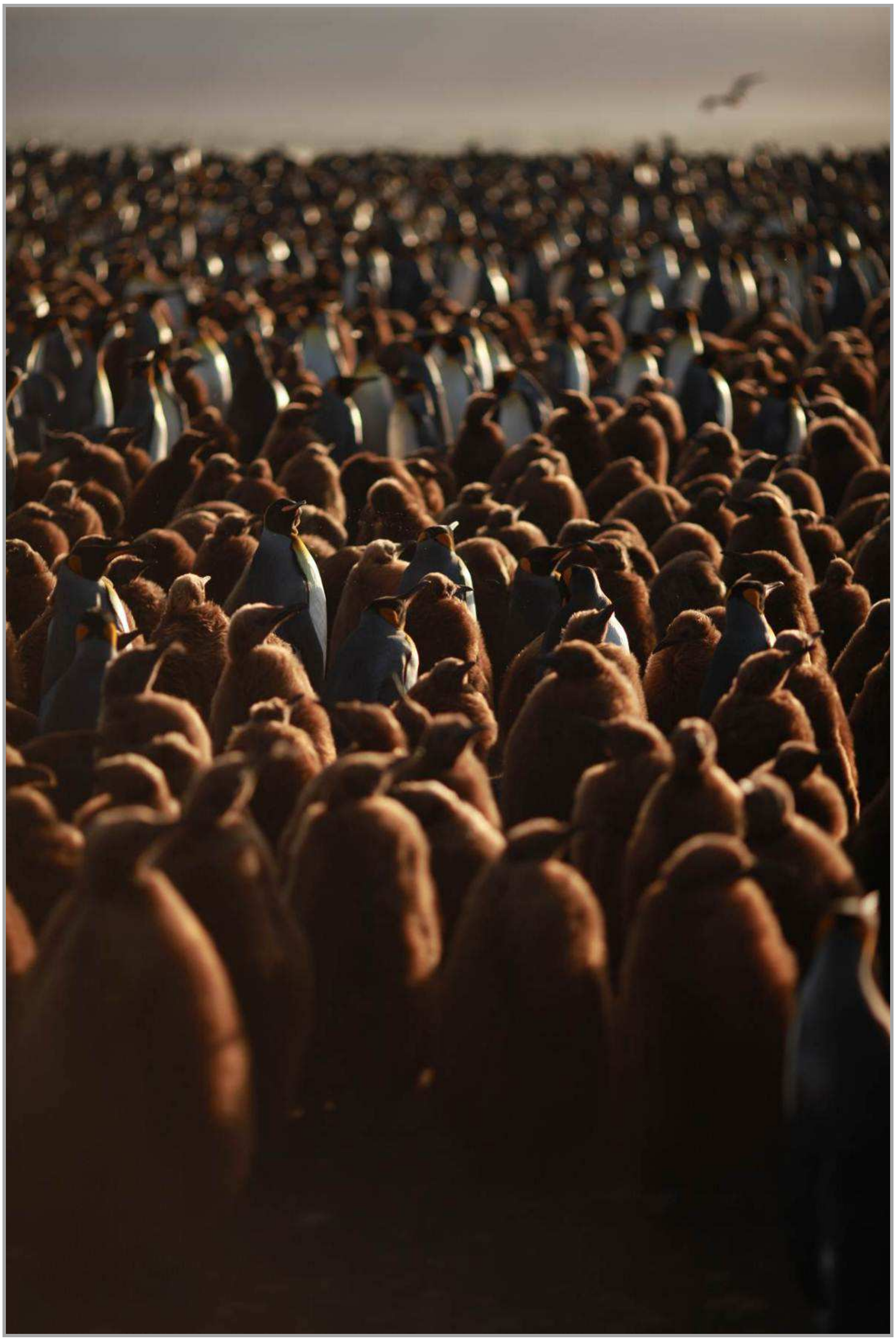
@A.Prudor

Pollution. The breeding colonies also reflect the effect of discarding millions of tons of non-degradable waste into the ocean; nonetheless this problem has received little attention until now.

Diseases. Wildlife faces a growing risk of contracting diseases related or not to human activities. Indian yellow-nosed albatrosses and sooty albatrosses from Amsterdam Island are known to be exposed to avian cholera and this threat has been previously identified as probably the most important factor influencing the demographic parameters of the two populations (Demay et al., 2013;Weimerskirch, 2004). Avian cholera is probably affecting the entire albatross populations on Amsterdam Island, thus constituting a serious threat for the rarer Amsterdam albatross. Biosecurity measures to limit the spread of the disease are necessary and presently in force on the island.

Hazards on land: introduced species. Invasive species (rats, cats …etc) are considered one of the main threats on land to the persistence of seabird breeding colonies (Brooke, 2004;King, 1985).

PENGUINS



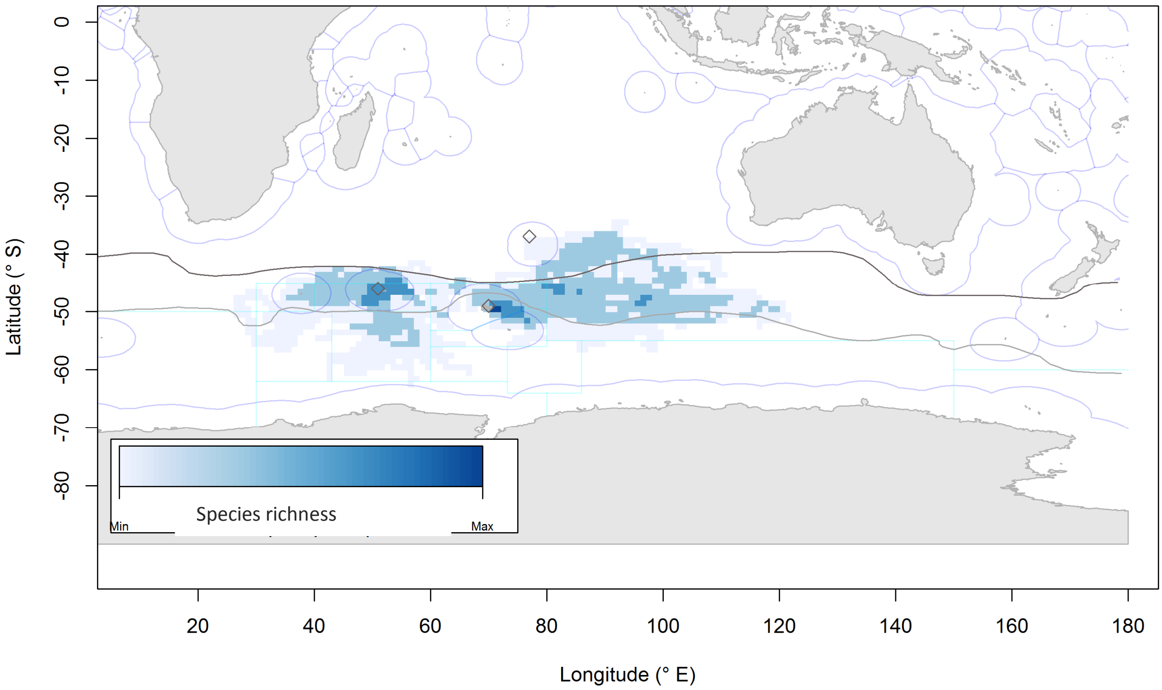
Penguins of French Southern Territories in the Southern Indian Ocean

Penguins constitute a key group of consumers of the food webs in the Southern Ocean, where they number several million breeding pairs. In the French Southern Territories they form more than 90 per cent of seabird biomass and consume more than 3 million tonnes of prey (macrozooplanktonic species, myctophids, squids) per year (Guinet et al., 1996). These predators also play a major role in the dynamic of the food webs through the major input of nutrients such as phosphates and nitrogen in the surrounding marine environment.

Nine species breed in the Southern Indian Ocean (cf Table 1; Map 6). The King (*Aptenodytes patagonicus*), Gentoo (*Pygoscelis papua*), Eastern rockhopper (*Eudyptes chrysocome filholi*), Northern rockhopper (*Eudyptes moseleyi*) and Macaroni (*Eudyptes chrysolophus*) penguins breed in the area and are resident year-round in the Subantarctic zone. Other species like the Royal (*Eudyptes schlegeli*), Adélie (*Pygoscelis adeliae*), Chinstrap (*Pygoscelis antarctica*) and Emperor (*Aptenodytes forsteri*) penguins breed on some islands or colony sites in more remote localities or in the Antarctic region, but, overall, they distribute throughout the Southern Indian Ocean.

The *Atlas* focuses on six species breeding in the French Southern Territories for which comprehensive tracking data are available: the King, Gentoo, Adélie, Eastern rockhopper, Northern rockhopper and Macaroni penguins.

The status of breeding populations of most of these species are poorly documented. Several are declining and 4 of them are included on the IUCN Red List as threatened species (Table 4; Endangered or Vulnerable. Some of these declines are recent and not well understood. Several hypotheses have pointed out the possible effects of density dependence, interactions with competitors (e.g. fur seals), decline in adult survival rate and breeding success and decrease of the marine productivity in the wintering grounds (Crawford et al., 2006;Delord et al., 2004;Hilton et al., 2006;Trathan et al., 2012).



Map 6. Specific diversity of sub-antarctic penguins. Observed cumulated *Presence* distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds for 5 subantarctic species of penguins (breeding and inter-breeding periods pooled). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Penguins/King penguin

Aptenodytes patagonicus

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

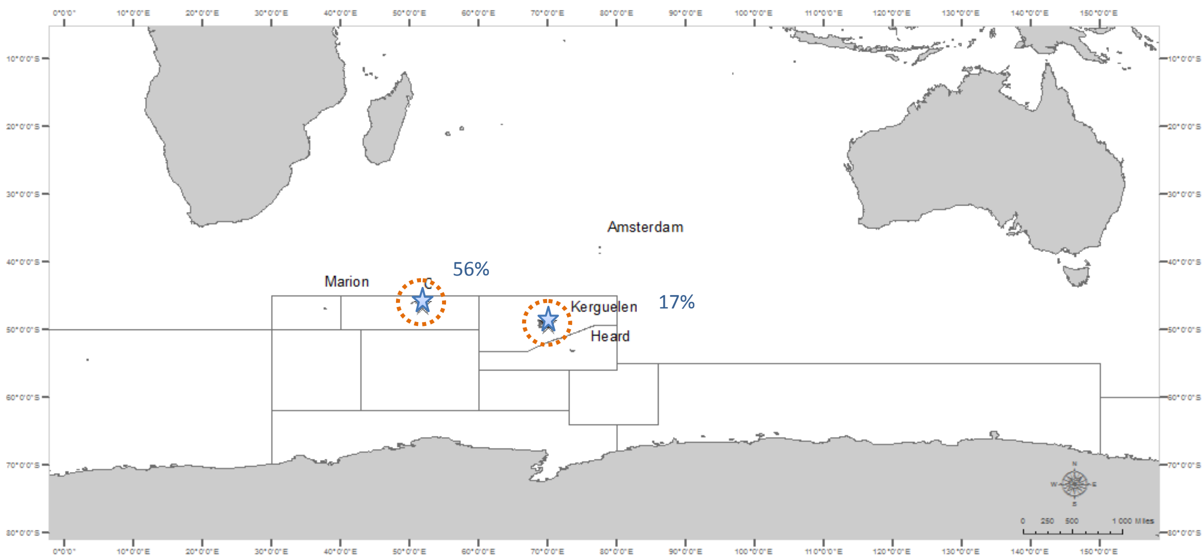
Order Sphenisciformes / Family Spheniscidae / Genus *Aptenodytes* /Species *A.patagonicus*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 7. *Breeding cycle and availability of tracking data (blue arrow) of* A. patagonicus

Regional Breeding Sites. *Aptenodytes patagonicus* breed on subantarctic islands between latitude 45° south and 55° south, namely on the Malvinas Islands and South Georgia Island in the South Atlantic Ocean, on Prince Edward, Crozet (including Cochons, Possession, and de l'Est Islands), Kerguelen, and Heard Islands in the southern Indian Ocean, and on Macquarie Island in the southwestern Pacific Ocean. All breeding sites are generally located within a distance of 400 kilometers from the Antarctic Polar Front. The Crozet and Kerguelen populations host most of the world population (56% and 17%, respectively, Delord et al. 2004, Bost et al. 2012).



Population trends. Exploitation of penguins for their oil associated with the sealing industry in the 19th and early 20th centuries resulted in king penguin populations decline in several localities. After commercial exploitation ceased, king penguin populations quickly recovered during the second part of the 20th century at all breeding sites (Kerguelen Islands: (Weimerskirch et al., 1989); Crozet Islands: (Delord et al., 2004)).
The largest population occurs on the Crozet Islands (at least 612000 pairs) especially at Cochons Island, the world's largest king penguin colony (500000 pairs in 1988, (Guinet et al., 1995)). However, whereas the breeding colonies on Possession Island are counted annually (Delord et al., 2004), no recent data are available for Cochons Island. On Kerguelen, colonies were slower to recover and are still increasing (Weimerskirch et al., 1989).

Diet and stable isotopes.
During the two periods of chick growth (summer and spring), chick food at Crozet and Kerguelen Islands consists almost exclusively of fish (>90%), with cephalopods accounting for the remainder. Fish diet was dominated by oceanic myctophids, with *Krefftichthys anderssoni*, *Electrona carlsbergi* and *Protomyctophum tenisoni* being the three main species at Crozet Islands (Cherel et al., 2007;Cherel and Ridoux, 1992;Cherel et al., 1993;Ridoux, 1994). At Kerguelen Islands, *K. anderssoni* forms the bulk of the food, with the pelagic stage of the eel-cod *Muraenolepis marmoratus* being an important item on some years (Bost et al., 2002), unpublished data). The dietary importance of squids increases in winter at the Crozet Islands, with large juveniles of the onychoteuthid *Moroteuthis ingens* being the main cephalopod prey at that time (Cherel et al., 1996;Cherel et al., 1993).

The similar chick blood $\delta^{13}C$ and $\delta^{15}N$ values in summer and spring at Crozet and Kerguelen Islands are consistent with a myctophid-based diet, as are the blood isotopic ratios of adult birds during the chick-rearing period (Cherel et al., 2010;Cherel et al., 2007). Both the stable isotope method and the use of lipids as trophic markers again indicate that adult birds feed on myctophids during the two periods of hyperphagia at sea preceding the breeding and moulting fasts on land (Cherel et al., 2010;Raclot et al., 1998). The trophic position of king penguins was estimated at 4.5-4.6 (Cherel et al., 2010).

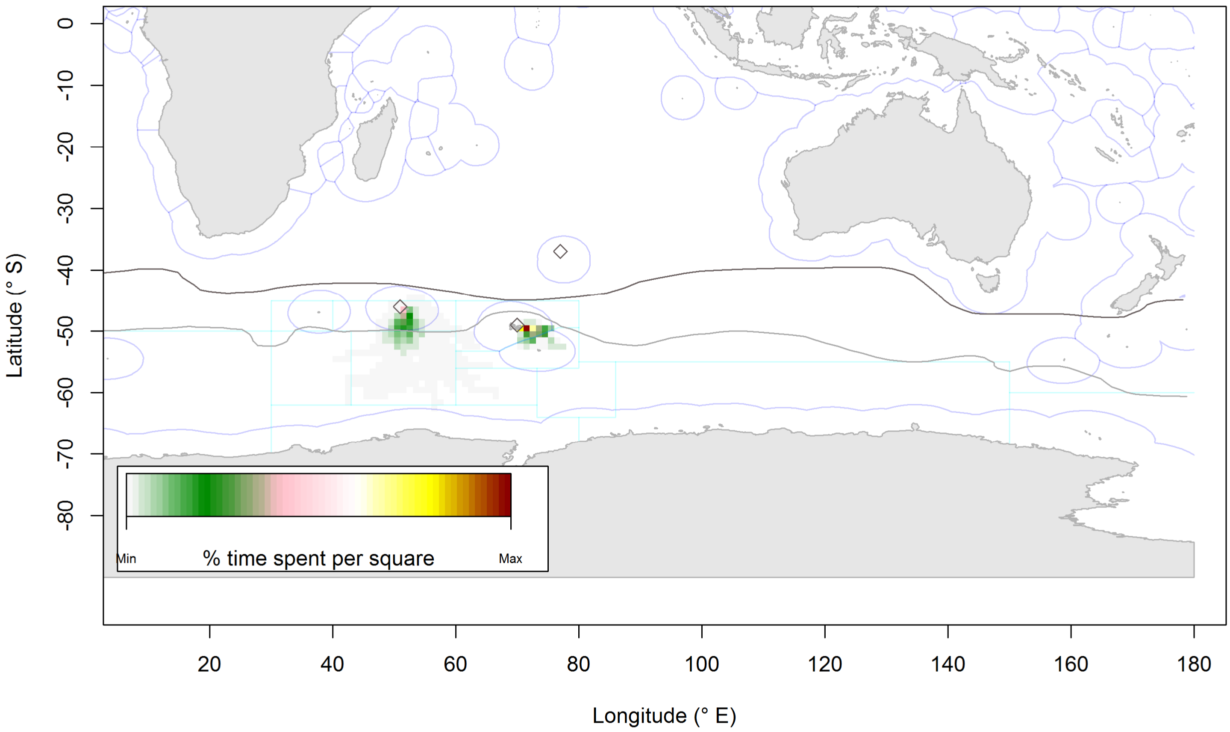
Marine distribution. *A. patagonicus* at-sea distribution is one of the most extensively studied among marine vertebrates. During summer, irrespective of the location of their breeding site, the at-sea distribution is strongly dependent on frontal zone features, particularly the Antarctic Polar Front. From autumn to the end of winter, the *A. patagonicus*' foraging area is encompassed by the Antarctic Polar Front to the north and the Antarctic Divergence (up to the limit of the sea-ice) to the south (Bost et al., 2012).

At Crozet, King penguins use mostly the northern limit of the Polar Front (PF) and accessorily the Subantarctic front (Bost et al. 2009b). During autumn and winter breeding adults forage beyond the PF, in Antarctic waters, up to the limit of the pack ice (Bost et al., 2004;Moore et al., 1999;Pütz et al., 1999). Except in spring, King penguins use strong vertically stratified waters especially at the PF and typically dive to the thermocline to avoid the Surface Mixed Layer (Charrassin and Bost, 2001).
At Kerguelen, King penguins forage closer to the colonies than at Crozet because of the closer proximity of the PF.

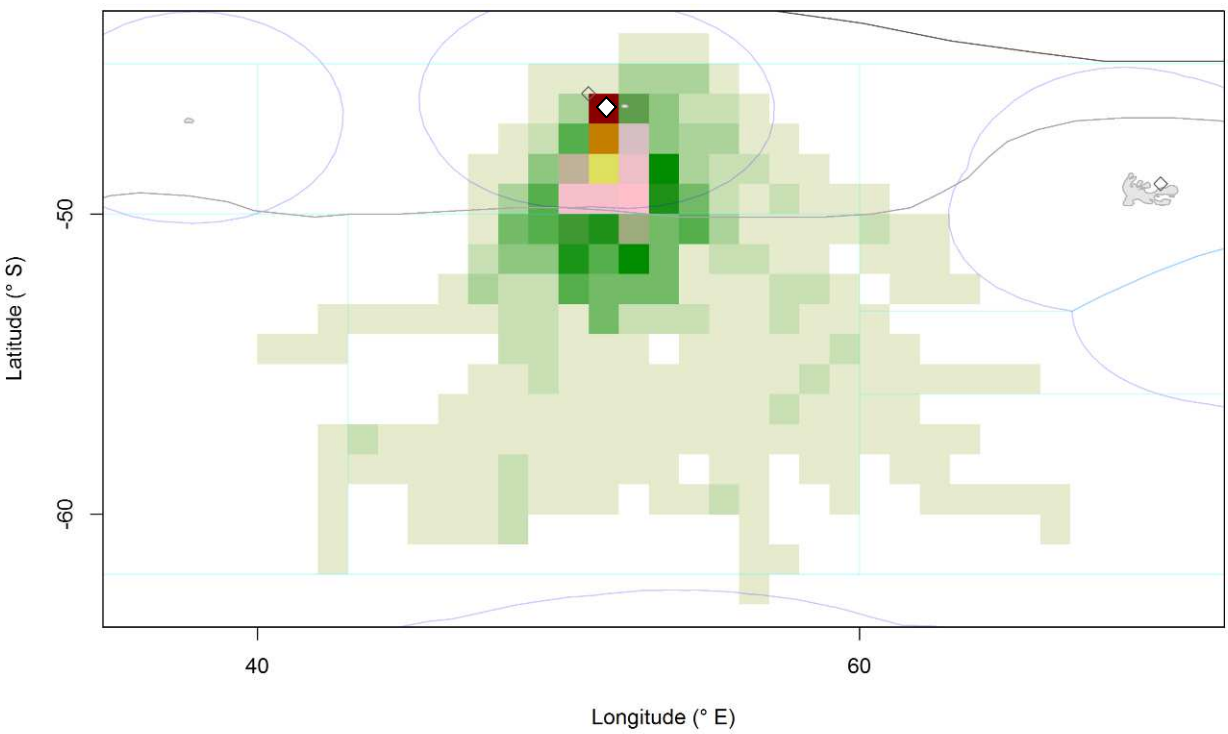
Important areas

The Crozet population essentially forages during summer in the oceanic sector 47.5-54°S, 50-54°E, south of the Crozet archipelago, i.e. in the waters of the Polar Frontal zone up to the south of the PF (Bost et al., 2009a;Bost et al., 1997). During winter, they distribute over a much larger scale and are strongly dependent of the marginal ice zone, which corresponds to the southern limit of their trips (Bost et al., 2004).

On Kerguelen, King penguins from the Courbet peninsula follow a path to the south-east up to 300 km from their colony, mainly along the eastern south eastern edge of the shelf. The preferential habitat is the wide shallow plateau (500–1000m) and along the shelf break where they encounter a cold northwest flowing current, in opposition to the general eastward flow of the ACC (Bost et al., 2009a;Charrassin et al., 2002).
The sector 49°-51°S; 71°-76°E, partially in the French EEZ, is of key importance for king penguins during incubation and the chick rearing period, also probably during the winter period . At this time of the year, the Crozet shelf (included in the French EZZ) is also an important foraging area for penguins feeding crèched chicks.

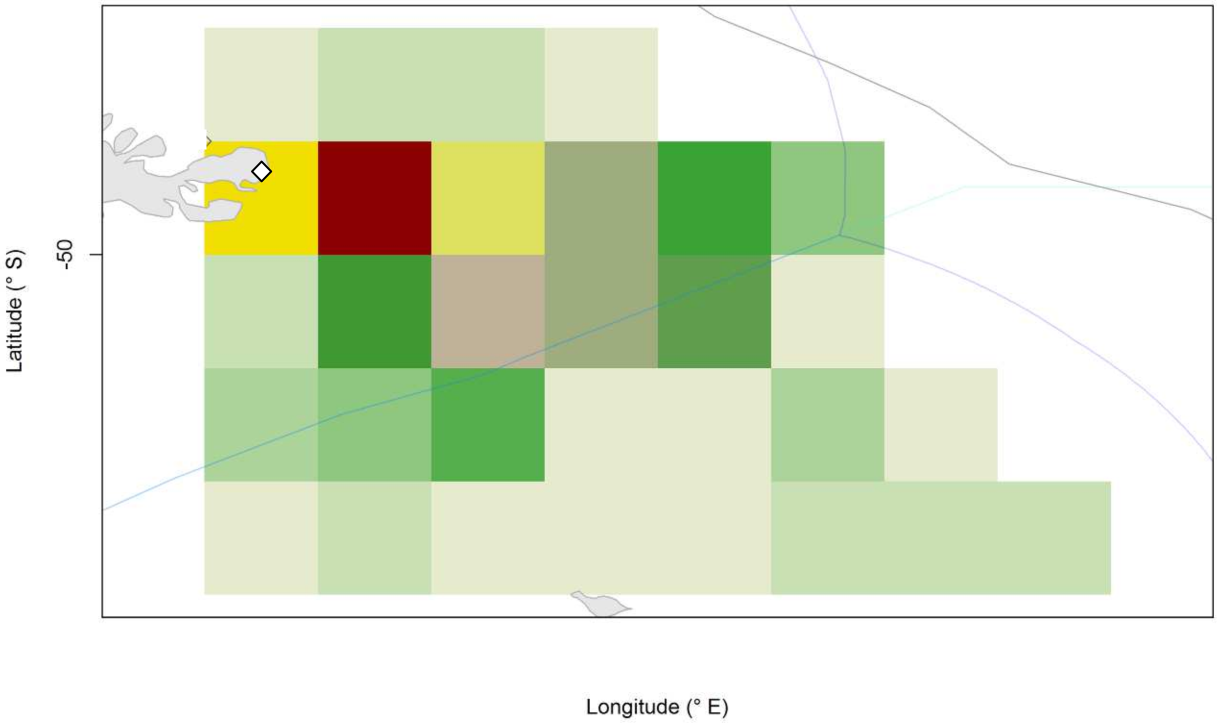


Map 7. *King penguin, Crozet and Kerguelen Islands*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



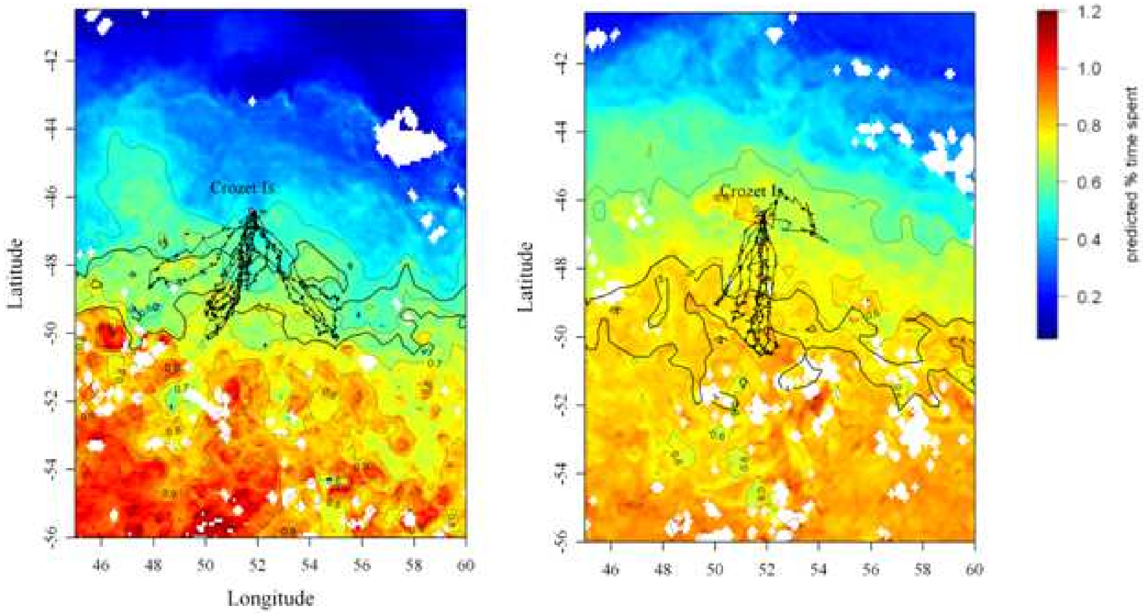
Map 8. *King penguin, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996)

updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 9. ***King penguin, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Habitat selection modeling



Map 10. ***King penguin, Crozet Island*. Spatial prediction of percentage of at-sea time spent per square in each 0.1° cell by adults king penguin from Possession Island (Crozet) during a: incubation, January and b: brooding (year: 2004) as predicted by a linear mixed-effects model.** *Thick black lines* correspond to the Polar Front position, *medium black lines* with points represent penguins' tracks and *thin lines* correspond to contours of predicted habitat suitability. *Blanks* correspond to areas where predictions could not be made because of cloud cover. Bathymetry is shown (Péron et al., 2012)

Habitat models (map 10, Annex IB for detailed methodology) predicting the spatial distribution are available for the incubation (Map 10a) and brooding period within the summer range. Sea surface temperature is the most important variable predicting the king penguins' foraging zones during both breeding stages. The penguins mostly forage in cold oceanic waters typical of the PF, where hydrography is not influenced by high topographic features. The predicted foraging areas are located further south during warmer years, indicating that penguins have to cover larger distances.

Threats. *A. patagonicus* is found to be sensitive to climate change. Warm phase of the Southern Oscillation and warm sea surface temperatures in foraging areas may negatively affect breeding success and adult survival and impact distribution and populations (Le Bohec et al., 2008;Péron et al., 2012). The main prey of *A. patagonicus*, myctophid fish, were commercially exploited by the end of the 1970s and the beginning of the 1990s, with more than 200.000 tons harvested in the South Georgia sector (Collins et al., 2008). Several attempts to develop new commercial fisheries on a limited scale within the Southern Ocean are ongoing. A large, uncontrolled development of myctophid fisheries close to key foraging areas, especially at Kerguelen or in the Scotia Sea (South Georgia) may have deleterious effects on the foraging success and long-term populations trends of the king penguin.

Gaps & Stakes. There is a lack of distribution data for very important breeding colonies (i.e. Cochons Is. at Crozet archipelago or colonies on the west coast of Kerguelen Island). Dispersion movements and wintering grounds of non-breeding adults, immatures and post-fledged birds is unknown. Complete censuses of breeding populations should be made at regular intervals in order to detect temporal trends and potential effects of environmental changes.

Penguins/Gentoo penguin

Pygoscelis papua papua

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

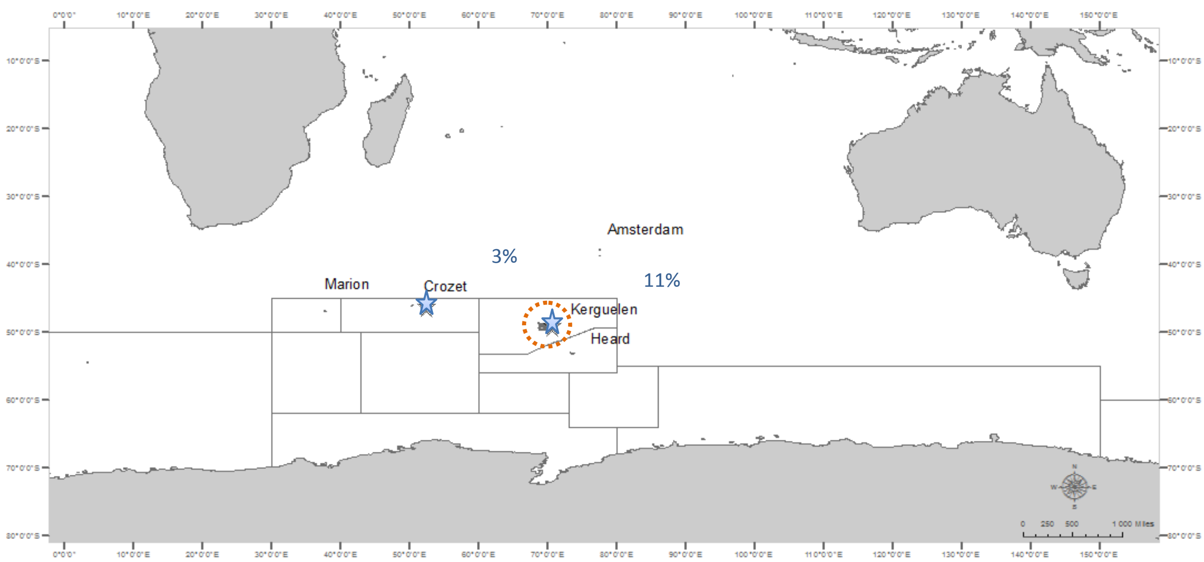
Order Sphenisciformes / Family Spheniscidae / Genus *Pygoscelis* /Species *P.papua papua*

Annual breeder, sabbatic years possible

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-nesting period																								

Table 8. *Breeding cycle and availability of tracking data (blue arrow) of* P. papua papua. Shaded cells indicates moulting period on land.

Regional Breeding Sites. *P. papua* is a colonial breeder nesting in small to medium colonies, circumpolar distributed, with a wide breeding range, from the Scotia sea (Antarctic peninsula, South Georgia, South Orkney) to the subantarctic islands south of the Subantarctic Front of the Pacific Ocean (Macquarie) and South Indian Ocean (Heard, Kerguelen, Crozet and Marion-Prince Edward islands). Overall this penguin is mostly confined to regions free of winter pack-ice(Bost and Jouventin, 1990).
Previously morphologically recognised as single species with a northern (*Pygoscelis papua papua*) and a southern (*P.papua ellsworthi*) sub-species, the Gentoo penguin has been recently splitted in 3 genetically distinct clades (de Dinechin et al., 2012): the Indian ocean population (including Crozet and Kerguelen birds), the Subantarctic and the Atlantic populations).
The Kerguelen and Crozet archipelagos host about 11% and 3 % of the world population, respectively, and more than 70 % of the Indian clide (Bost and Jouventin, 1990;Jouventin et al., 1994;Weimerskirch et al., 1989).



Population trends. Populations are increasing at the southern extent of their breeding range, on the Antarctic Peninsula (Lynch et al., 2012), while colonies on subantarctic islands may have decreased substantially in the past and appear to have stabilised at several localities (South Georgia, Macquarie island)(Lynch et al., 2012).
On Kerguelen, the Gentoo penguin population appears to have recovered since the mid 2000s.
On Crozet, the population of Possession Island has not recovered since a drastic decline between 1970 and the early 1980s and another decline recorded at the end of the 1980s. In 2010, the population size was about 50% less than the 1970 count, but stable since the early ninetines despite large inter-annual variations (CNRS Chizé database).

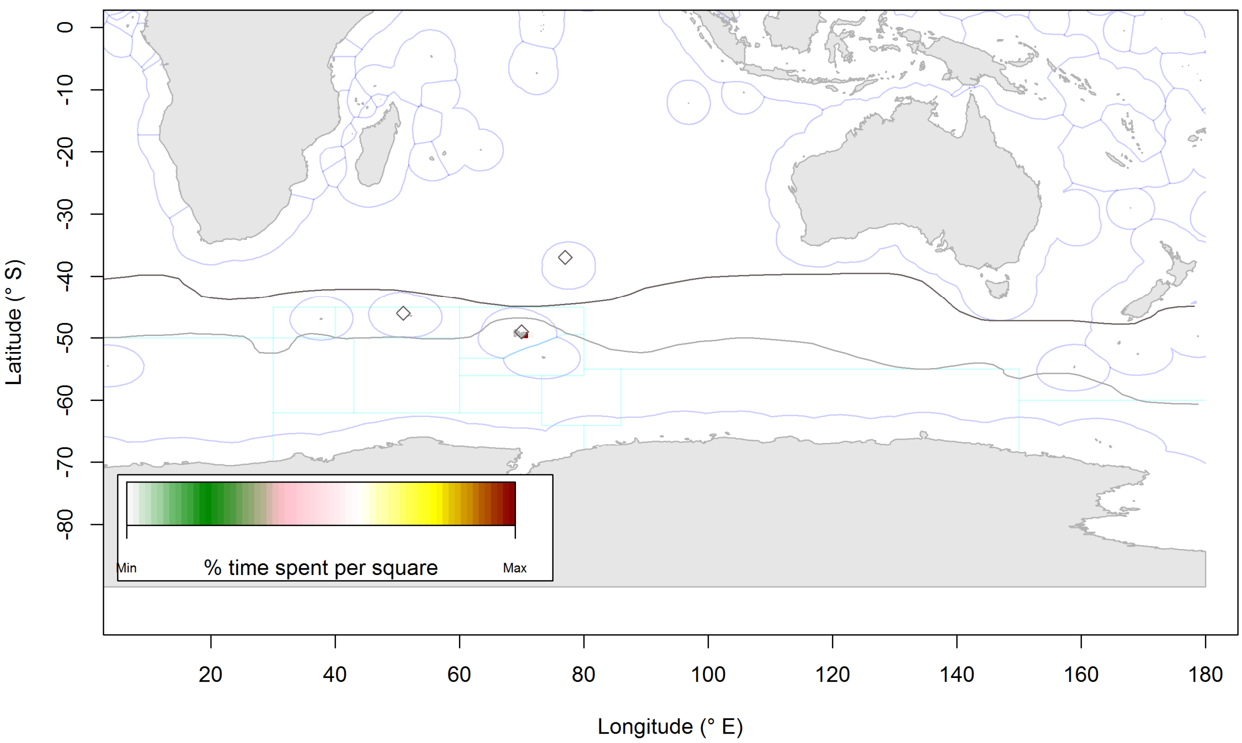
Diet and stable isotopes.
The inshore foraging habits of Gentoo penguins allow collecting food samples during the whole breeding period. At Kerguelen Islands, the species has a catholic diet including many benthic and pelagic organisms, their relative proportions depending on colony location and breeding stages. Overall food is dominated by fish in open-sea localities (38 to 95% by mass) and by crustaceans in closed-sea localities (84%). Gentoo penguins also feed significantly on annelids and cephalopods. Fish prey include postlarvae, various nototheniids and the icefish *Champsocephalus gunnari*, while the

main crustacean item is the subantarctic krill *Euphausia vallentini* with the hyperiid *Themisto gaudichaudii* ranking second (Bost et al., 1994;Lescroel et al., 2004).
Different δ^{13}C baselines allow distinguishing chick and adult gentoo penguins living in different marine environments at a small spatial scale in Kerguelen Islands, with blood δ^{13}C values being higher at closed-sea than at open-sea localities (Cherel and Hobson, 2007), unpublished data). The isotopic variance in both δ^{13}C and δ^{15}N values is higher at open-sea localities, suggesting some degree of individual specialization in the birds' feeding habits (Carravieri et al., 2013).

Marine distribution. Gentoo penguin is a costal, neritic species, exhibiting several foraging strategies according to the local environment (Bost and Jouventin, 1990;Lescroel and Bost, 2005). Tracking information (Argos PTTs) are available for 2 localities of the Kerguelen archipelago (pooled in this analysis), including one open sea locality of the eastern coast, Courbet Peninsula, and one inside the Morbihan Gulf. Birds from open sea colonies have large foraging ranges and perform long trips, long benthic dives on demersal fish while birds from closed bays have small foraging ranges, perform short trips and short pelagic dives on swarming crustaceans (Lescroel and Bost, 2005).

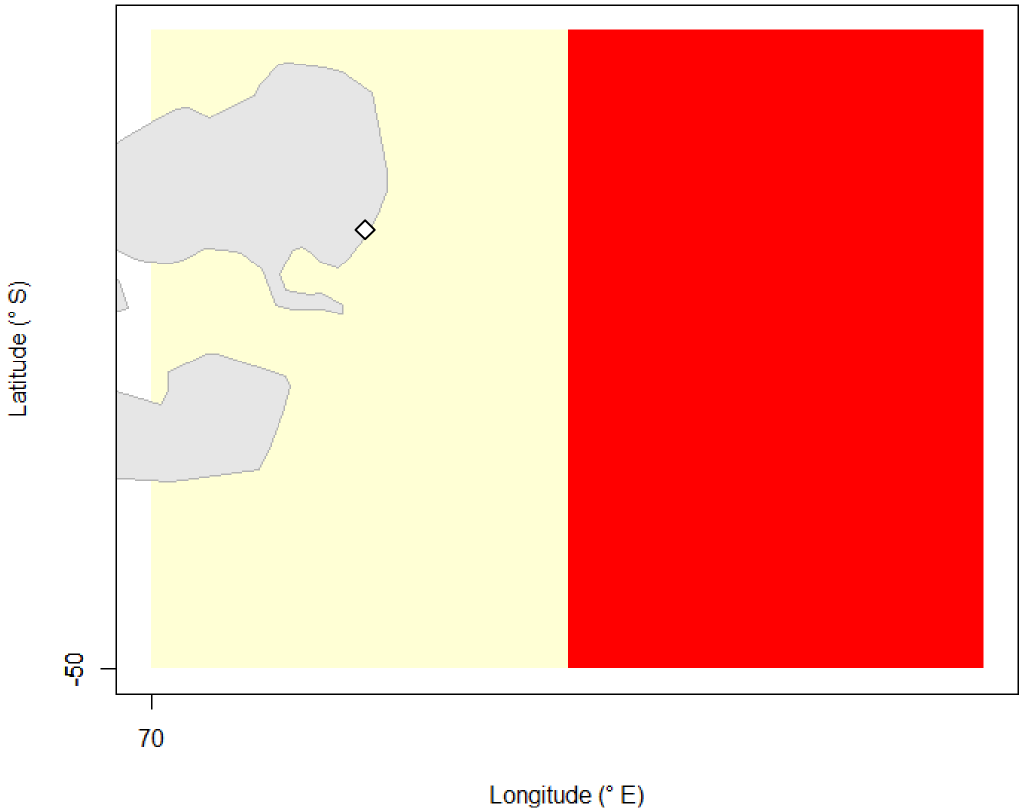
Important areas

Gentoos foraging off the eastern side of the Courbet peninsula (open sea conditions) used similar areas during the incubation and chick guard periods. All tracked birds head towards the plateau slope and use mostly waters over 100 to 200m depths, more than 46km away from the breeding colony (see Map 12 for zoom on the distribution). Habitat suitability mapping shows that the highest suitability levels over the plateau correspond to specific isobaths around 500m.
In the Morbihan Gulf, birds are extremely coastal and perform mostly daily trips, remaining inside the Gulf at a maximum distance of 13 km from the colony.



Map 11. *Gentoo penguin, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period). Oceanographic frontal structures are shown: the subtropical waters north of the South

Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 12. ***Gentoo penguin, Kerguelen Island*****. Zoom on the observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period).** Breeding colony of is indicated (white diamond).

Threats. The population of Possession Island (Crozet) has strongly decreased between the 1970s and the end of the 1980s. The reasons of the decline are unclear although human disturbance in the past have certainly affected the breeding success of the most accessible colonies of this shy population until the mid 1980s. The colonies are now strictly protected. The decrease observed in the 1980s may result in part of the low fledging success, probably as a consequence of trophic conditions in the Crozet plateau as suggested for Marion island (Cooper, 2003). Any further change in dynamic of inshore food webs may affect the population.

At Kerguelen, the comeback of trawl fisheries (icefish) may drastically affect the gentoos' breeding success at open sea localities (East and North of Kerguelen).

On the long-term, food availability on the Kerguelen and Crozet shelf may be affected by climate changes.

Gaps & Stakes. On Crozet, there is no tracking data during the breeding /non breeding seasons and juvenile dispersion. Information on the at-sea distribution is needed at Possession Island and Cochons Island which hosts the main colonies.

On Kerguelen, tracking studies concern a minority of the whole population whose colonies are distributed on very different coastal environements. Information on the dispersion of fledgings is limited. Additionnal tracking data are especially required during the breeding period and fledging dispersion for the large colonies of the North (Nuageuses, Leygues islands) and the southern coasts (Antarctic Bay).

Gentoo populations of Crozet and Kerguelen constitute more than 70% of the Indian clide (Bost & Jouventin 1991, Jouventin et al. 1994) and are fully dependant of the EEZ because of their limited foraging range.

Penguins/Adelie penguin

Pygoscelis adeliae

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

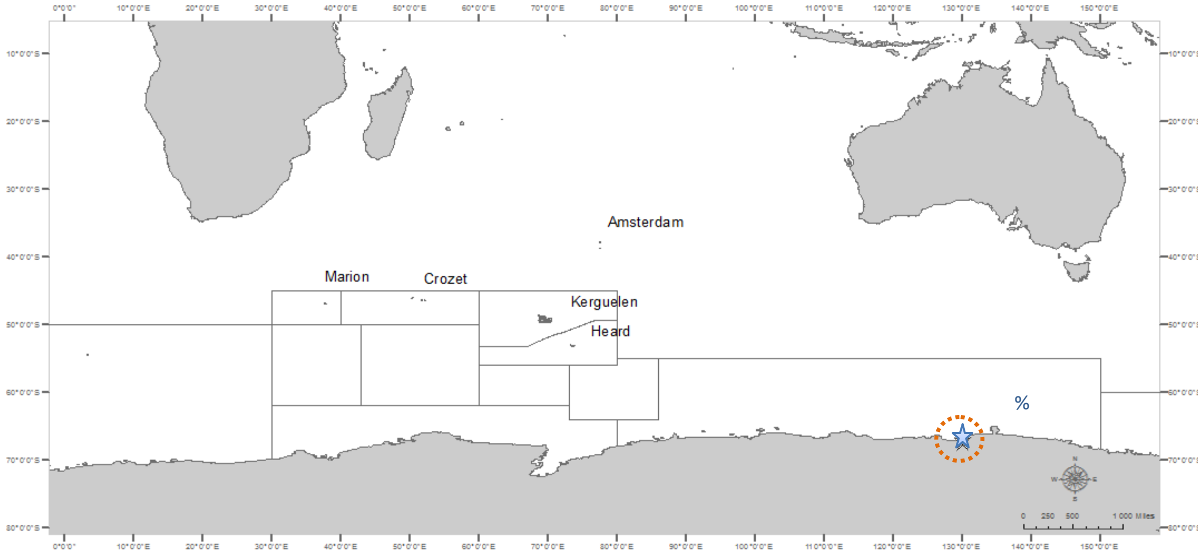
Order Sphenisciformes / Family Spheniscidae / Genus *Pygoscelis* /Species *P.adeliae*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-nesting period																								

Table 9. *Breeding cycle and availability of tracking data (blue arrow) of* P. adeliae. Shaded cells indicates moulting period on land.

Regional Breeding Sites.



The Adélie penguin is a strictly ice dependant species while at-sea. It breeds along the entire Antarctic coast and its nearby islands (38 breeding localities known). The overall breeding range extend from 56 to 78° S; i.e. 22° (Woehler 1993). After breeding, Adélie penguins also move towards areas of persistent sea ice to moult (Ainley *et al*. 2010).

Population trends. The total number of breeding Adélie penguin is estimated at 2.3 10^6 pairs (range 1.8-2.9 10^{6}, Woehler 1993). Numbers are increasing in the Ross Sea region and decreasing in the Peninsula region, with the net global population increasing overall but could start to decline in a few decades (Ainley *et al*. 2010). On Dumont d'urville, the breeding population of the Pétrels islands is estimated at about 16.000 pairs (CNRS Chizé database).

Diet and stable isotopes. Chick food in Adélie Land is dominated by crustaceans (79-94% by mass), with fish ranking second (6-18%) and cephalopods third (<1-3%) (Cherel, 2008;Ridoux and Offredo, 1989). The major crustacean prey are euphausiids, with two species involved, the neritic ice krill (*Euphausia crystallorophias*) and the oceanic Antarctic krill (E. superba). By far the main fish prey is the Antarctic silverfish (*Pleuragramma antarcticum*) (Cherel, 2008;Wienecke et al., 2000).

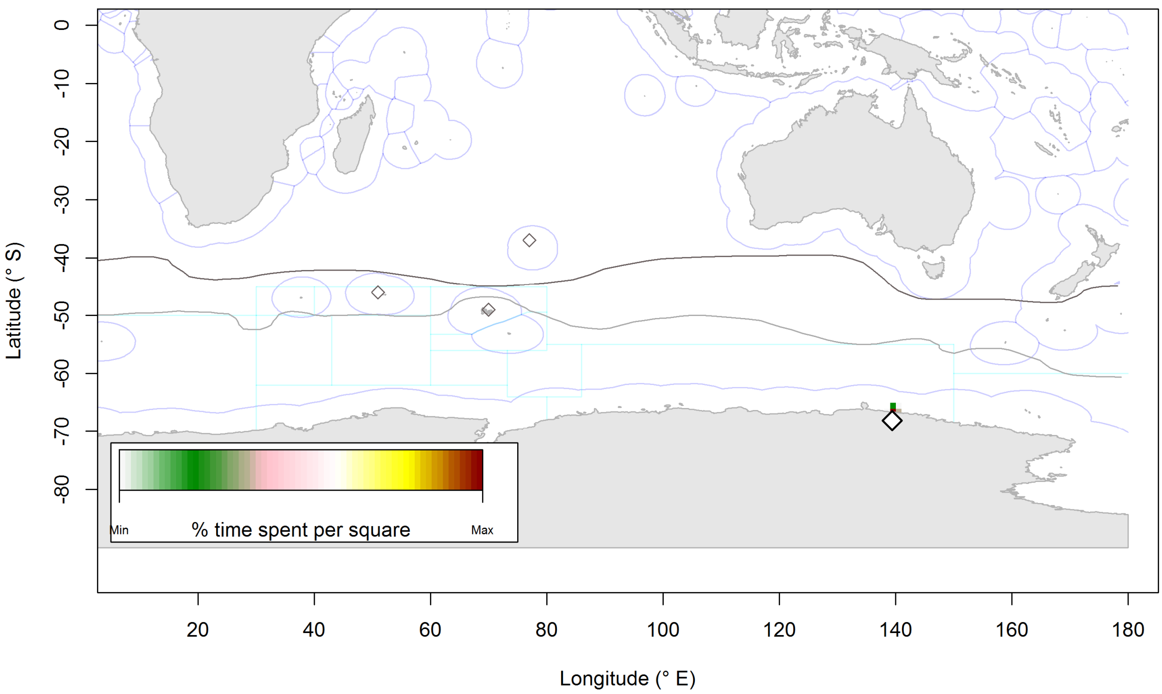
Blood $\delta^{13}C$ values show that chicks are fed with prey caught in nearby pelagic waters. Chick $\delta^{15}N$ values are consistent with a mixed diet of krill and fish. The lower blood $\delta^{15}N$ values of adult birds point out two interesting features. Firstly, adults prey more upon crustaceans and less on fish when they feed for themselves during the chick-rearing period. Secondly, they feed primarily on Antarctic krill in oceanic waters in spring at the end of the inter-nesting period (Cherel, 2008).

Marine distribution. The Adélie Penguin is a pelagic diver, feeding mostly at mean depths of 50-36 m according to the breeding stage but may dive to a maximum of 124 m (Rodary et al., 2000). At Dumont d'Urville, they dive more frequently around midnight than during the day, in relation to the diel migration of one of its main prey, *Euphausia christallorophias*. Incubating penguins perform distinct trips according to their body condition (Cottin et al., 2012). Some birds do long trips toward oceanic waters as far as 320 km from the colony. Some birds target open-ocean areas and follow the currents of persistent eddies while some other forage to the north-west, close to the Antarctic shelf slope at the limit of the pack ice. Finally some individuals cover much shorter distances northwards or eastwards (Cottin et al., 2012).

During the brooding period (December-January), the birds forage exhibit a shorter mean foraging range ranging from 42 km to 71 km. Overall they forage over the continental shelf and western slopes of the Dumont D'Urville Sea, using preferentially in denser seawater but also, at smaller scale, in colder water masses(Jaeger, 2006). Increases in foraging range, as the chick rearing period progress can be related to changing energy requirements of adults and chicks (Clarke et al., 2006).

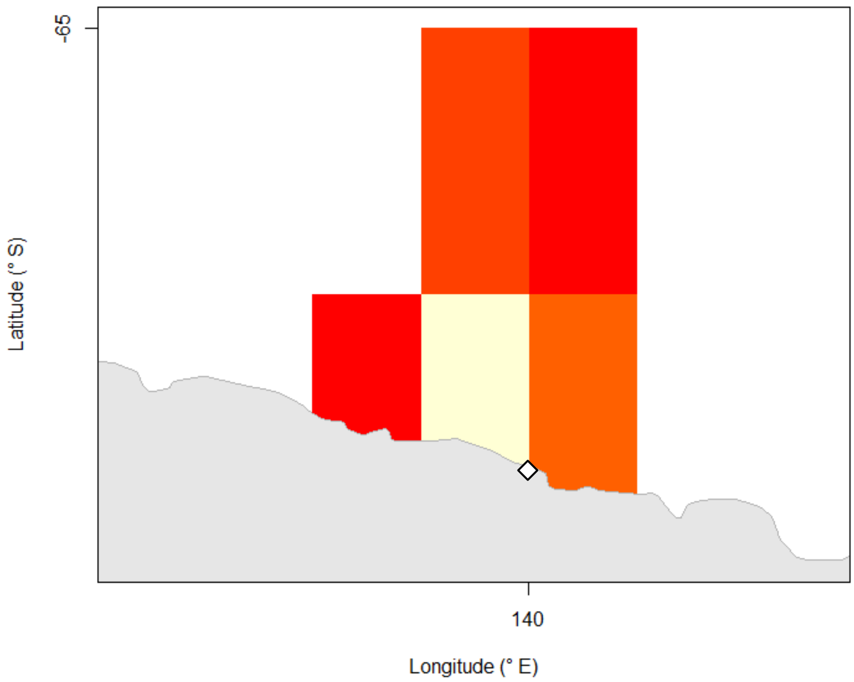
Important areas

During the chick rearing period Adélie penguins concentrate their foraging effort on the edges of a wide inner shelf depression of the Dumont d'Urville Sea open to the North to oceanic waters. This foraging habitat corresponds to sectors where their major preys, *Euphausia superba* and *Pleuragramma antarcticum*, have a high probability to be found (P. Koubbi pers. Comm.)



Map 13. ***Adelie penguin, Adelie Land Antarctica*****. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period).** Oceanographic frontal structures are shown: the subtropical waters north of the

South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 14. *Adelie penguin, Adelie Land Antarctica*. Zoom on the observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds (breeding period). Breeding colony of Dumont d'Urville is indicated (white diamond).

Threats. The Adélie penguin is thought to be threatened by the effects of projected climate change, primarily through future decreases in sea ice concentration (Ainley et al., 2010).

Gaps & Stakes. Nothing is known about the at-sea distribution of immatures, fledged and non-breeding birds for the Adélie penguin at Dumont D'Urville.

Penguins/Eastern rockhopper penguin

Eudyptes chrysocome filholi

CRITICALLY ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED

@ C.A. Bost

TAXONOMY

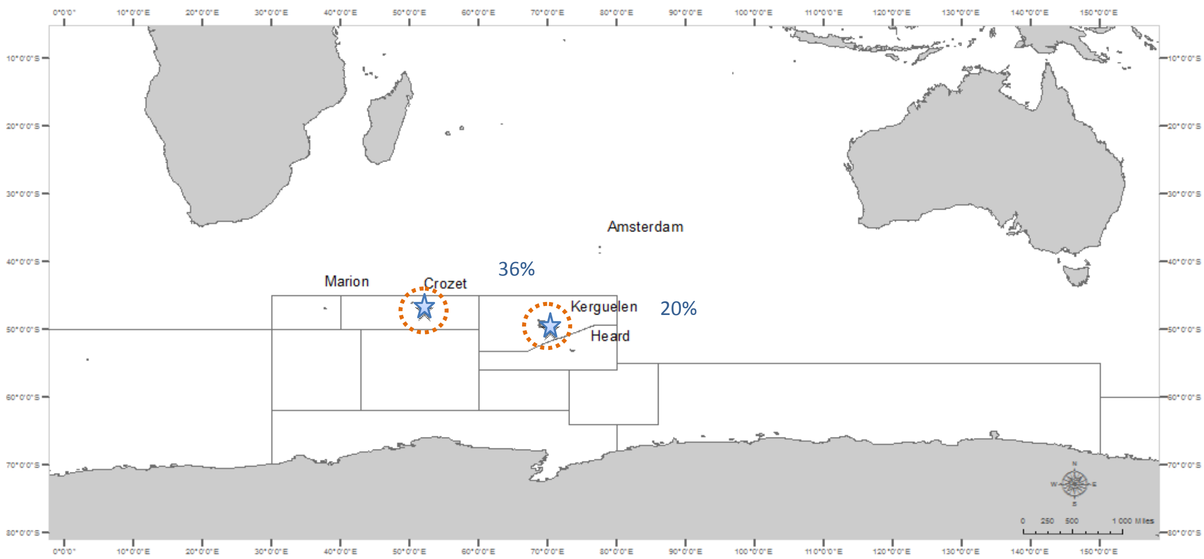
Order Sphenisciformes / Family Spheniscidae / Genus *Eudyptes* /Species *E.chrysocome filholi*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 10. *Breeding cycle and availability of tracking data (blue arrow) of* E. chrysocome filholi. Shaded cells indicates moulting period on land.

Regional Breeding Sites.



The Eastern rockhopper penguin has a circumpolar distribution, breeding on the subantarctic islands of the Southern Indian Ocean (4 localities: Marion-Prince Edward, Crozet, Kerguelen, Heard islands) and South Pacific Ocean (5 localities: Macquarie, Auckland, Campbell, Antipodes, Bounty islands). In the early 1980s, the French Southern Territories have accounted for more than half of the world population, as the Crozet and Kerguelen populations were estimated in 1982 to be 152000 pairs (36%) and 85000 pairs (20%), respectively.

Population trends. Most of the populations across the breeding range have exhibited declines, sometime drastic since the early 1970s. No recent and exhaustive counts are available at Crozet and Kerguelen islands since the early 1980s. Some small colonies have disappeared at Possession Island since the early 1990s. At Marion Island, the population has drastically decreased after 1994 with respect to the early 1980s (61% of decrease).

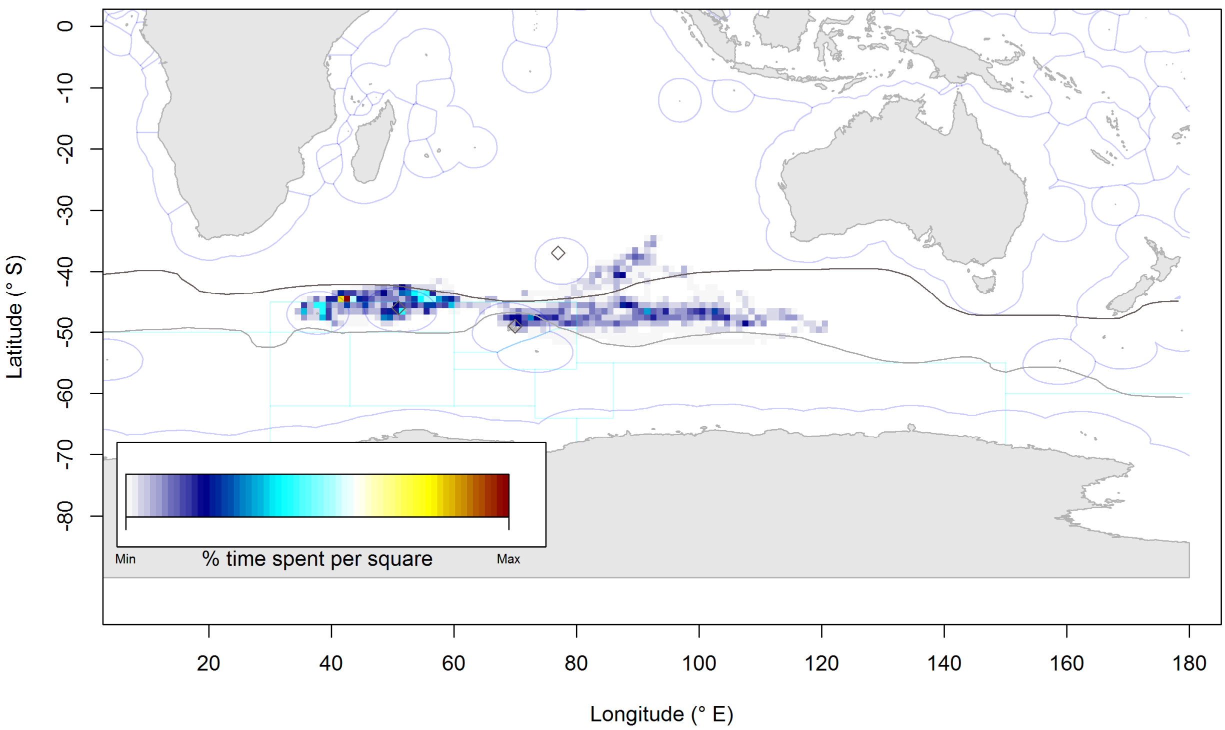
Diet and stable isotopes. Chick food at Crozet Islands is dominated by crustaceans (65-95% by mass), with fish ranking second (4-24%) and cephalopods third (<1-17%) (Cherel et al., 2007;Ridoux, 1994;Tremblay and Cherel, 2003). At a closed-sea locality from Kerguelen Islands, rockhopper penguins feed on crustaceans (78-97%), with fish accounting for the remainder (3-22%) (Tremblay and Cherel, 2003), unpublished data). Overall, the main crustacean prey is the subantarctic krill *Euphausia vallentini*, but other species of pelagic crustaceans can be important items depending on localities and years. Fish items include the myctophid *Krefftichthys anderssoni* at Crozet and notothenioid postlarvae at Kerguelen Islands (Ridoux, 1994;Tremblay and Cherel, 2000;Tremblay and Cherel, 2003), unpublished data).
At Crozet and Kerguelen Islands, blood $\delta^{13}C$ values show that chicks are fed with prey caught in nearby pelagic waters. $\delta^{15}N$ values are consistent with a crustacean-based diet and allow estimating a trophic position of 4.0 (Cherel et al., 2010;Cherel et al., 2007), unpublished data). Isotopic values of blood collected at the arrival in the colony in spring indicate that adult birds forage in subantarctic waters where they feed mainly on crustaceans in late winter (Cherel et al., 2007;Thiebot et al., 2012).

Marine distribution. The Eastern rockhopper penguin exhibits different use of the marine environment according to the season. Individuals are coastal during the chick rearing period (Tremblay and Cherel, 2003), and undertake large scale movements over deep, oceanic waters during the non-breeding period (Thiebot et al., 2012).

No tracking data are available for the breeding period. However the short duration of the daily foraging trips (11h) indicates a limited foraging range (estimated to 6 km, (Cherel et al., 1999). The at-sea distribution during the incubation and pre/post-moult periods is still unknown.

Important areas

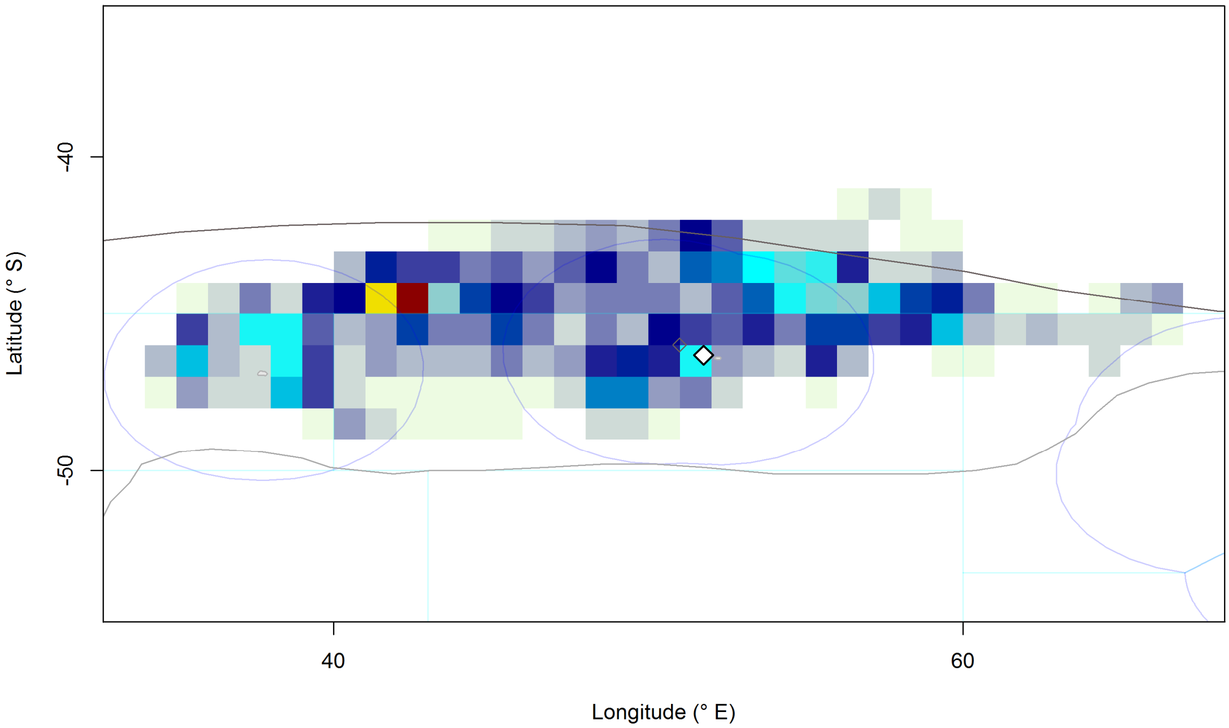
At Crozet and Kerguelen, the species is strongly dependent of the inshore environment.
During winter tracking data (geolocators) for penguins tracked from Kerguelen and Crozet islands indicate wide dispersion up to 2500km without any return at land during 6 months. No bird forage north of the Northern Subtropical Front and almost all the rockhoppers penguins distribute north of the Polar Front, using waters of depths mainly ranging between 3000 and 3500m, with apparently greater seafloor slope for birds from Crozet. The 2 populations are found in waters with highly heterogeneous sea surface temperature anomalies and chlorophyll-a.



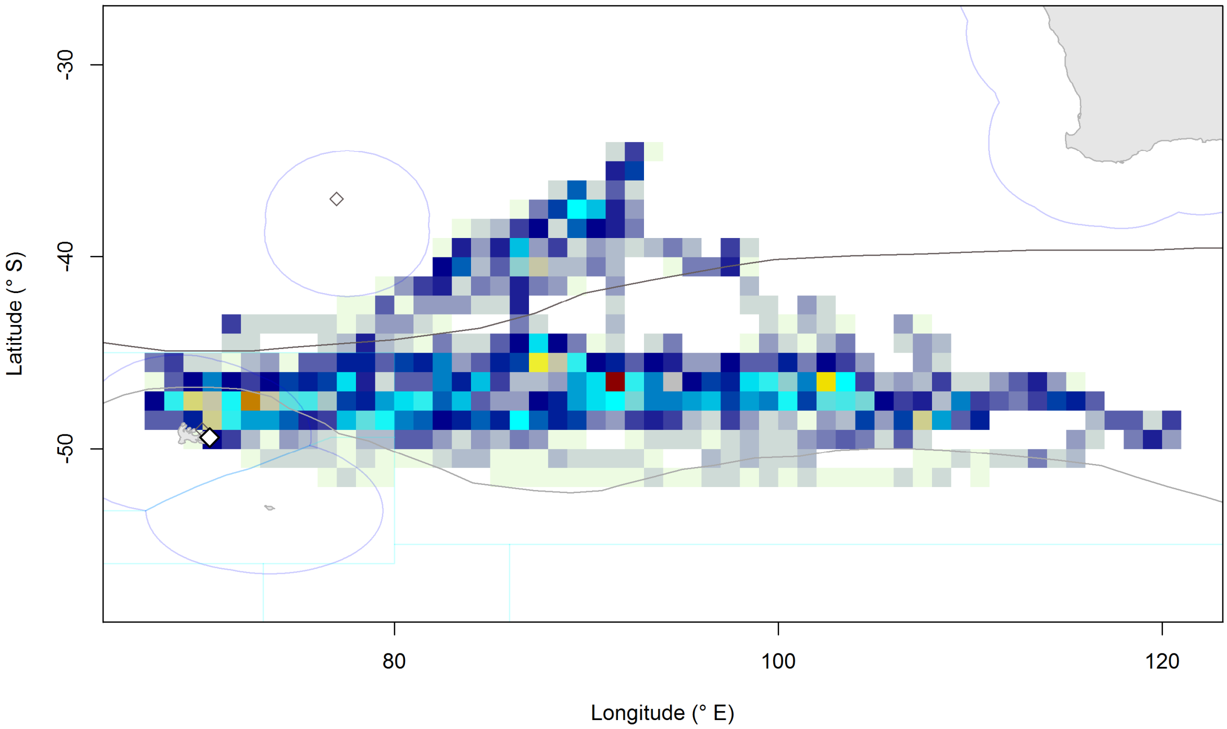
Map 15. ***Eastern rockhopper penguin, Crozet and Kerguelen Islands*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Importantly these 2 populations have distinct wintering areas (Map 15), without any overlap (Thiebot et al., 2012). Overall, rockhoppers from Kerguelen head (Map 17) eastward to the Southeast Indian Ridge, into the Subantarctic Zone, some birds dispersing up to the Subtropical Zone and the Polar Frontal Zone (47%%). They have a wide maximal foraging range (2520km) and spend the majority of their time in the Subantarctic Zone (43%) and the Polar Frontal Zone (35%), and a minor fraction in the Subtropical Zone (16%), using waters with deeper mixed-layer depth, compared to birds from Crozet.
Rockhoppers from Crozet (Map 16) have a more restricted maximal foraging range (950km). They head westward or northwestward, reaching the edge of the Southwest Indian Ridge, and then extensively use the Subantarctic Front sector towards the West (including the Del-Cano area), East, and North of the Crozet region. They spend most of the inter-breeding period in the Subantarctic

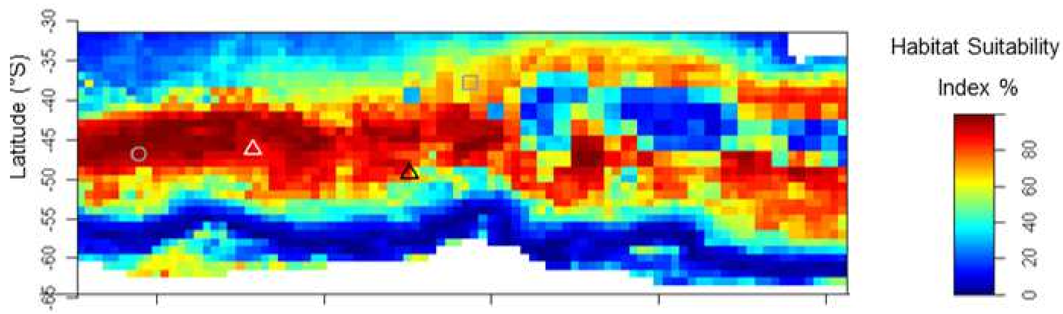
Zone (53%) and the Polar Frontal Zone (47%), using waters with the highest and most variable eddy kinetic energy values (Thiebot et al., 2012).



Map 16. *Eastern rockhopper penguin, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 17. ***Eastern rockhopper penguin, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 18. ***Habitat suitability map for Eastern rockhopper penguin during the non–breeding season.*** Model was based on the distribution of animals from Crozet only during September (i.e.the month with minimum swimming speed). Location of the colonies are indicated: Marion (grey circle), Crozet (white triangle), Kerguelen (black triangle)(From (Thiebot et al., 2013)

The modelled foraging habitat (Map 18, Annex IB for detailed methodology) for *E. filholi* from Crozet show the primary influence of SST gradient and also of other variables (Chlorophyll A, SST, Bathymetry and gradient of Bathymetry). The mapping of habitat suitability show a latitudinal band of more suitable habitat around 45°S that separate into two branches east of 80° E.

Threats. The Eastern rockhopper penguin is strongly dependent of the prey availability in the inshore waters of Crozet and Kerguelen inside the EEZs because of their limited foraging range. Isotopic analysis from feathers samples dating back 1861 indicate that there have been major changes in the feeding ecology of rockhopper penguins during the period ca. 1840–2000 with a shift in diet to prey of lower trophic status over time and in warm years (Hilton et al., 2006). A decrease in the body condition of individuals at their return to the colonies has been also observed at Marion island from 1994 (Crawford et al., 2006). These factors may cause substantial non-breeding, and therefore ultimately contributing to a decrease of the populations. However the specific relationships between the demographic parameters and the marine productivity during the premolting, breeding and wintering areas remain unknown. Any change in the marine productivity and dynamic food webs may however negatively affect the breeding success and the survival.

Gaps & Stakes. Tracking information during the summer period (breeding) is needed for the other islands of the Crozet archipelago and for the open sea localities of Kerguelen, including as the northern, western, and southern sectors. Nothing is known about the at-sea distribution of immatures, fledged and non-breeding birds both for the Crozet and Kerguelen populations.
The French southern territories of Kerguelen-Crozet host most of the world population of *Eudyptes chrysocome filholi*.

Penguins/Northern rockhopper penguin
Eudyptes moseleyi

CRITICALLY ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED

@Y. Tremblay

TAXONOMY

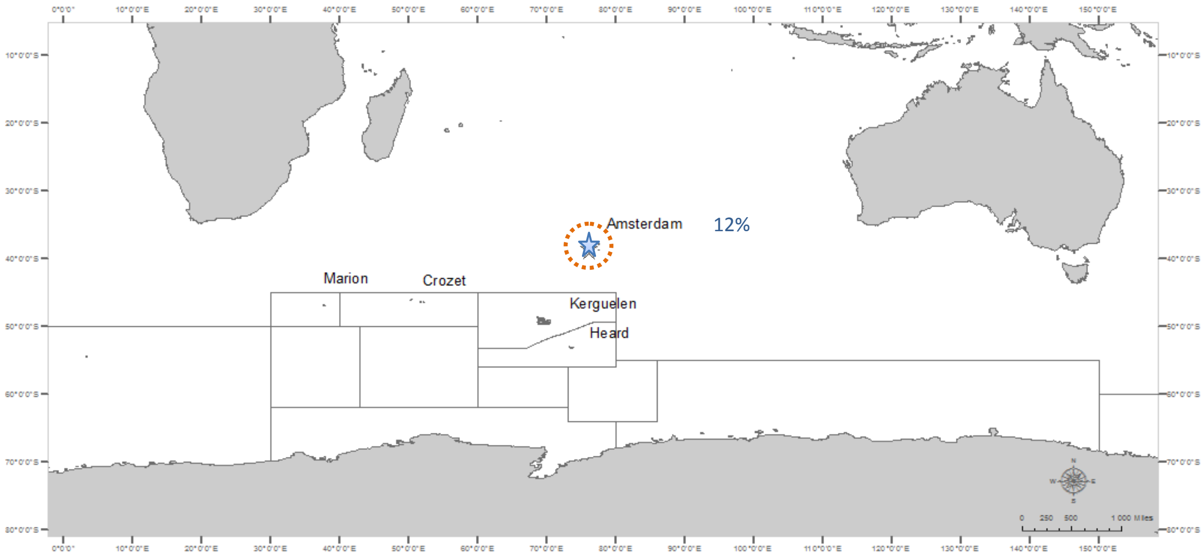
Order Sphenisciformes / Family Spheniscidae / Genus *Eudyptes* /Species *E.moseleyi*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 11. *Breeding cycle and availability of tracking data (blue arrow) of* E. moseleyi. Shaded cells indicates moulting period on land.

Regional Breeding Sites. The *E. moseleyi* has a restricted breeding range, limited in the Atlantic to the Tristan da Cunha and Gough localities, and to the French subantarctic islands of Amsterdam and Saint Paul islands in the South Indian Ocean. It is a colonial breeder, nesting in dense colonies.



Population trends. Of the 3 breeding localities (Tristan group, Gough and Saint Paul-Amsterdam islands), the Northern rockhopper has declined by 57% over the past 37 years (Birdlife International 2010). The breeding colonies on Amsterdam Island have decreased at a rate of 2.7% per year between 1972 and 1992 (57% of decrease) while the neighboring island of Saint Paul increased by 56 % during the same period (Guinard et al., 1998). However, accurate surveys of the colonies are difficult to obtain for this species because of the presence of dense vegetation.

Diet and stable isotopes.

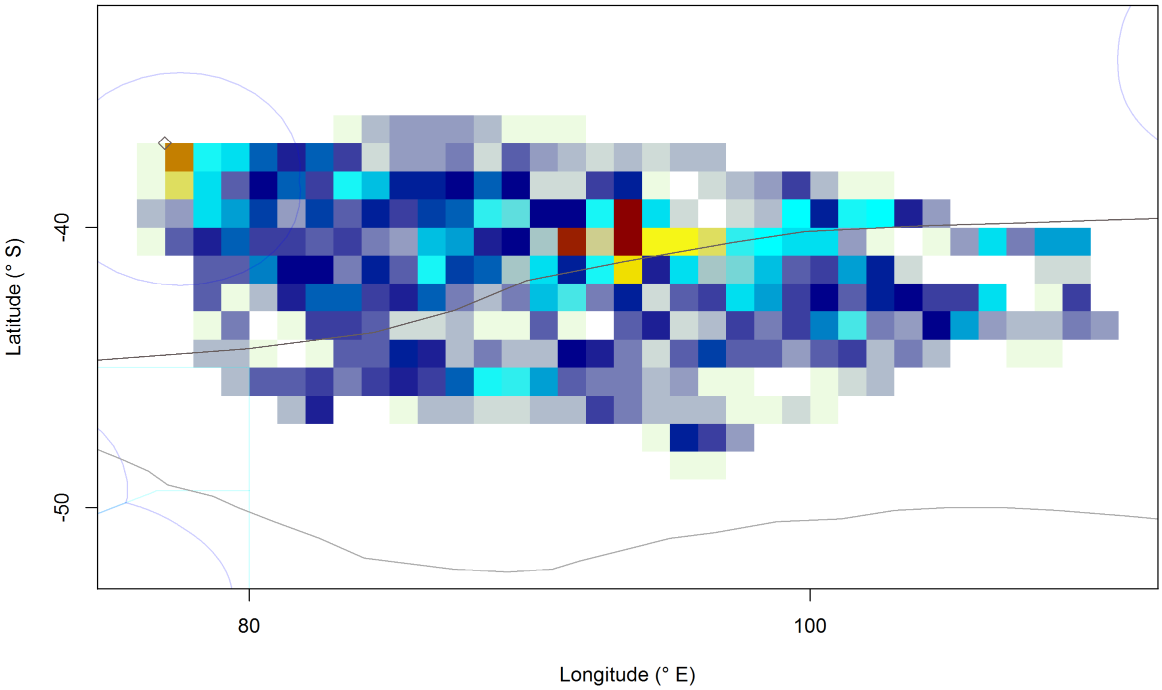
Overall, chick food is very diverse, with crustaceans (21-58%), cephalopods (14-44%) and fish (12-64%) being almost equally important. Proportions of the main prey classes and species show strong intra- and inter-annual variations. The major crustacean prey are euphausiids, primarily *Thysanoessa gregaria*. Cephalopods are small juvenile squids, mainly *Todarodes filippovae* and *Teuthowenia pellucida*. Fish prey includes various inshore and epi- and mesopelagic species, including the latridid *Mendosoma lineatum*, the Atlantic saury *Scomberesox saurus* and the photichthyid *Vinciguerria attenuata* (Cherel et al., 1999;Tremblay and Cherel, 2003;Tremblay et al., 1997).

Blood $\delta^{13}C$ and $\delta^{15}N$ values are higher than those of the closely-related Southern rockhopper penguin, which is in agreement with elevated isotopic baseline levels in subtropical waters (Cherel and Hobson, 2007). Isotopic values of blood collected at the arrival in the colony in spring indicate that adult birds also forage in subtropical waters in late winter (Thiebot et al., 2012).

Marine distribution. Available tracking data from Amsterdam Island (Argos PTTs during breeding: incubation, GLS during inter-breeding) indicate the use of 2 distinct marine habitats. During the incubation, the penguins perform distant, looping foraging trips, up to 220km off the island without any clear preferential direction. During winter, the penguins perform large scale movements over deep oceanic waters of the southern Indian Ocean (2100 km), without any return to land. All the penguins from Amsterdam Island head south-eastward along the Southeast Indian Ridge and then move eastward, with the majority south of the South Subtropical Front into the Subantarctic Zone, before returning to their colony.

Important areas

During the incubation and also the first part of chick rearing, the Northern rockhopper penguin extensively uses the whole EEZ of Amsterdam Island (Map 19). During the winter migration, they use almost exclusively the Subtropical Zone (59%) and the Subantarctic Zone (40%).



Map 19. *Northern rockhopper penguin, Amsterdam Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. The Northern rockhopper penguin is strongly dependent of the prey availability in the coastal waters and the shelf inside the EEZ of Amsterdam-Saint Paul islands. During breeding and moulting, any change in marine productivity and the dynamic of trophic food webs in this area could drastically affect the populations.

Gaps & Stakes. Tracking information is needed concerning the chick-rearing period and the pre-moulting period, both at Amsterdam and Saint Paul islands.
The Amsterdam and Saint Paul islands host the entire population of the whole Indian Ocean and more than 12 % of the world population.

Penguins/Macaroni penguin

Eudyptes chrysolophus

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

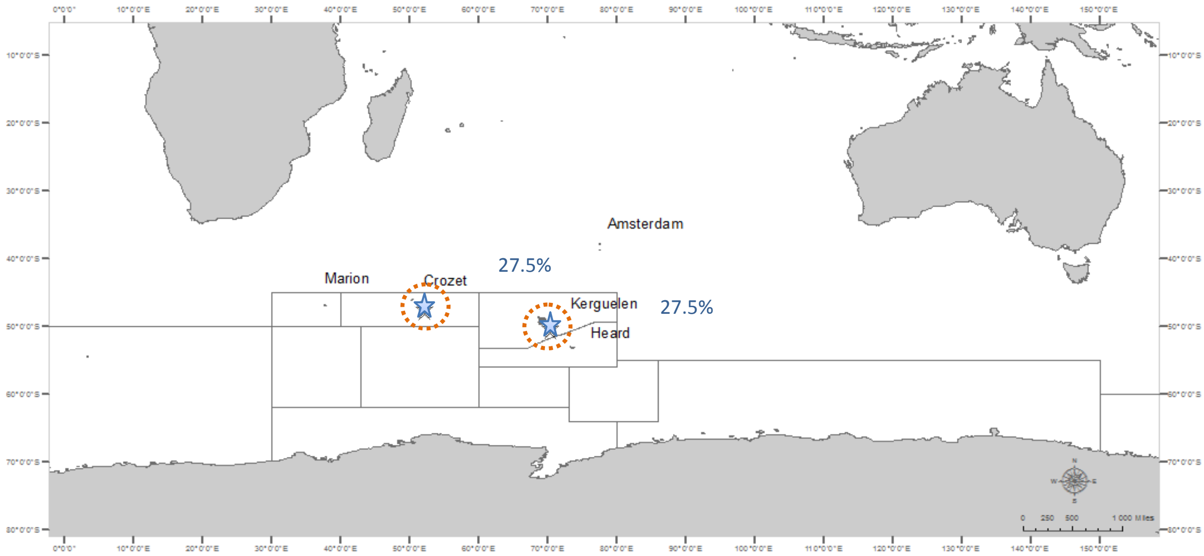
Order Sphenisciformes / Family Spheniscidae / Genus *Eudyptes* /Species *E.chrysolophus*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 12. *Breeding cycle and availability of tracking data (blue arrow) of* E. chrysolophus

Regional Breeding Sites. *E. chrysolophus* is a colonial breeder, nesting in dense, sometime very large colonies (up to 500.000 pairs). Most of the colonies are found in the subantarctic (10 localities: South Georgia, Crozet, Kerguelen, Marion & Prince Edward, Heard & Mc Donald, South Sandwich, Bouvet, and South Orkney) as well on Southern Chile offshore islands and in the Antarctic peninsula (Boersma et al. 2012).

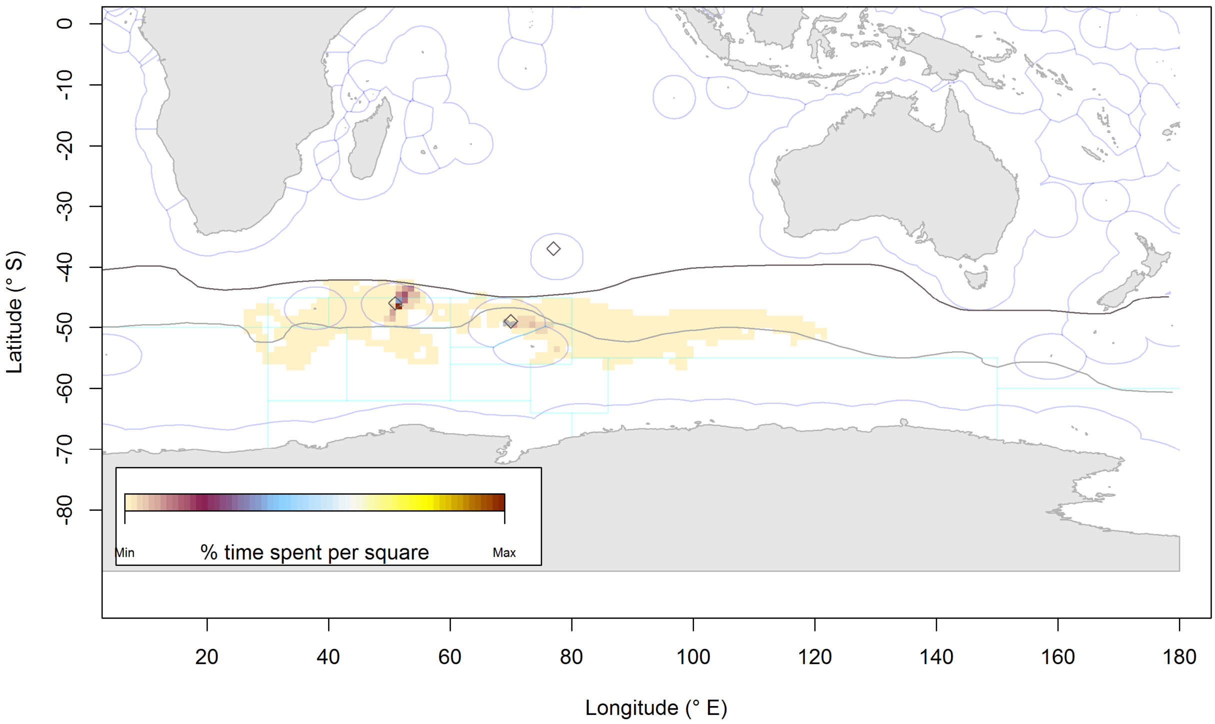


Population trends. In the French Southern Territories, population estimates from 1982 indicate that the Crozet and Kerguelen populations accounted for about 55% of the world population (Kerguelen: $3x10^6$ pairs, Crozet: $3x10^6$ pairs). The interannual monitoring of large colonies in these 2 localities is too recent to highlight reliable population trends. At Possession Island, a decrease of some small colonies during the last decade has been reported. At Marion Island, the numbers of macaroni penguins estimated to breed decreased markedly after 1994/95 (Crawford et al., 2006). Recent surveys on South Georgia, i.e. the stronghold of the breeding population, indicate a dramatic decline of very large colonies compared to the 1970s (Trathan et al., 2012). Overall macaroni penguin populations have substantially declined across the Southern Ocean since the last 30 years. Although the factors of decline remain unclear, tropho-dynamic interactions may be locally sufficient to explain the observed changes (Trathan et al., 2012).

Diet and stable isotopes. Chick food at Crozet Islands is dominated by crustaceans (61-91% by mass), with fish ranking second (7-29%) and cephalopods third (3-10%) (Cherel et al., 2007;Ridoux, 1994). At Kerguelen Islands, crustaceans (52%) and fish (48%) are equally important (unpublished data). The main crustacean prey is the subantarctic krill *Euphausia vallentini*, but hyperiids (including *Themisto gaudichaudii*) are also significant items at Crozet islands. The myctophid *Krefftichthys anderssoni* is consistently the major fish prey of macaroni penguins (Cherel et al., 2007;Ridoux, 1994), unpublished data).
At Crozet and Kerguelen Islands, blood $\delta^{13}C$ values show that chicks are fed with prey caught in nearby oceanic waters. $\delta^{15}N$ values are consistent with a crustacean-based diet, but with more fish at Kerguelen than at Crozet Islands. The trophic position of the species was estimated at 4.1 at the former locality (Cherel et al., 2010;Cherel et al., 2007), unpublished data). Isotopic values of blood collected at the arrival in the colony in spring indicate that adult birds forage in subantarctic waters where they feed mainly on crustaceans in late winter. Two strategies co-occurred at Crozet Islands: a

majority of birds prey almost exclusively on crustaceans, while some birds also catch fish (most probably myctophids) in colder waters (Cherel et al., 2007;Thiebot et al., 2011).

Marine distribution. *E.chrysolophus* is a pelagic forager with high flexible diving activity at mid-depth during day and night. The at-sea distribution is circumpolar, ranging from the Polar Frontal Zone to the Antarctic waters. In the Southern Indian Ocean as well in the Southern Atlantic Ocean, macaroni penguins use 2 distinct marine environments: the shelf and the shelf break during the summer (i.e. chick rearing) and oceanic, deep waters in the Polar Frontal Zone during the incubation and the non-breeding periods (winter).

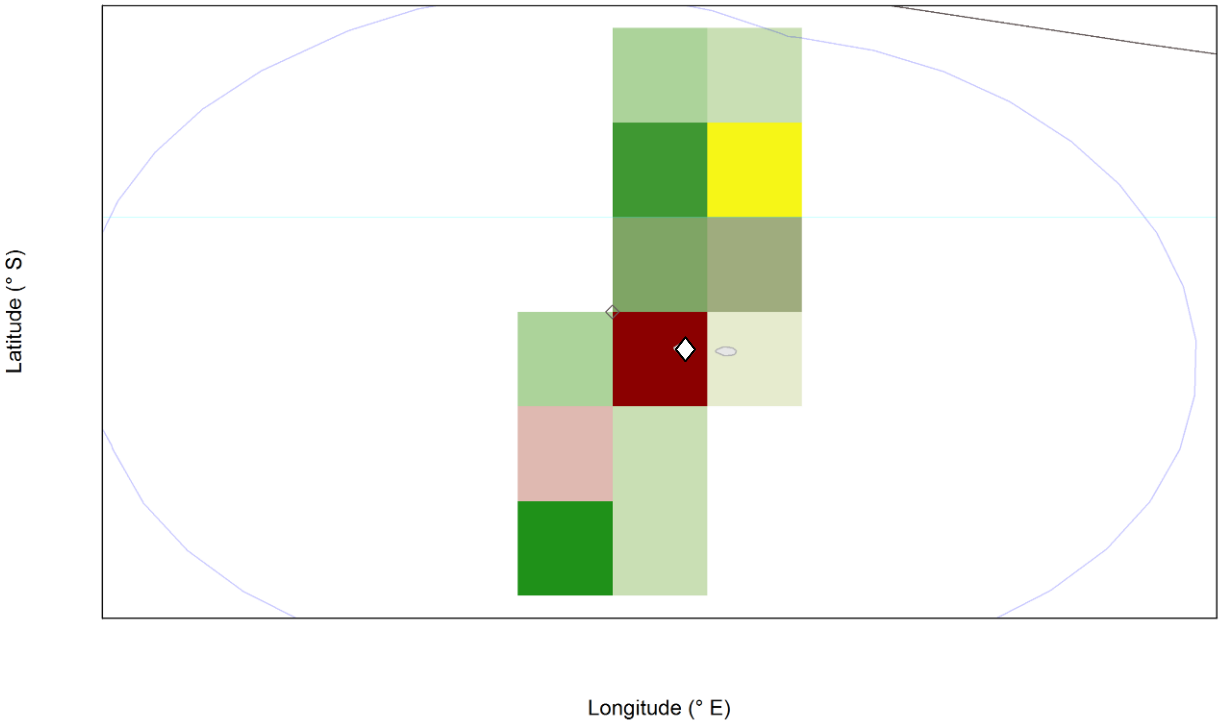


Map 20. *Macaroni penguin, Crozet and Kerguelen Islands*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (breeding and inter-breeding periods pooled). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Important areas

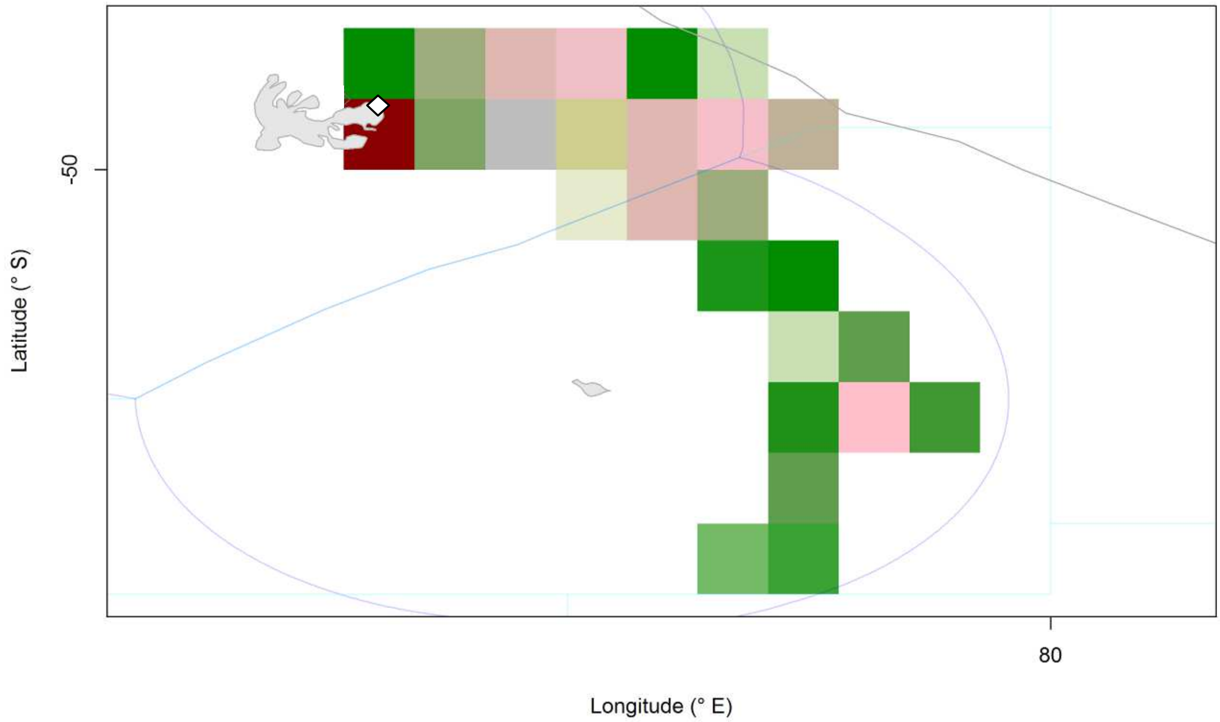
Breeding period. Macaroni penguins exhibit marked differences in foraging trip characteristics between males and females, both during incubation and chick rearing in South Georgia (Barlow and Croxall , 2002) and in the French Southern Territories of Crozet and Kerguelen. The females are highly constrained during the first part of the chick rearing period as they have the exclusive charge of supplying food for the chick. During chick rearing, their residence times are highly influenced by the location of the breeding colonies and are mainly distributed around the Crozet and Kerguelen archipelagos, in the French EEZs.

1. Crozet. The movements and at-sea and marine habitats used are much more diversified than at Kerguelen as indicated by tracking data (Argos PTTs, GPS; Map 21). During the incubation (November-December) males and females perform extended, direct or looping trips toward the north, over deep waters and up to the Subantarctic Front as far as 300 km from the island. During the beginning of the chick rearing period (December: brooding) birds from Crozet use extensively the shelf with a much limited range (9-60km). From crèching to the emancipation of the chick, the habitat used by males and females is more variable between years and individuals. Some males continue to extensively use the shelf while some other head south toward the Polar Front as far as 300 km from Possession island.



Map 21. ***Macaroni penguin, Crozet Island*****. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (breeding and inter-breeding periods pooled).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

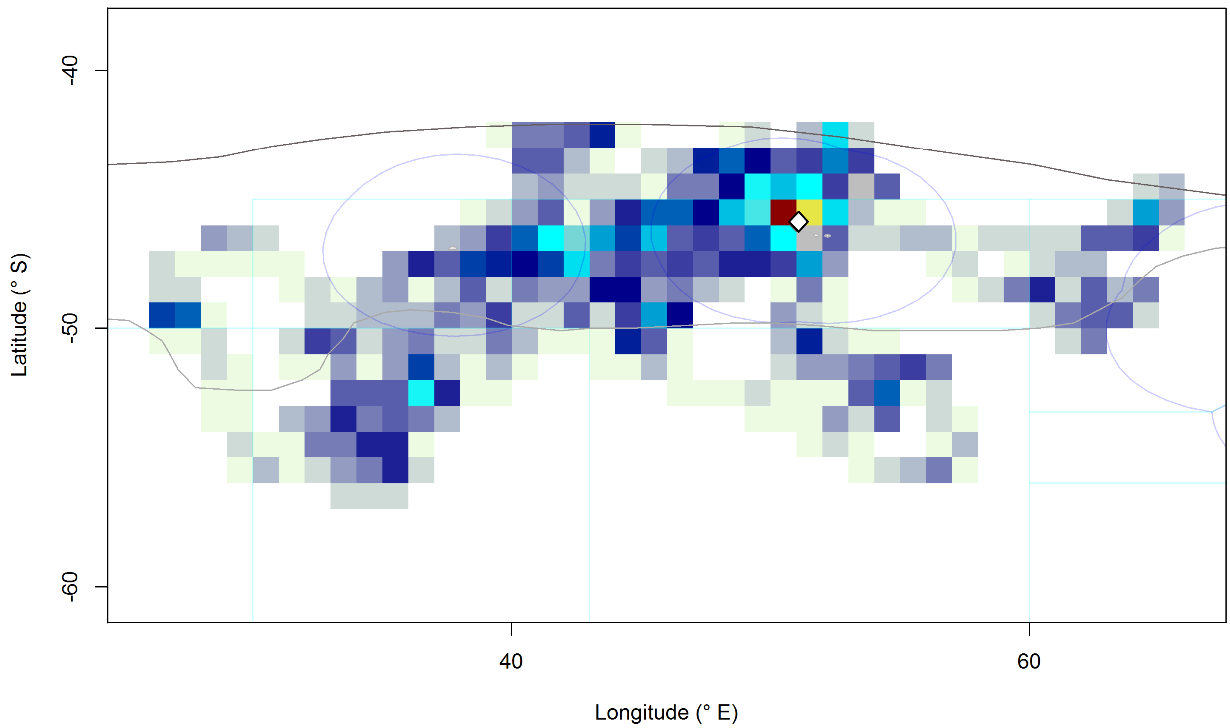
2. Kerguelen. The foraging movements of tracked penguins (Argos PTTs, GPS; Map 22) generally headed toward the eastern sector of the shelf, over 1000-2000m water depth, with an extended foraging range during incubation, maximal during the first trip (performed by the male, up to 600km). During the second incubation trip, the females perform looping trips orientated toward the Southeast. Brooding birds have a more restricted range (65-110km), consistently heading toward the Eastern side of the shelf break (1000m).



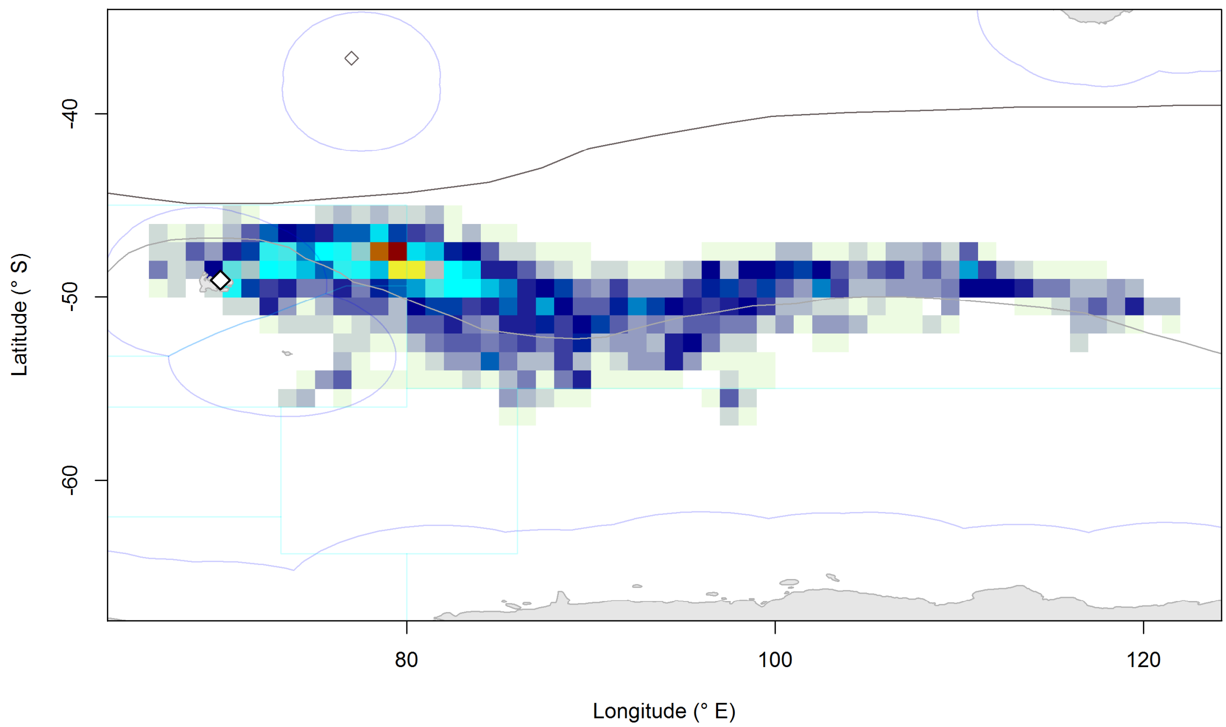
Map 22. ***Macaroni penguin, Kerguelen Island*****. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Inter-breeding period. Tracking data (GLS data) indicate that macaroni penguins distribute widely during winter, over deep (3000-4000m) oceanic waters of the Polar Frontal Zone characterised by a temperature of 3.0° to 3.5°C. The penguins use waters of high sea surface temperature gradient and eddy kinetic energy (Bost et al., 2009b;Thiebot et al., 2011).

The populations from Crozet (Map 23) and Kerguelen (Map 24) islands show distinct migratory patterns and wintering areas without any overlap. Birds from Kerguelen disperse eastward as far as 2400km, while individuals from Crozet head south-westwards (up to 1200km), including the Del-Cano area. Birds from Kerguelen have a consistent interannual winter distribution (the pattern is still unknown for Crozet birds).



Map 23. *Macaroni penguin, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 24. *Macaroni penguin, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin,

1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. Macaroni penguins strongly depend of the availability of myctophid fish during the chick rearing period. A large, uncontrolled development of myctophid fisheries close to key foraging areas, especially in the eastern, northern and south-eastern sectors of the Kerguelen shelf may have deleterious effects on the foraging success and ultimately populations of the macaroni penguin.

Gaps & Stakes. There is a crucial lack of distribution data for some very important breeding colonies (Kerguelen: Peninsule Rallier du Batty; Crozet: Ile des Pingouins). Nothing is known about the at-sea distribution of immatures, fledged and non-breeding birds.
The Macaroni penguin is still the major avian consumer of the Southern Ocean and the largest consumer across all marine birds of the world. The Crozet and Kerguelen archipelagos host more than half of the world populations according to available counts.

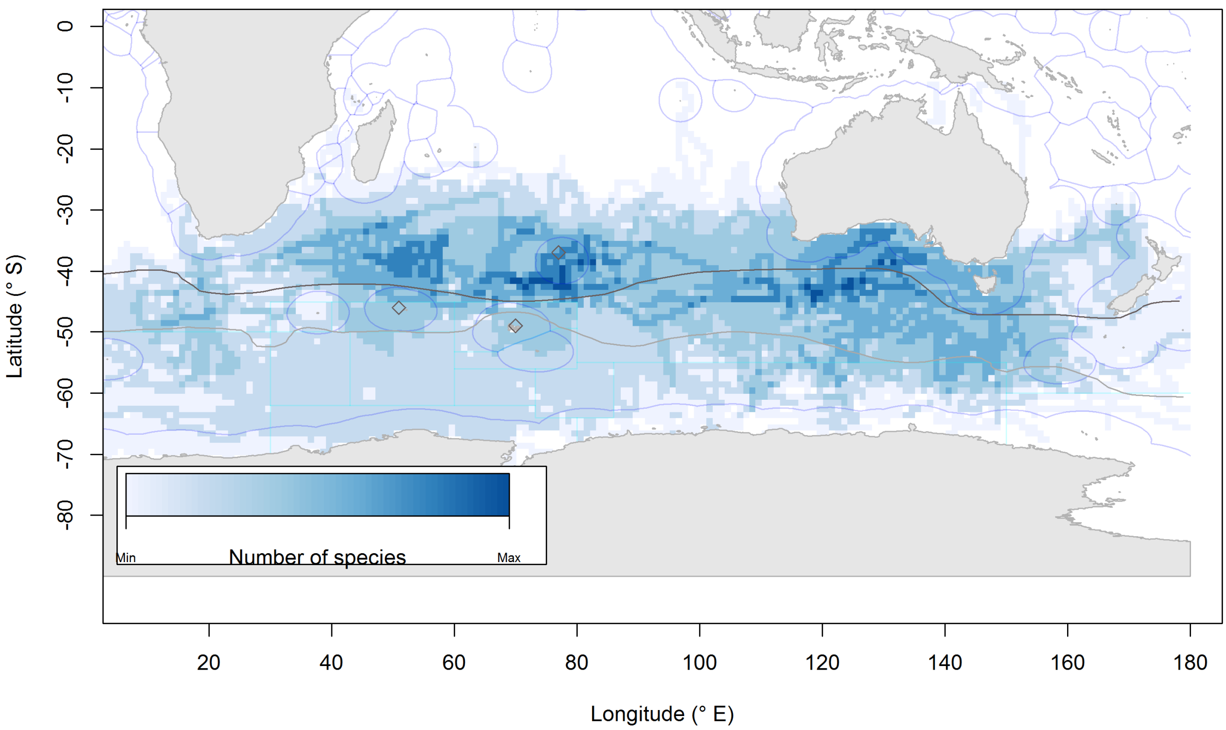
ALBATROSSES


NICOLAS GASCO

Albatrosses of French Southern Territories in the southern Indian Ocean

The Southern Indian Ocean is regularly used by 7 common albatross species that have nesting sites in this ocean, and it is visited less frequently by 5 other species. The Amsterdam albatross *(Diomedea amsterdamensis)*, Wandering albatross (*D. exulans*), Black-browed albatross *(Thalassarche melanophrys)*, Indian yellow-nosed albatross (*T. carteri*), Grey headed albatross (*T. chrysostoma*), Light-mantled albatross *(Phoebetria palpebrata)* and Sooty albatross *(P. fusca),* breed in the area and are resident year-round, although part of the population of some species can migrate outside the zone during the non-breeding season. Other species are rare nesters, such as the Salvin's albatross *(T. salvini*) on Crozet, or are visitors outside the breeding season, such as the Tristan albatross (*D. dabbena*), the Northern and Southern royal albatrosses (*D. sanfordi* and *D. epomophora*, respectively), and the Shy albatross (*T. cauta*).
The *Atlas* focuses on six species breeding in the French Southern Territories for which tracking data are available: the Amsterdam, Wandering, Black-browed, Indian yellow-nosed, Light-mantled and Sooty albatrosses.
It is noteworthy that tracking data are still missing for several important colony sites (e.g. the Indian yellow-nosed and Black-browed albatrosses from Crozet Islands) and for some species (e.g. the Grey-headed albatross).

The breeding populations of most of these species have declined and some are still in decline, all are included on the IUCN Red List as threatened species (Table 4*; Critically Endangered, Endangered* and *Vulnerable*), largely due to incidental mortality in longline fisheries, and in a lesser extent trawl fisheries.



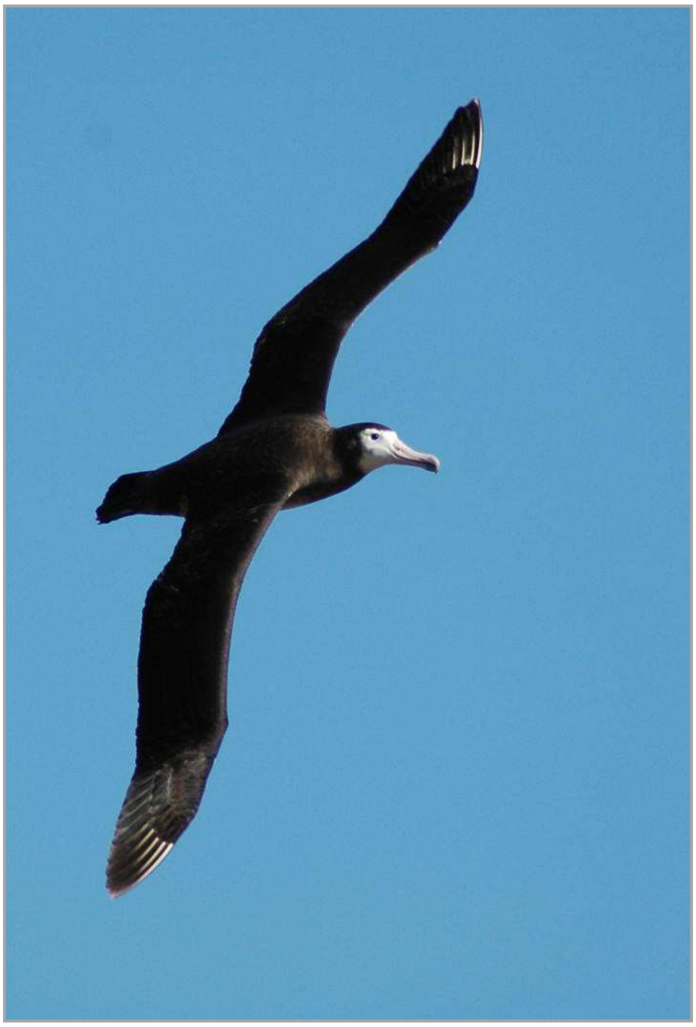
Map 25. Specific diversity of albatrosses. Observed cumulated *Presence* distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds for 6 species of albatrosses (breeding and inter-breeding periods pooled).

Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Albatrosses/Amsterdam albatross

Diomedea amsterdamensis

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED



@J.B. Thiebot

TAXONOMY

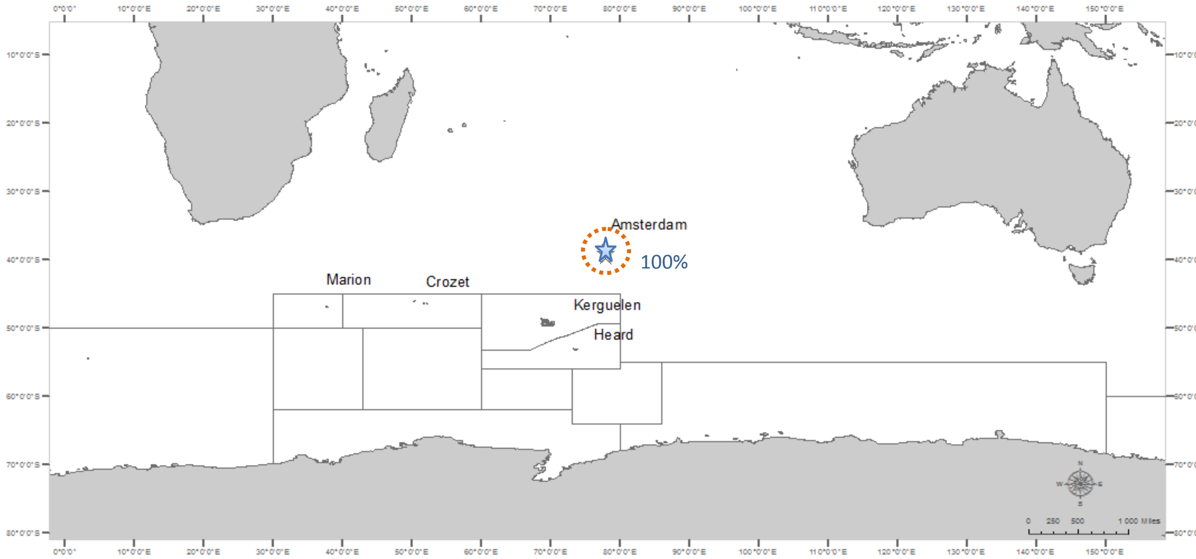
Order Procellariiformes / Family Diomedeidae / Genus *Diomedea* /Species *D. amsterdamensis*

Biennial breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 13. *Breeding cycle and availability of tracking data (blue arrow) of* D. amsterdamensis

Regional Breeding Sites. The species is a biennial breeder. It breeds only on Amsterdam Island where its current annual breeding population is ~35 pairs (unpublished data, ACAP 2010a).



Population trends. Observed for the first time in 1955 (Paulian 1960) and described as a new species in 1983 (Jouventin and Roux, 1983) *D. amsterdamensis* had a very small whole population of 30-50 individuals at this time.The population has been monitored continuously since 1983. Annual counts of eggs laid have increased from a very low value of five in 1984 to the highest value of 39 in 2012 (unpublished data). Since 2004, the number of breeding pairs varied between 24 and 35 per year. (Inchausti and Weimerskirch, 2001) suggested that the population could have been reduced by longline fishing activity that was operating around Amsterdam Island between the mid 1960s and mid 1980s. Indeed the observed recovery correspondsto a shift in fishing activity away from the island in the late 1980s and 1990s (Weimerskirch et al., 1997a).

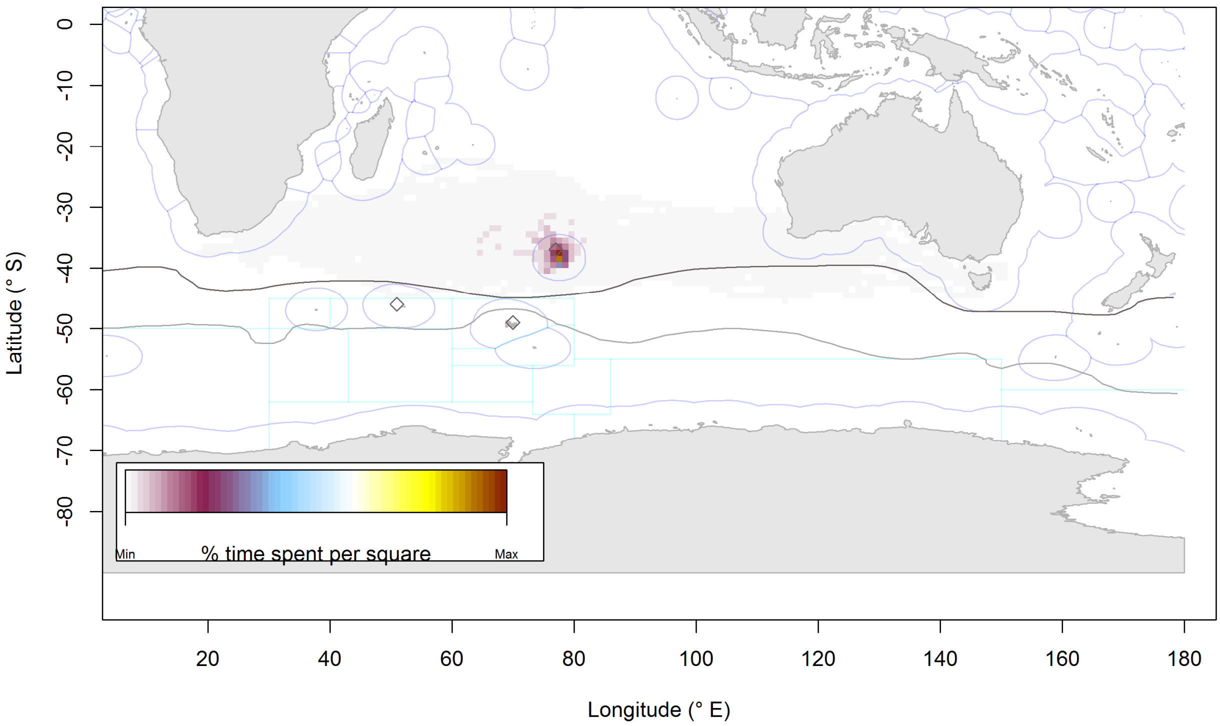
Today the unique global population is composed of only 86 mature individuals, and an additional mortality over 6 individuals a year would be enough to cause population decline (Rivalan et al., 2010). Demographic projections show that when considering different scenarios (with / without additional bycatch in fisheries, and with predicted climate change) the population would continue to grow between 2.8 to 5.4% annually without incidental mortality (Rivalan et al., 2010).

Diet and stable isotopes. No dietary data available (chick food was not investigated). $\delta^{13}C$ and $\delta^{15}N$ values of chick feathers show that the species forages in subtropical waters, where it is an apex predator that feeds at a higher trophic position than the sympatric Yellow-nosed and Sooty albatrosses (Cherel et al. unpublished data). Amsterdam albatrosses are thus likely to prey upon large squids, fish and carrion, as other albatrosses from the genus *Diomedea* do (Cherel and Klages, 1998). The $\delta^{13}C$ values of adult feathers indicate moulting in warmer oceanic waters of the northern subtropical zone and even in fringing tropical waters (Cherel et al., 2013).

Marine distribution. Satellite tracking data of *D. amsterdamensis* have been collected for all the life stages. The species is typically subtropical, rarely foraging south of the subtropical convergence. During breeding they have been tracked during incubation and chick rearing stages. During breeding, because of the central place foraging behavior, higher densities occur around Amsterdam Island, but the overall range extent as far as 3000 km to the east where birds venture when rearing large chicks (Thiebot et al. submitted). Tracking of inter-nesting adults show that they venture from the coasts off Western Australia to eastern Africa, but always remain over oceanic waters.

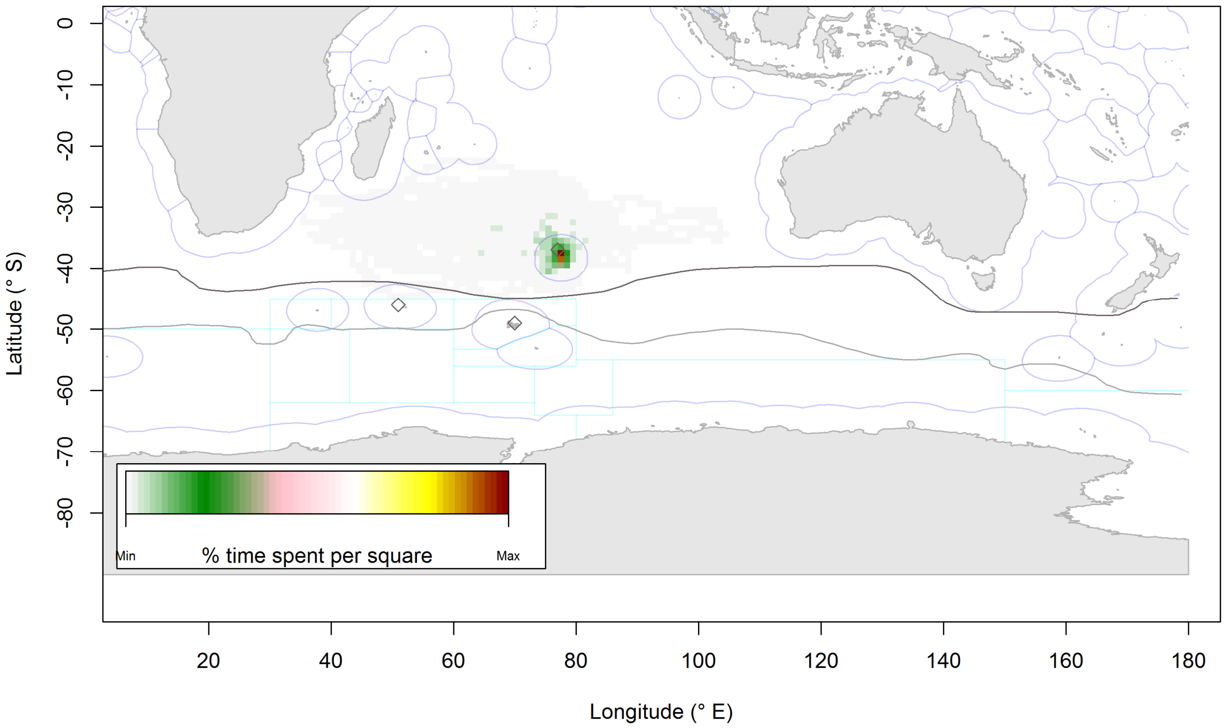
Important areas

The Southern Indian Ocean is a foraging area of great importance year round for the Amsterdam albatross. The adults distribute on a large area between Africa and Australia. The principal areas used by adults are situated in subtropical waters, north from the South Subtropical Front.



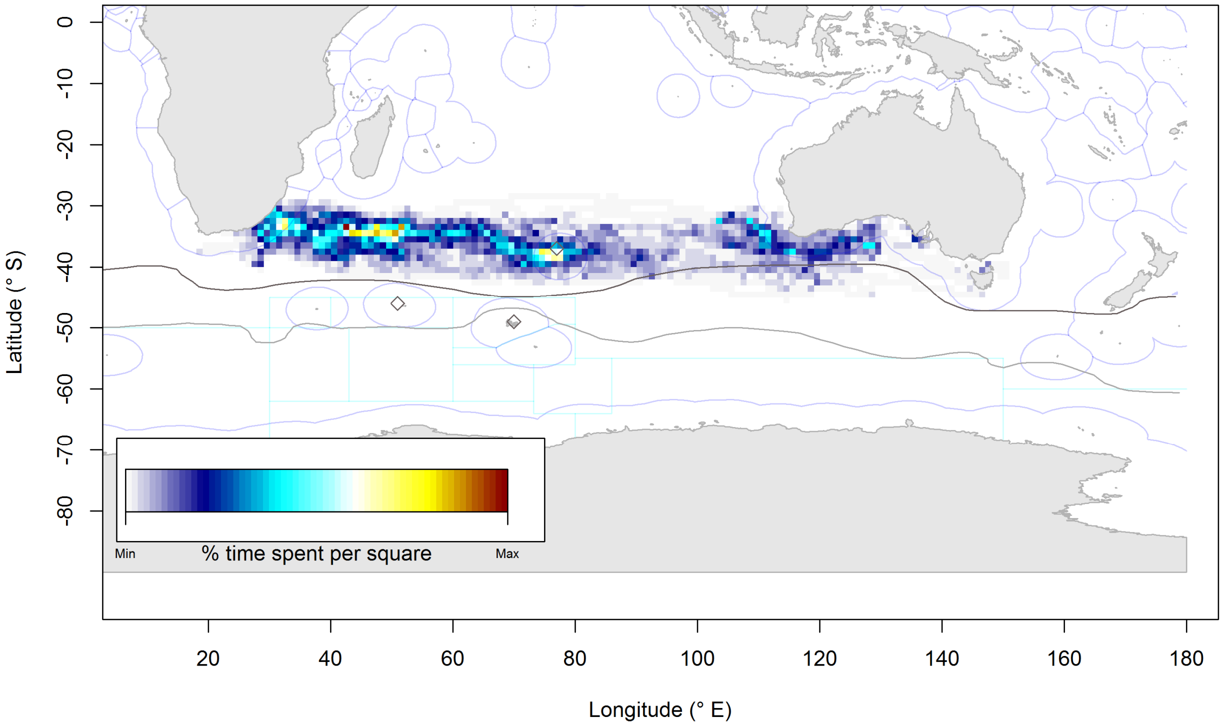
Map 26. *Amsterdam albatross*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (breeding and inter-breeding periods pooled). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The highest residence time are observed in the Amsterdam EEZ (Map 26), largely influenced by the distribution data during the breeding period linked to the location of the breeding colony (Map 27).



Map 27. *Amsterdam albatross*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Adults of *D. amsterdamensis* target oceanic subtropical waters around their breeding colony, where they spend a large amount of time throughout the breeding period, and westward from Amsterdam, north of the South Subtropical Front up to -22°S.



Map 28. *Amsterdam albatross*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the inter-nesting period *D. amsterdamensis* is largely distributed in the subtropical waters, principally in the western part of southern Indian Ocean, between Africa and Amsterdam. They spend the largest amount of time on the north of the spreading ridge flank of the southwest Indian ridge.

Threats. Avian cholera has recently been identified as a likely cause of decline in the population of Indian yellow-nosed albatross (*T. carteri*) on Amsterdam Island (Weimerskirch, 2004). In 2013, the disease has been found in *D. amsterdamensis* (Jaeger et al. submitted): if effects to the species are similar to those found in yellow-nosed albatrosses the population could face a high risk of extinction within a few decades.

Due to the low population size, few records exist that quantify threats at sea. Longline fishing activities around the island during the 1970s and 1980s may have well contributed to the population decline in the past (Inchausti and Weimerskirch, 2001) BirdLife International 2012). The foraging range of *D. amsterdamensis* extends up to 4000 km from the breeding site, and overlaps with longline fishing operations targeting tropical tuna species (National Plan of Action for Amsterdam Albatross 2011, Thiebot et al. *in prep.*).

Gaps & Stakes. *D. amsterdamensis* is one of the most comprehensively studied albatross species and is probably the only seabird species, and perhaps marine animal for which all stage of the life cycle are known through tracking studies. So there is no real gap for this species that breed in a single site.

Potential interactions with subtropical longline fisheries in the Indian Ocean are considered to be the apex risk and have justified the implementation of a National Plan of Action to promote conservation of the species. This Plan has been launched in 2010 and set up for five years, including seven frameworks relative to both research and management (Weimerskirch et al., 2011).

Albatrosses/Wandering Albatross

Diomedea exulans

CRITICALLY ENDANGERED | ENDANGERED | VULNERABLE | NEAR THREATENED | LEAST CONCERN | NOT LISTED

@A.Prudor

TAXONOMY

Order Procellariiformes / Family Diomedeidae / Genus *Diomedea* /Species *D. exulans*

Biennial breeder

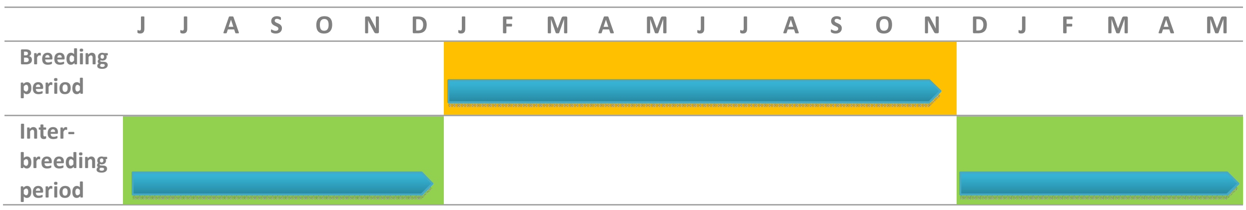
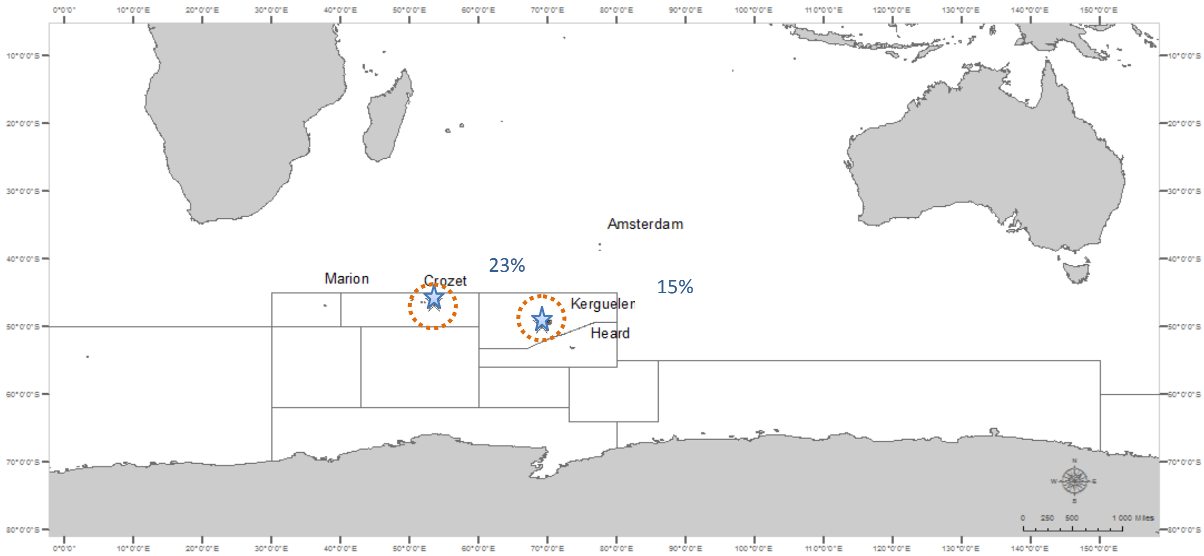


Table 14. *Breeding cycle and availability of tracking data (blue arrow) of* D. exulans

Regional Breeding Sites. *Diomedea exulans* breed on the French subantarctic island groups of Crozet and Kerguelen, on South Africa's Prince Edward Islands, Australia's Macquarie Island and at South

Georgia. The total annual breeding population is estimated at approximately 8050 pairs (ACAP 2010b). This is 5 percent less than the 1998 figure of 8500 pairs, thought to represent about 28000 mature individuals and a total population of 55000 (Gales and Pemberton, 1988). The three island groups in the Indian Ocean sector (Prince Edward, Crozet and Kerguelen) account for approximately 82% of the global population. Approximately 3000 pairs, or 38% of the total population, breed on the Crozet and Kerguelen Islands.



Population trends. Long term population studies have been conducted on all five islands or island groups where *D. exulans* breed. All populations have shown a decrease at some stage over the last 25 years. The Indian Ocean populations (Crozet, Kerguelen and Prince Edward Islands) have increased recently, whereas the South Georgia population has shown a continuous decline.

Crozet and Kerguelen Islands

The breeding population of *D. exulans* on Possession Island (Crozet) has been one of the most closely monitored of all albatross populations, with long term demographic data collected for a large number of birds (Weimerskirch and Jouventin, 1998). This population decreased steeply during the 1970s (around 7% per annum between 1970 and 1976), then more moderately during the early 1980s (1.4 % per annum from 1977 to 1985) (Weimerskirch and Jouventin, 1998). By 1986, the population has been reduced by 53.8% from c. 500 breeding pairs observed in the late 1960s (Weimerskirch and Jouventin, 1998). Between 1986 and 2004 the population increased steadily at 1.6% (Delord et al., 2008). Over the last few years the numbers have been maintained at 300 to 380 pairs (unpublished data).

Although demographic data are lacking for Kerguelen Islands, the population trend has followed a similar pattern to that at Crozet (Weimerskirch et al., 1997a). The Courbet Peninsula population declined from c. 500 pairs in 1971 to c. 200 pairs in 1987, and then recovered to over 300 pairs in 1996, reaching 419 breeding pairs in 2004 ((Weimerskirch et al., 1997a)unpublished data).

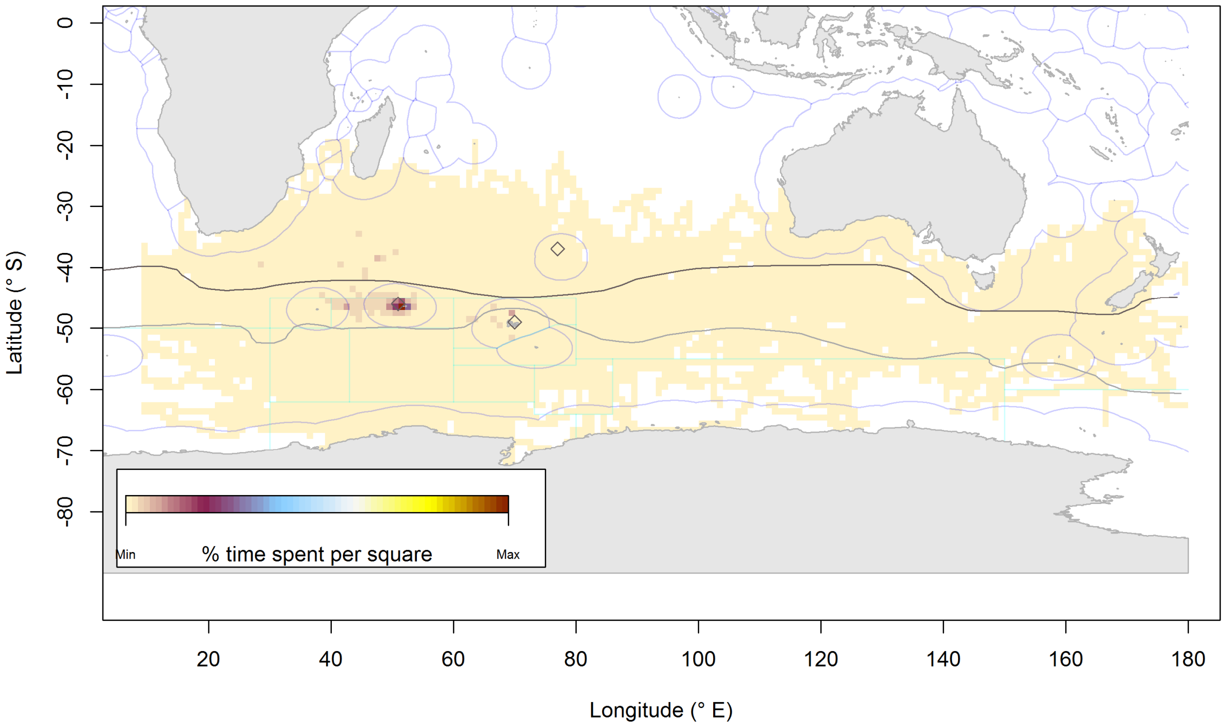
Diet and stable isotopes. Chick food at Crozet is consistently dominated by squids (75% by mass), with fish ranking second (18%) and carrion third (7%) (Cherel and Weimerskirch, 1999;Ridoux, 1994). At Kerguelen in 1998, squids and fish were equally important (respectively 46% and 48%, unpublished data). Most of the squids are adult individuals (Weimerskirch et al., 2005), and the cephalopod diet is dominated by mass by large onychoteuthids, primarily *Kondakovia longimana*

(Cherel and Weimerskirch, 1999;Ridoux, 1994). The main fish prey is the Patagonian toothfish *Dissostichus eleginoides*, which occurs both as a natural prey and a fishery-related item ((Weimerskirch et al., 1997b), unpublished data). Close association with toothfish longliners is also exemplified by the presence of hooks in the stomach contents of some chicks (unpublished data). At the two localities, feather $\delta^{13}C$ and $\delta^{15}N$ values show that adults caught prey for their chicks in subantarctic waters, where the species occupies the highest trophic position within the community of oceanic seabirds (Blévin et al., 2013;Jaeger et al., 2010a). The $\delta^{13}C$ values of adult feathers confirm moulting in oceanic subtropical waters, with some sex-related differences in the main foraging zones (Cherel et al., 2013;Jaeger et al., 2009;Jaeger et al., 2010a).

Marine distribution. With the Amsterdam albatross, this species is one for which there is the most comprehensive data on the distribution at sea, since it has been tracked continuously from Crozet since 1989, and all life cycle stages are known for this population. This wide ranging species has a circumpolar distribution, and both breeding and non-breeding birds from Crozet and Kerguelen have very large foraging ranges (Maps 17 to 22). Satellite tracking data indicate that breeding birds forage at very long distances from colonies (up to 4000 km) and that foraging strategies change throughout the breeding season (Louzao et al., 2011;Weimerskirch, 1998). Long term tracking indicates that distribution has changed over the past 20 years (Weimerskirch et al., 2012).

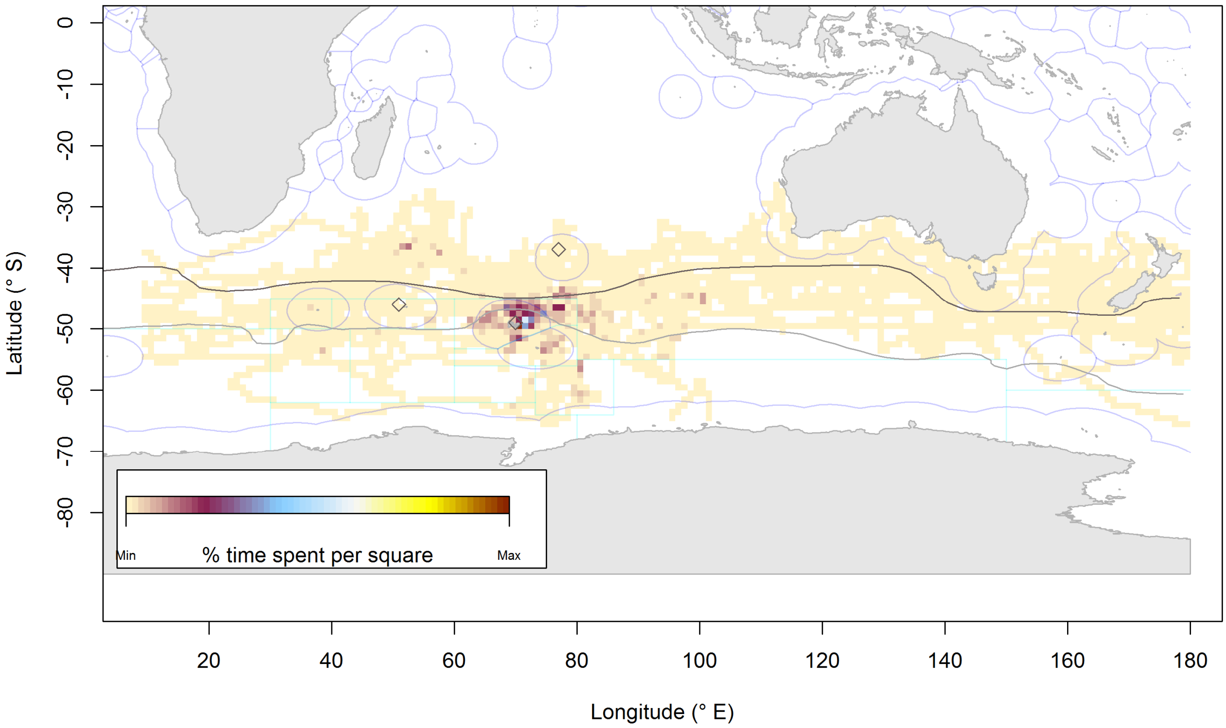
Important areas

Map 29 and 30 show the distribution of wandering albatrosses from Crozet and Kerguelen. High amounts of time are observed within the Crozet EEZ and the Kerguelen EEZ.



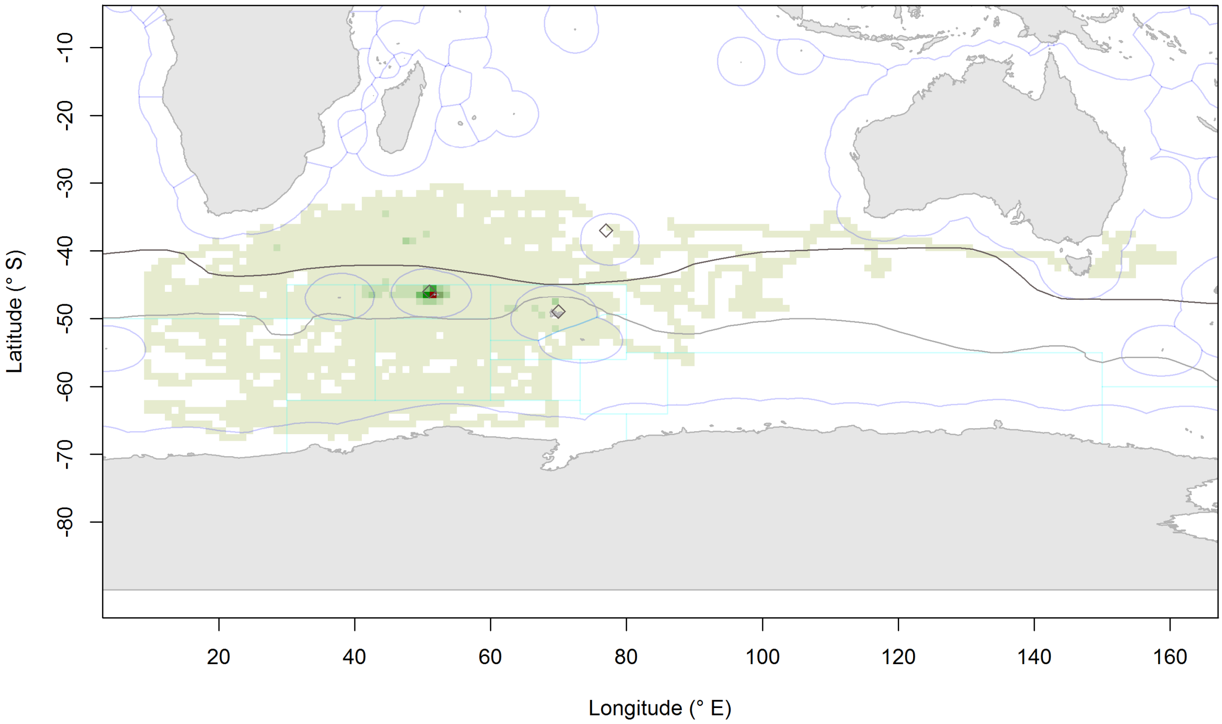
Map 29. *Wandering albatross, Crozet Island*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds from Crozet Island (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR -

Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



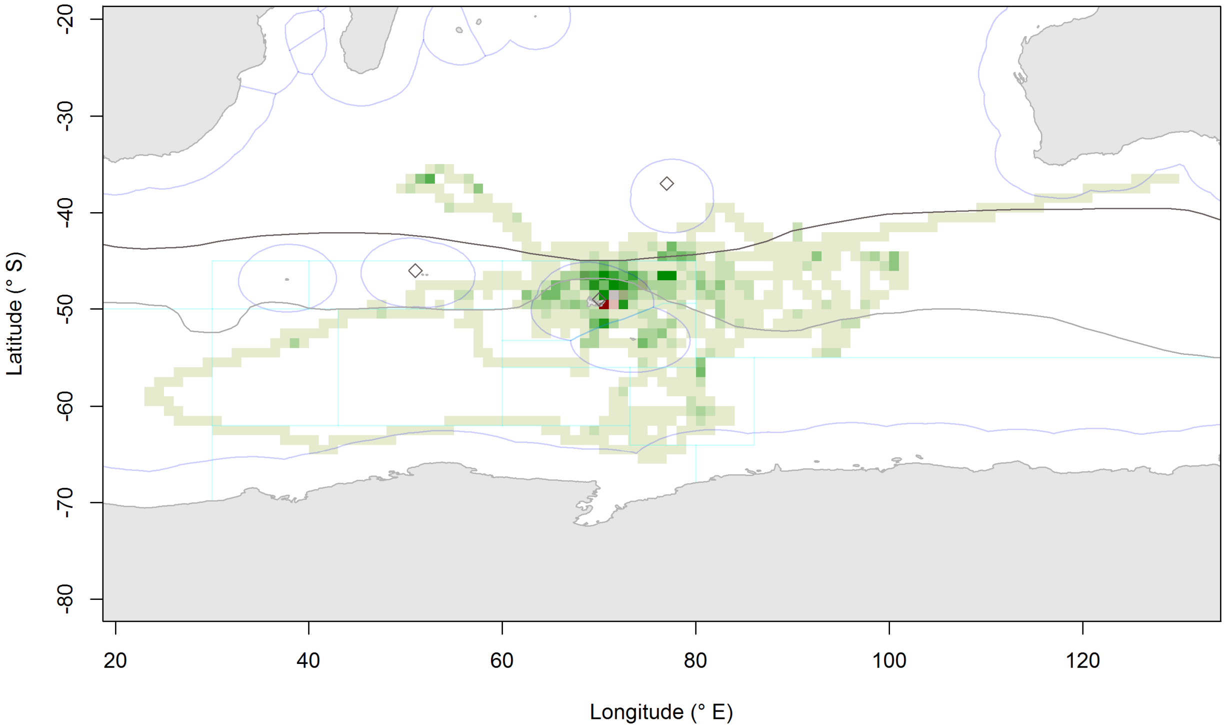
Map 30. *Wandering albatross, Kerguelen Island*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds from Kerguelen Island (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During early incubation, *D. exulans* from Crozet and Kerguelen forage over pelagic waters between the Antarctic continent and subtropical latitudes (Lecomte et al., 2010;Nel et al., 2002a;Weimerskirch, 1998;Weimerskirch et al., 1997a;Weimerskirch et al., 2012;Weimerskirch et al., 1993). Females forage further from the islands and in warmer waters (Weimerskirch, 1998;Weimerskirch et al., 1997b;Weimerskirch et al., 2012;Weimerskirch et al., 1993). During late incubation and early post-hatching, foraging is reduced to the edge of the island shelf in close proximity to the breeding grounds (Louzao et al., 2011;Weimerskirch et al., 1993). During later stages of chick-rearing, *D. exulans* forage in short trips close to the colony in neritic waters, or in long trips far from the colony in oceanic waters to the north (Weimerskirch et al., 1997b;Weimerskirch et al., 1993).



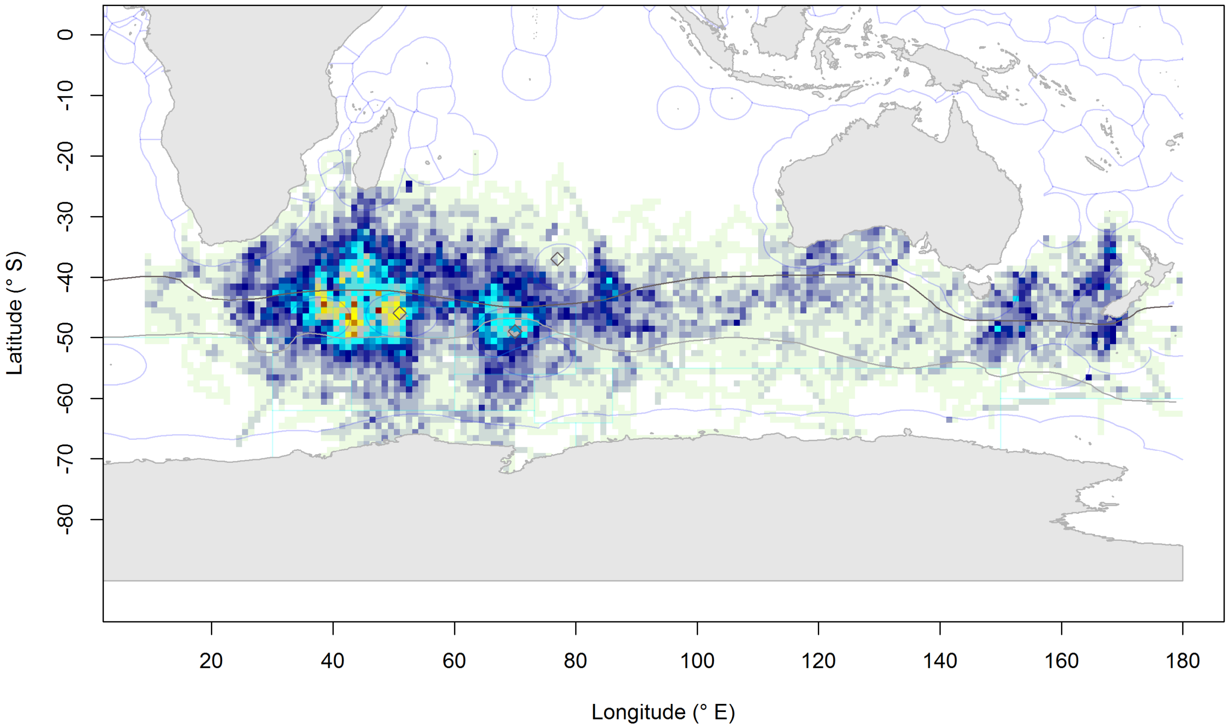
Map 31. *Wandering albatross, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds from Crozet Island during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding period the residence time is skewed by the location of the breeding colony, birds from Crozet and birds from Kerguelen spending high amounts of time within the Crozet EEZ and the Kerguelen EEZ respectively (Maps 31 & 32). Birds from Crozet tend to use areas around Crozet Islands, Del Cano rise, Marion Island. Males breeding on Crozet forage in the Kerguelen shelf area, but not females (Weimerskirch et al., 1997a;Weimerskirch et al., 2012). Adults breeding at Kerguelen Islands use more intensively the Kerguelen Plateau.



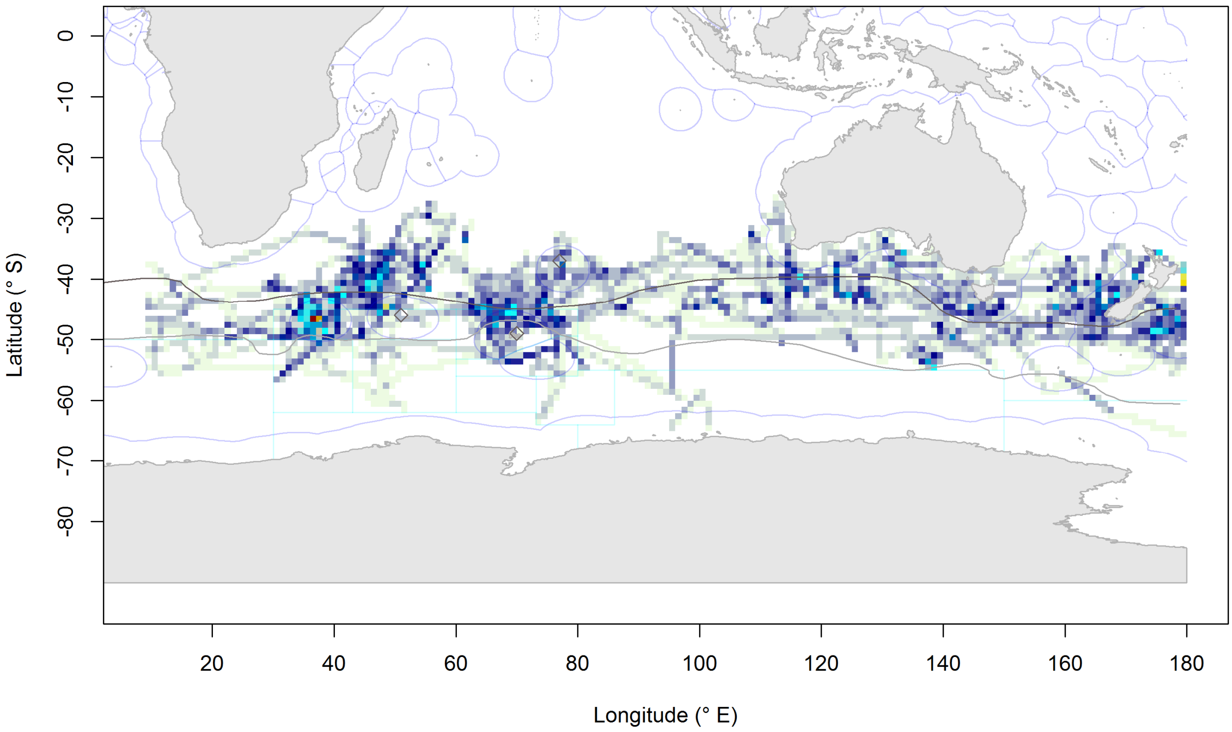
Map 32. *Wandering albatross, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

At the end of the breeding season that lasts one year, wandering albatrosses that fledged a chick take a sabbatical year of one year before starting a new breeding season. During the sabbatical year, birds disperse throughout the Indian Ocean and further away to the Pacific Ocean. In the Indian Ocean, non-breeding birds are found north of 50°S between subantarctic and subtropical waters with a significant proportion crossing the Indian Ocean to wintering grounds around the southern and eastern coast of Australia (Weimerskirch et al., 2006;Weimerskirch et al., 1985). The patterns of distribution of birds differ between adults from Crozet, which tend to spend a large part of the inter-nesting period in the western part of the southern Indian Ocean (Map 33), and adults from Kerguelen which migrate eastward to the Pacific, especially the waters east of New Zealand and the continental shelf along the Chilean coast, before returning to Kerguelen for a new breeding season (Map 34).



Map 33. *Wandering albatross, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds from Crozet Island during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Non breeding adults from Crozet tend to spend more time on the north of the southwest Indian ridge, between the Marion/Prince Edwards Islands, the Del Cano Rise and the Crozet Islands (Map 33). A significant part of the population spends a high amount of time around the Kerguelen Plateau. Few adults circumnavigate during the inter-nesting period and some visit the Tasman Sea.



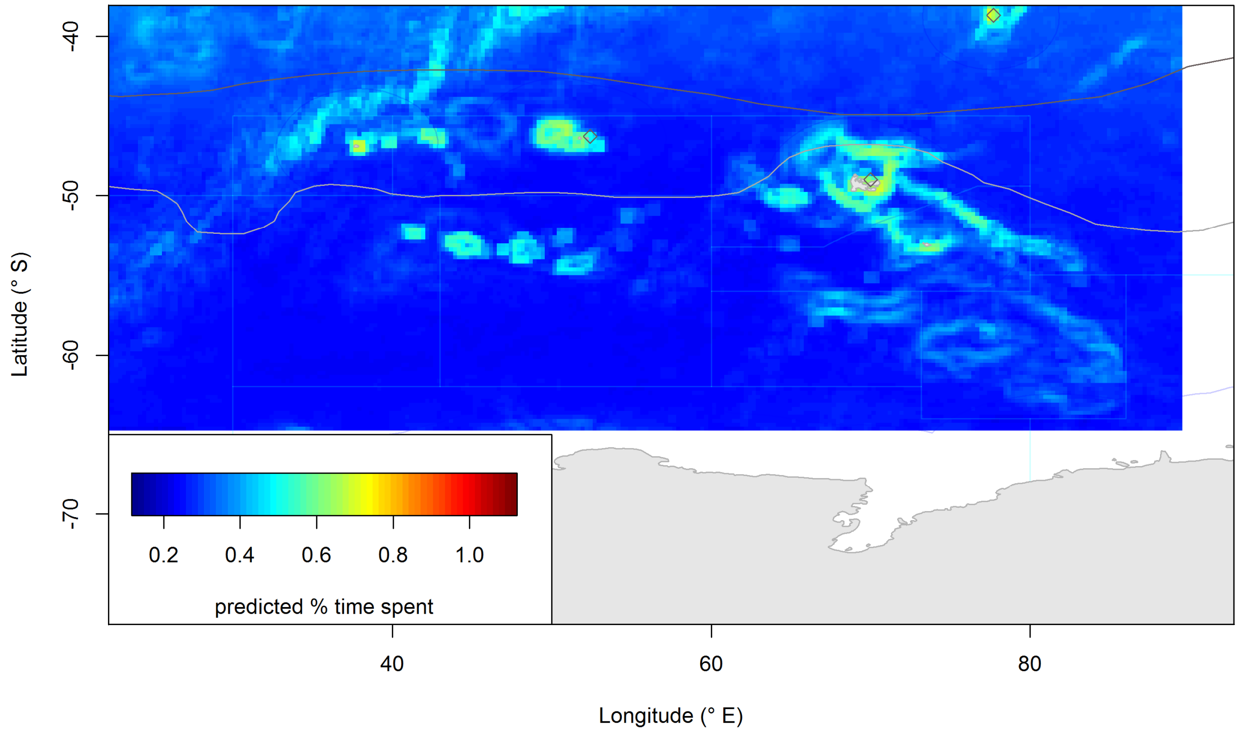
Map 34. *Wandering albatross, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds from Kerguelen Island during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The at-sea distribution of non-breeding adults from Kerguelen differs greatly from those of Crozet. Most birds circumnavigate Antarctica, departing from Kerguelen at the end of breeding period and migrating eastward using the dominant wind flow. Consequently, Kerguelen birds show high residence time over the Pacific and Atlantic, with most important areas off our area of interest in the *Atlas*. A small part of the population spends time north of the southwest Indian ridge, between the Marion/Prince Edwards Islands, the Del Cano Rise and the Crozet Islands and around the Kerguelen Plateau, in strong overlap with Crozet non breeding birds and Kerguelen breeding birds (Map 34).

Habitat selection modeling.

Breeding period

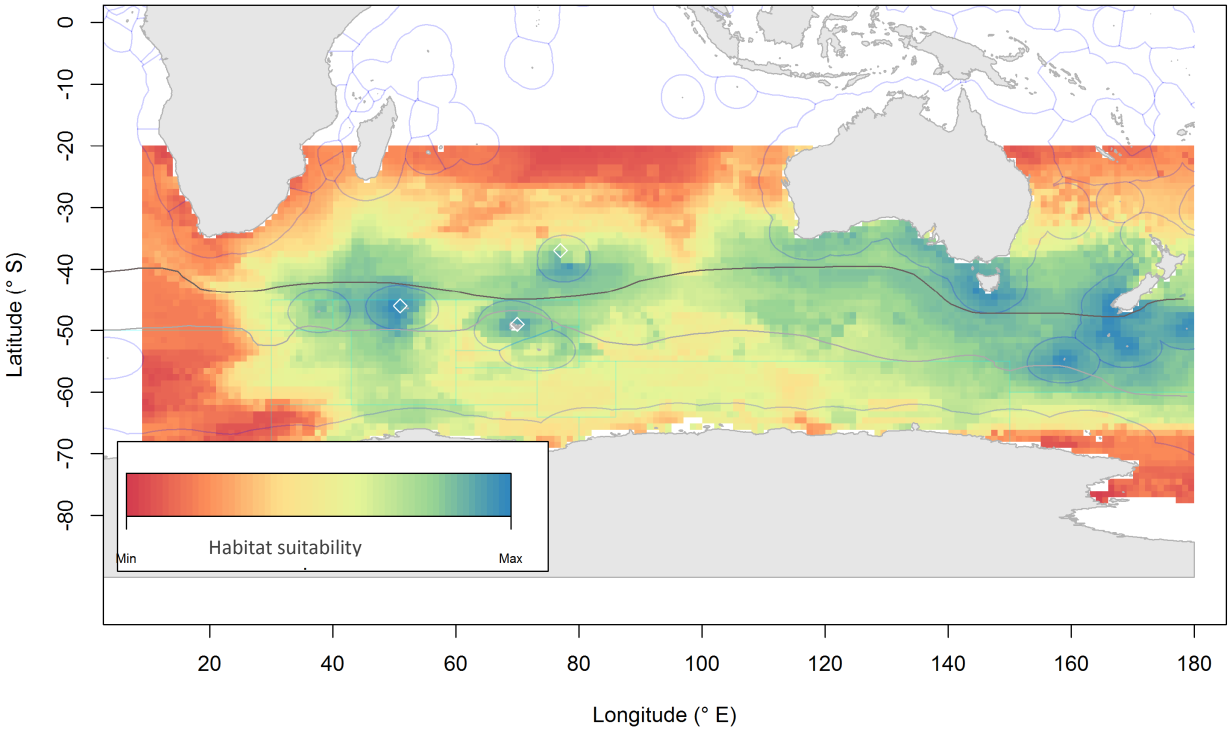
Predictive habitat models (Map 35; Annex I for detailed methodology) for breeding birds during incubation described *D. exulans* multi-scale habitat use as a hierarchical arrangement: albatrosses foraged preferentially over topographic features and in subtropical waters, whereas feeding occurred nested over the continental shelf and seamounts in areas of low oceanographic variability within the Polar Frontal Zone (Louzao et al., 2011). Thus the most favourable habitats for the species in the southern Indian Ocean are areas surrounding subantarctic oceanic breeding colonies, the Southwest Indian Ridge (N-NW sector of Crozet), and seamounts such as Del Cano Rise (between Crozet and Prince Edward Islands) and the seamount complex of Ob and Llena south of Crozet and Kerguelen. Those areas were consistently identified as important during incubation.



Map 35. *Wandering albatross*. Mean predictions of habitats models for time spent (Argos data; presence in each 1° cell) of adult birds from Crozet Island hierarchical modeling approach during the incubation period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown. From (Louzao et al., 2011)

Inter-nesting period

The observed track distributions (e.g. Map 33) show the geographic space directly utilized by the tracked birds. By building a statistical model (Annex I for detailed methodology) that discriminates the environmental characteristics of the actual tracks from those of the surrogate tracks, an indication of environmental conditions that are preferred by the birds was obtained. The model output gives an estimate of habitat suitability across the region, where “habitat suitability” is an indication of the expected habitat usage in relation to the range of habitat that is accessible to the birds.



Map 36. *Wandering albatross*. Habitat suitability predicted (geolocator data; presence in each 1° cell) by a boosted regression tree model of adult birds from Crozet Island during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown. (Collaboration. B. Raymond, Australian Antarctic Division, unpublished data)

The resulting estimated habitat utilization is shown in Map 36. The corresponding partial effects (environmental dependencies) fitted by the model are shown in Annex I, Figure 1. The most important predictors are SST and wind residual. The SST response (dropping off below ≈ 5 °C and above ≈ 20 °C) provides a broad latitudinal delineation of habitat. The wind residual has a strong response for negative wind residual values, indicating the birds' preference for areas that are most easily accessible when wind patterns are taken into account (i.e. downwind, or to the east of Kerguelen Island). The remaining predictors indicate preferences for areas relatively close to subantarctic islands and for areas covered by sea ice during less than 6 months, but no obvious dependence on water depth (bathymetry). The zones that appear as the most favorable are oceanic waters around the breeding grounds in the western Indian Ocean and in the New Zealand area. However, the mean predictive accuracy of the model was low indicating not particularly strong predictive performance.

Threats. According to ACAP (ACAP 2010b), the major threat affecting *D. exulans* (as with many other albatross and petrel species) is incidental mortality in long-line fishing operations. The growth of the southern bluefin tuna long-line fishery in the Southern Ocean until the mid 1980s and subsequent development of the Patagonian toothfish longline fishery coincided with the steady decline of *D. exulans* populations at Crozet, Kerguelen and Marion Islands (Nel et al., 2002b;Tuck et al., 2003;Weimerskirch et al., 1997a). Although the increased adult survival and upward trends in the Crozet population since the 1980s are thought to be related to the tuna fishery moving further away from the colony (Barbraud et al., 2012;Weimerskirch et al., 1997a), there is still a high degree of overlap with long-line fisheries in the region (BirdLife International, 2007), and recovery is hindered by low juvenile survival (Weimerskirch et al., 2006). Juvenile birds forage mainly in subtropical Indian

Ocean waters where the tuna long-line fishery has expanded in recent times (Weimerskirch et al., 2006).
D. exulans overlap with longline fisheries throughout the year and will be impacted by even low bycatch rates due to their small population size, but rates and risks of incidental mortality can be affected by seasonal variation in albatross distribution and fishing effort [93]. During late chick-rearing and the non-breeding period, Marion Island and Crozet populations overlap spatially within areas of intense tuna long-line fishing effort south of South Africa (Nel et al., 2002a) where bycatch rates are high (Huang and Liu, 2010b). Non breeding birds foraging in warmer waters show the highest spatial overlap with tuna fisheries (BirdLife International, 2007).
Outside the breeding season, birds from the Indian Ocean sector are also at risk from southern bluefin tuna long-line fishing operations off South Africa (shelf, shelf slope and adjacent oceanic areas) and in the Tasman Sea, off eastern and southern New Zealand, because of their circumpolar migrations (Brothers, 1991;Weimerskirch et al., 1997a).

Gaps & Stakes. Despite extensive and covering a long time period, the Wandering albatrosses database from Crozet and Kerguelen concerntwo sites only within each archipelago, Possession Island (Crozet), and the Courbet Peninsula at Kerguelen. The main gaps to be filled are the largest colony of the French Territories at Cochons Island (Crozet) and the large colony of the Rallier du Baty Peninsula (Kerguelen).
D. exulans is one of the most comprehensively studied albatross species. There is an urgent need to improve our understanding of the movements and distribution of birds during sabbatical periods in relation to long-line fisheries, especially in international subtropical waters where a large tuna fishery has recently expanded (Huang and Liu, 2010b;Weimerskirch et al., 2006). There is also a need to acquire information on the large populations for which no information exists on the at sea distribution.

Albatrosses/Black-browed albatross

Thalassarche melanophrys

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

Order Procellariiformes / Family Diomedeidae / Genus *Thalassarche* /Species *T. melanophrys*

Annual breeder

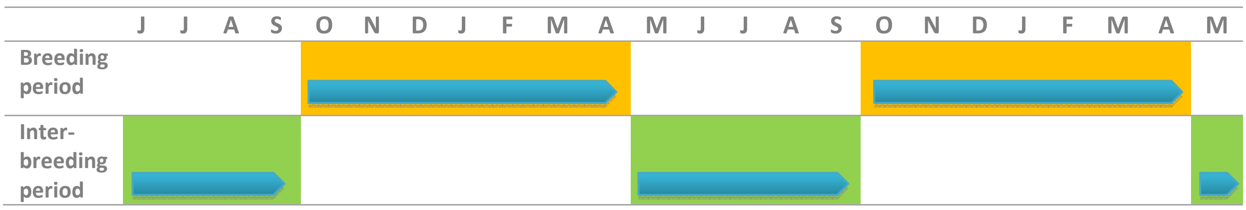
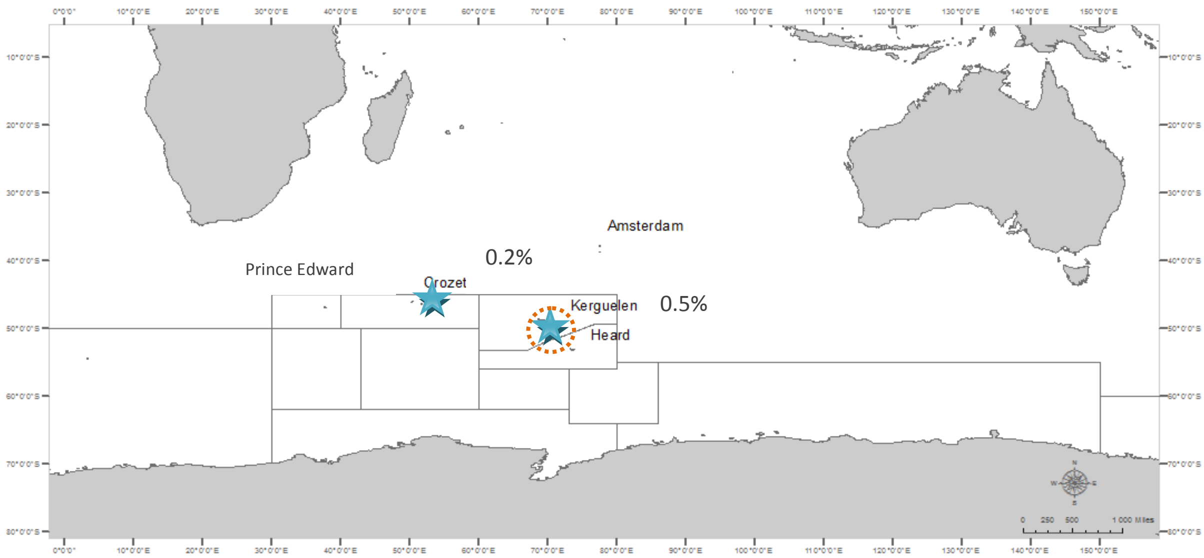


Table 15. *Breeding cycle and availability of tracking data (blue arrow) of* T. melanophrys

Regional Breeding Sites. The species is a colonial annual breeder. It breeds on seven subantarctic islands or archipelagoes - South Georgia, Crozet, Kerguelen, Heard and McDonald, Macquarie, Antipodes, and Campbell, as well as on the Falkland Islands (Islas Malvinas) and four island groups off southern Chile (ACAP 2010c). French Southern Territories hosts around 0.7% of the world population that is estimated to amount to 600 700 annual breeding pairs (Kerguelen: ≈ 3200 pairs, and Crozet: ≈ 980 pairs).



Population trends. The data available to establish population trends for *T. melanophrys* are limited due to a lack of regular surveys at most breeding sites. The large Falkland Islands population (c. 67% of world total breeding population) decreased at c. 1% per annum between 2000 and 2005, although trends are not consistent between years and sites. The Kerguelen population was stable or slightly increased between the early 1970s and early 2000s (Rolland et al., 2009b). There is no comprehensive and recent data concerning the Crozet population which breeds on rarely visited islands.

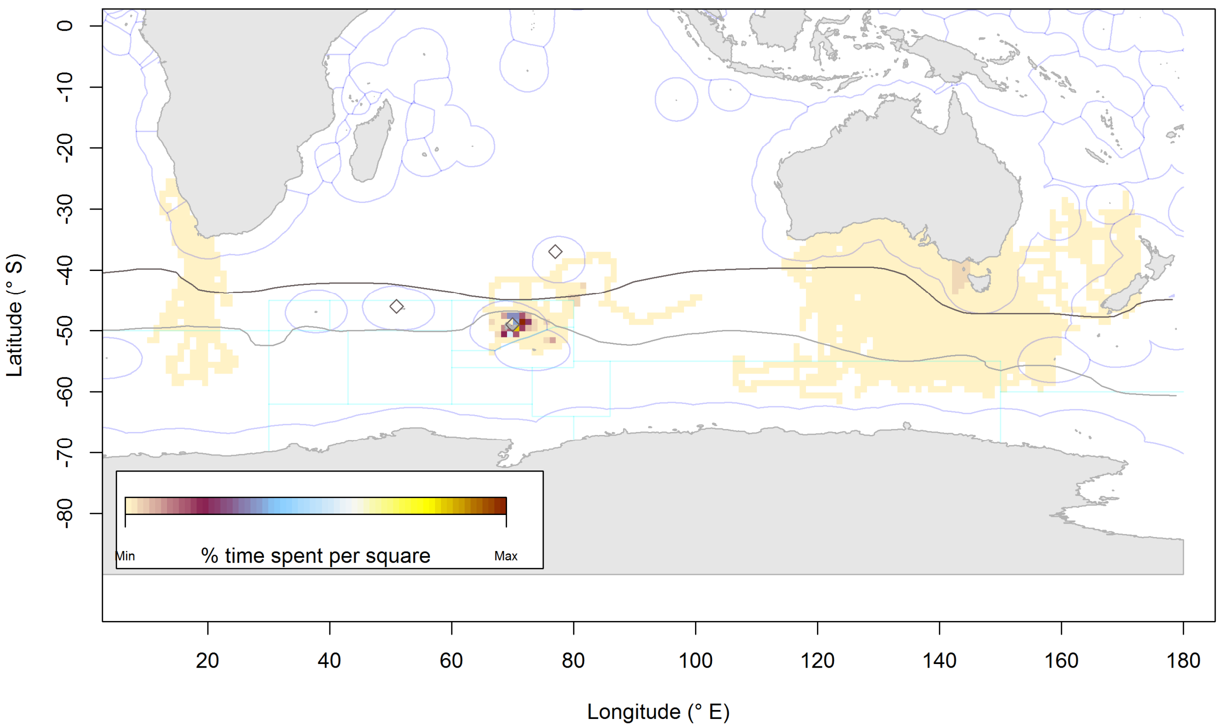
Diet and stable isotopes. Chick food at the study colony of Canyon des Sourcils Noirs (southeast of the Jeanne d'Arc Peninsula, Kerguelen) is consistently dominated by fish (73% by mass), with penguin carrion ranking second (14%) and cephalopods third (10%) (Cherel et al., 2000b). In 1994, birds from Iles Nuageuses (north of Kerguelen) fed more on cephalopods and less on fish (39% and 31%, respectively) (Cherel et al., 2002). Almost all the fish are neritic and slope species, which occur mainly as natural prey, but also as fishery-related items. The way albatrosses catch naturally those demersal organisms remains a mystery. The main penguin and squid prey are macaroni penguins and juvenile ommastrephids, respectively. When compared to other localities (Cherel and Klages, 1998), three main features characterize the food of black-browed albatrosses at Kerguelen Islands: the importance of (i) benthic fish and (ii) penguin carrion, together with (iii) the almost lack of crustaceans (<1% by mass).
The relatively high feather δ^{13}C values of chicks (Blévin et al., 2013) together with the abundance of beaks from benthic octopods in food samples (Cherel et al., 2000b;Cherel et al., 2002) are in agreement with parent birds foraging over the Kerguelen shelf and slope. The δ^{13}C and δ^{15}N values of

adult feathers indicate moulting in warmer waters of the subtropical zone where they feed at a high trophic level. Unlike most adults that are known to winter in southern Australia, one individual had a typical isotopic signature of the Benguela Current (Cherel et al., 2000a;Cherel et al., 2013).

Marine distribution. *T. melanophrys* has a circumpolar distribution, ranging from subtropical to polar waters, with the majority of breeding birds found in the subantarctic zone, and the majority of non-breeding birds occurring in subtropical as well as subantarctic waters. *T. melanophrys* tend to prefer shallow (<1000 m) waters but they also frequently forage over deeper waters in association with the Polar Front or other oceanic frontal systems (Petersen et al., 2008;Phillips et al., 2004b;Wood et al., 2000). Breeding birds from all major populations have been tracked but information is lacking for some breeding stages in most areas (Huin, 2002;Phillips et al., 2004b;Terauds et al., 2006).

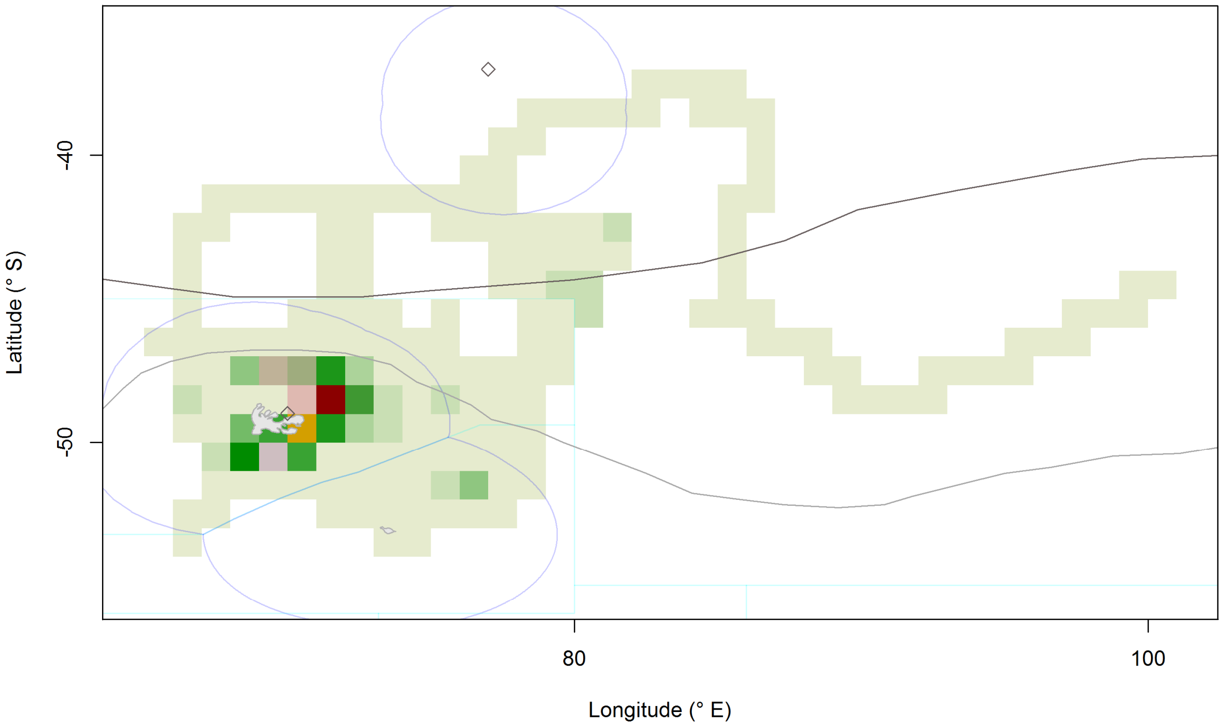
Important areas for Kerguelen birds

Tracking data are available for the colony situated at the southeast of the Jeanne d'Arc Peninsula. Tracking data reveal that breeding adults stay in subtropical as well as subantarctic waters, mainly north of the Polar Front (Map 37). Their residence time is highly skewed by the breeding colony, the highest values are observed on the Kerguelen Plateau in the French EEZ. During winter *T. melanophrys* from Kerguelen Island disperse from their colony and migrate in waters off southern Australia and in the Tasman Sea (Maps 37 & 39), with few birds migrating in the Benguela Current System, off South Africa coasts.



Map 37. ***Black-browed albatross, Kerguelen Island*****. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey

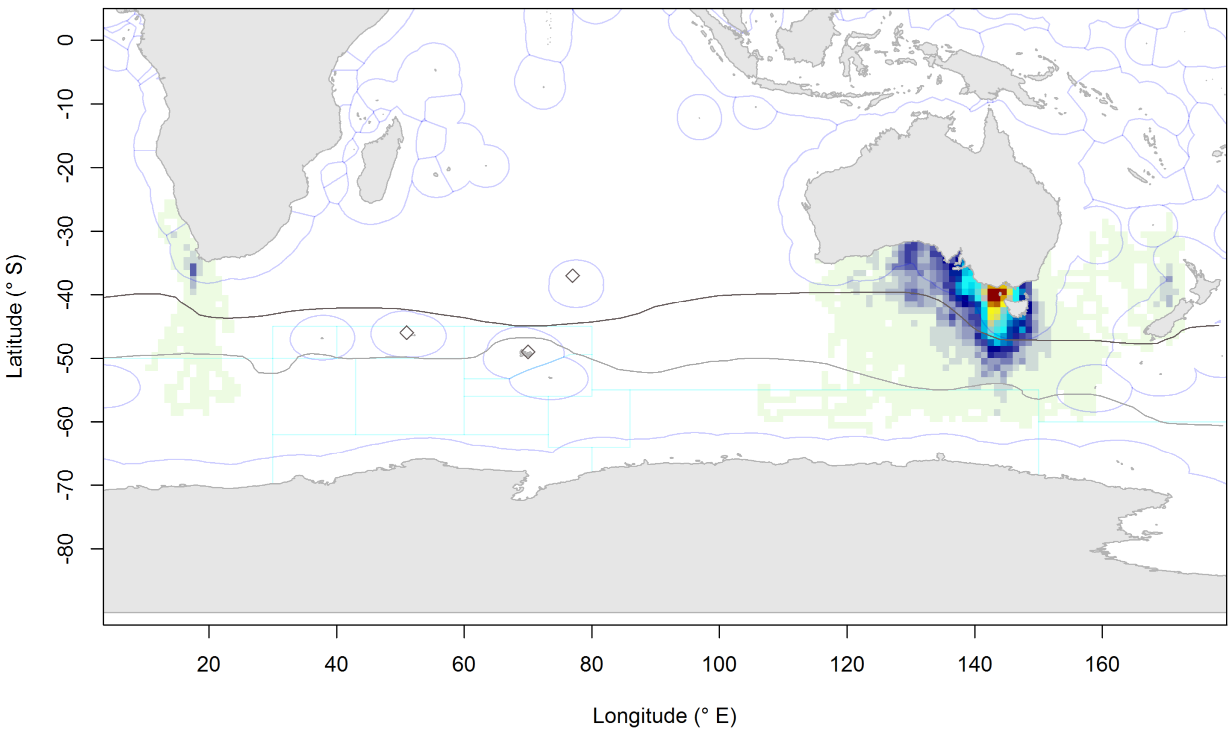
line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 38. ***Black-browed albatross, Kerguelen Island*****. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Throughout the breeding season breeding *T. melanophrys* tend to favor slopes to the east and south of the Kerguelen shelf, and in a lesser extent to the north, but also adjacent waters of the shelf and oceanic waters. These areas do not change extensively throughout the breeding season, except that after the thermal emancipation of the chick birds may forage a bit farther still (within c. 500 km) (unpublished data; (Pinaud and Weimerskirch, 2007;Weimerskirch et al., 1997c).

Earlier information on the distribution of two breeding colonies at Kerguelen (Jeanne d'Arc Peninsula and Iles Nuageuses) based on marked birds observed from fishing vessels indicated that the foraging zones of the two colonies overlapped little, with the Nuageuses birds foraging over the north and western slopes, whereas Jeanne d'Arc birds foraged mainly over the southern and eastern slopes, as confirmed later by tracking (Weimerskirch et al., 1988). Modelling of habitats of black browed albatrosses confirm the propensity of this species to favor shelf slopes during breeding (Wakefield et al., 2011).



Map 39. *Black-browed albatross, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Tracking data (using GLS) during the non-breeding period revealed that during winter *T. melanophrys* from Kerguelen Island leave rapidly the Kerguelen sector and migrate eastward in waters off southern Australia and as far as the Tasman Sea (Map 39), with few birds migrating westward to the Benguela Current System. The important areas during the non-breeding period are the southern Australian EEZ, particularly the waters surrounding Tasmania, but also the Great Australian Bight, where the highest values of residence time occur. The waters off southern Australia are not considered highly productive (Poloczanska et al., 2007;Ridgway and Condie, 2004). These areas of high residence time matches areas of locally enhanced productivity and known feeding aggregations of other species (Alderman et al., 2010), including yellow-nosed albatross (see above section), bluefin tuna *Thunnus thynnus* (Willis and Hobday, 2007) -in particular the Kangaroo Island Canyons, the Eyre Peninsula and Cape Mentelle upwellings, and meso-scale eddies along the shelf break (Ward et al., 2006).

Threats. According to ACAP (ACAP 2010c), the distribution of *T. melanophrys* overlaps with a number of major fisheries. Consequently this is one of the most common bycatch species in many fishery operations throughout its range (González-Zevallos and Yorio, 2006;Weimerskirch et al., 2000);(Bugoni et al., 2008;Neves and Olmos, 1998;Sullivan et al., 2004), including longliners targeting tuna *Thunnus spp.* off southern Africa (Ryan et al., 2002). In contrast, the fairly recent longline fishery for toothfish in the Kerguelen EEZ showed little overlap with foraging grounds (Cherel et al., 2000b) and with very low numbers caught (Delord et al., 2005;Delord et al., 2010b) in the early 2000's which did not appear to affect adult survival or breeding success (Rolland et al., 2008). Adult survival was however depressed as a result of the considerable longlining effort for tuna by Japanese and Taiwanese vessels around southern Australia between 1981 and 2004 (Rolland et al., 2008). Although longlining operations are known to present the main threat for black-browed albatrosses, interactions with trawl fisheries have been identified recently as another major source of mortality (Reid et al., 2004;Watkins et al., 2008). *T. melanophrys* is also killed in the deep-water hake (*Merluccius paradoxus* and *M. capensis*) trawl fishery in South African waters during winter, representing 37% of all birds killed at a rate of 0.30 individuals per 1000 hooks, with an estimate of at least 5000 *T. melanophrys* killed annually across this fleet (Watkins et al., 2008).

Gaps & Stakes. Further Information on the distribution of birds from different breeding colonies (Crozet Islands and Nuageuses Islands), at different stages of the annual cycle (especially during the migratory period) is required to better assess overlap with fishing operations.
While data on the distribution of breeding birds from all major breeding populations have been collected, there is a considerable lack of knowledge about the distribution of non-breeding birds. Given that the threats to this species are predominately sea-based, with large populations decreasing and the status of many populations unknown, there is an urgent need to better assess overlap with fishing operations and document levels of bycatch, so that programmes and mitigation measures can be targeted (Huang and Liu, 2010b).

Albatrosses/Indian yellow-nosed albatross

Thalassarche carteri

CRITICALLY ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED

@Y. Tremblay

TAXONOMY

Order Procellariiformes / Family Diomedeidae / Genus *Thalassarche*/Species *T.carteri*

Annual breeder

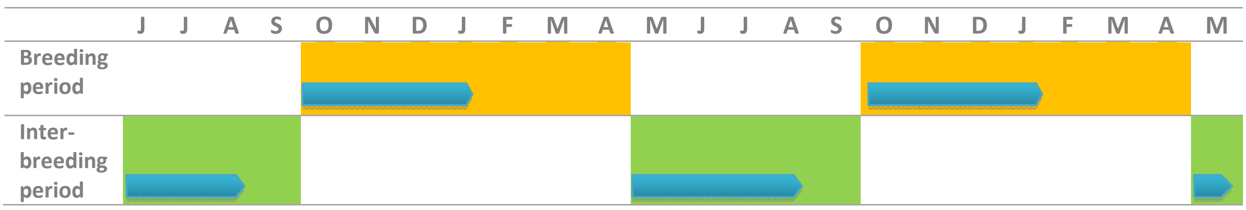
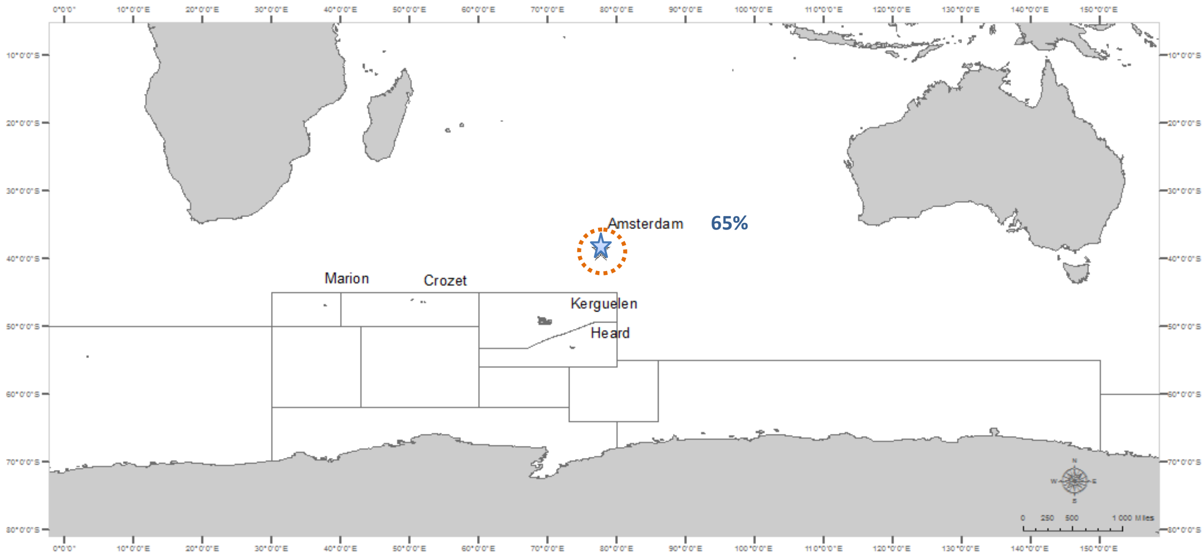


Table 16. *Breeding cycle and availability of tracking data (purple arrow) of* T.carteri

Regional Breeding Sites. *Thalassarche carteri* nests colonially and is an annual breeding species. *T. carteri* breed on the French subantarctic island groups of Amsterdam, St Paul, Crozet, and Kerguelen Islands and on South Africa's Prince Edward Islands (ACAP 2010d).



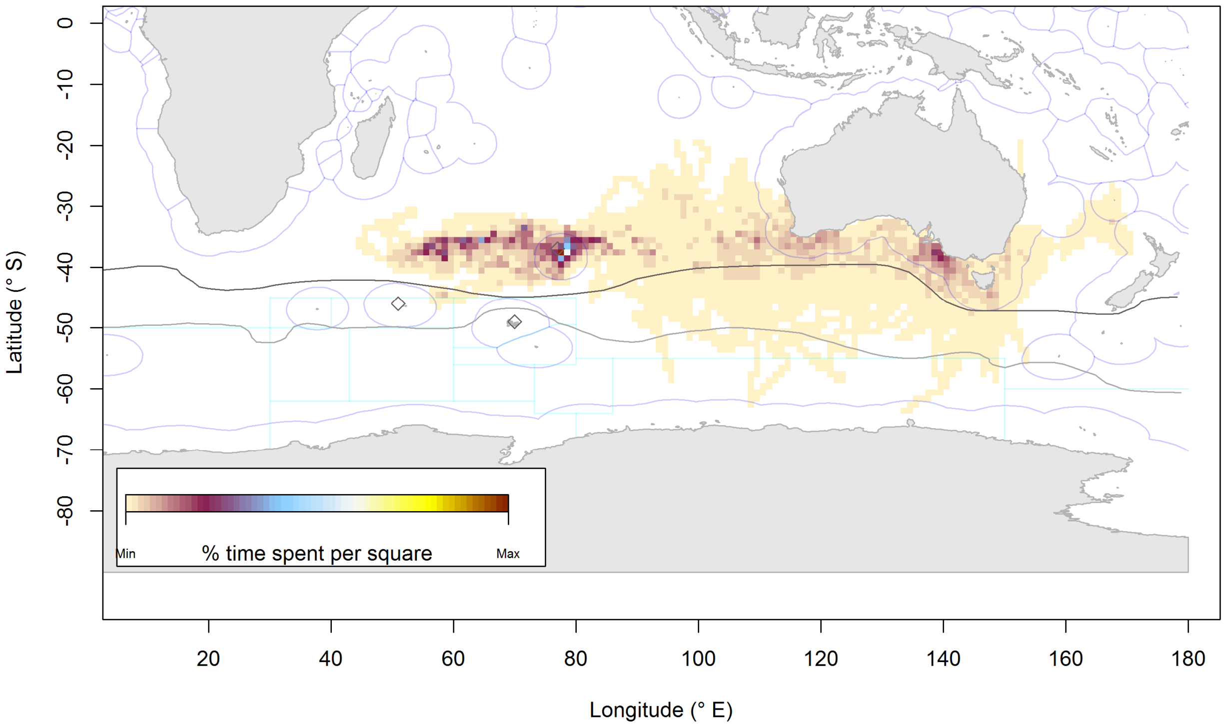
Almost 65% of the whole population occurs on Amsterdam Island. In 1998 the breeding population was estimated to be approximately 36 500 breeding pairs, corresponding to a total population of between 160 000 and 180 000 individuals (Gales, 1998).

Population trends. Of the six islands where *T. carteri* breed, only on Amsterdam Island have there been regular surveys of breeding pairs. These surveys mainly concerned designed demographic colony monitoring study plots of breeding birds within the colony at Entrecasteaux cliffs. At this site the number of breeding pairs has declined from over 250 pairs in 1978 to just 113 pairs in 2005 (Rolland et al., 2009a;Weimerskirch, 2004). Trend analyses indicate that this study population of *T. carteri* is decreasing at a rate of approximately 7.2% per year.
Between 1982 and 2006 the total population of *T. carteri* on Amsterdam Island is estimated to have decreased from 37 000 to 27 000 pairs (Rolland et al., 2009a).

Diet and stable isotopes. Chick food at Amsterdam Island is dominated by fish (81-92% by mass), with cephalopods accounting for most of the remaining prey (7-13%). Fish are mainly epi- and meso-pelagic species, with the two commonest items being the blue fathead *Cubiceps caeruleus* and the Atlantic saury *Scomberesox saurus*. Accumulated beaks highlight the importance of juvenile ommastrephids in the cephalopod part of the diet. The large mysid shrimp *Neognathophausia ingens* is the major crustacean prey (Pinaud et al., 2005), unpublished data).
Feather $\delta^{13}C$ and $\delta^{15}N$ values show that chicks are fed with prey caught in the subtropical zone, where the Indian yellow-nosed albatross occupies a high trophic position ((Jaeger et al., 2010a), unpublished data). The $\delta^{13}C$ values of adult feathers indicate moulting in subtropical waters (Cherel et al., 2013).

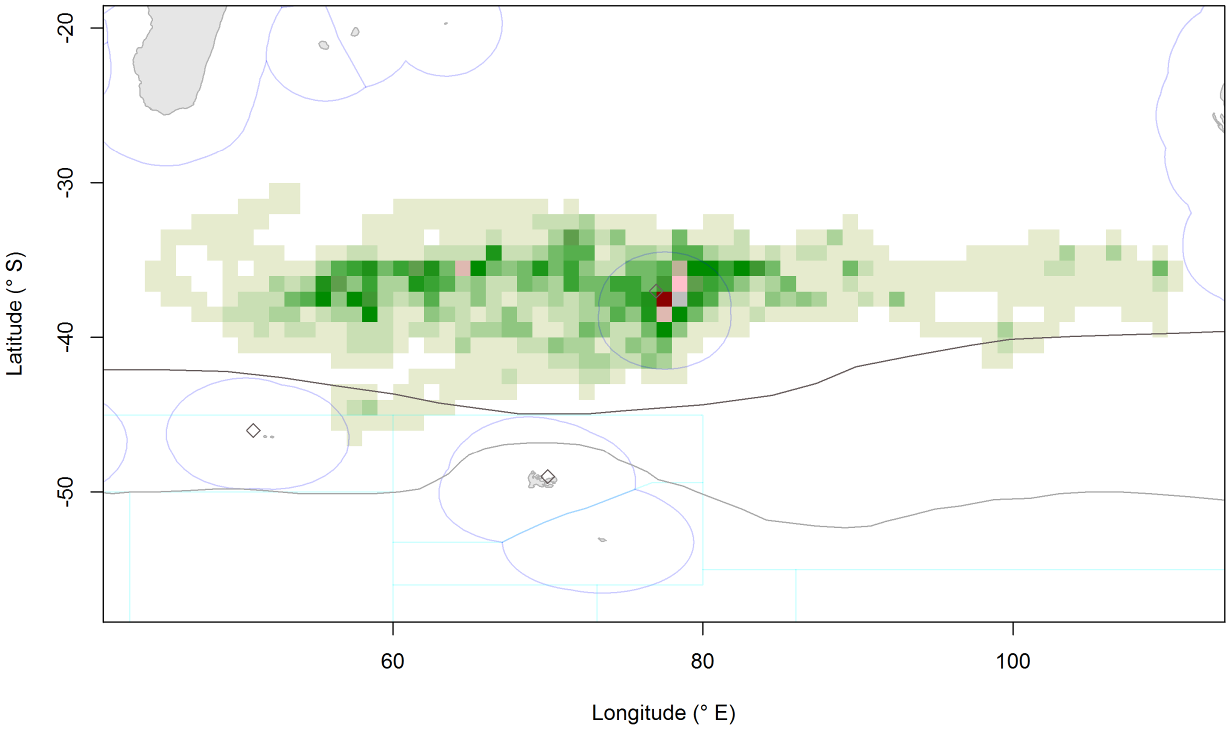
Marine distribution.
Important area

Tracking data reveal that adults favour subtropical waters whatever the period, north of the South Subtropical Front (Map 40).



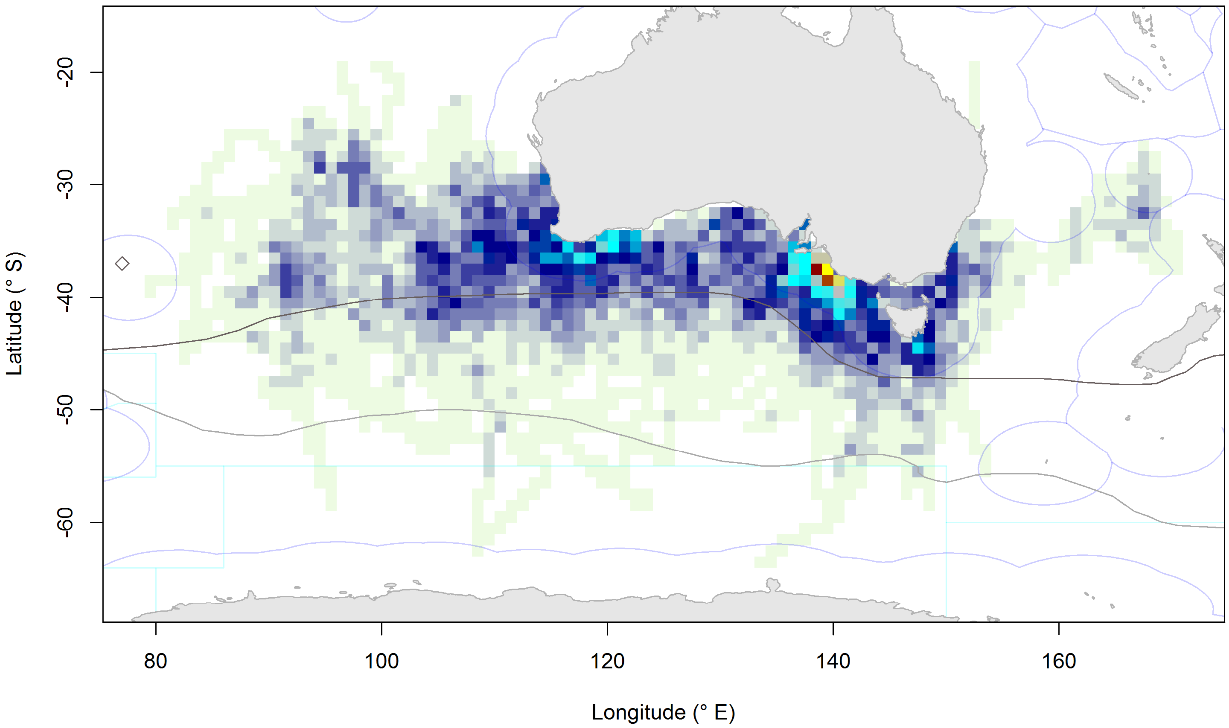
Map 40. *Yellow-nosed albatross, Amsterdam Island*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Satellite-tracking data during the breeding stage reveal that adults stay in subtropical waters, north of the South Subtropical Front (Map 41). Breeding birds forage as far as 1800 km of their nest sites during the breeding period, targeting strong eddies systems produced by the Agulhas return current (Pinaud et al., 2005;Pinaud and Weimerskirch, 2005;Pinaud and Weimerskirch, 2007). The highest residence times occur within the EEZ of Amsterdam Island and west of the colony.



Map 41. ***Yellow-nosed albatross*****. Amsterdam island Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Tracking data (using geolocators) during the non-breeding period revealed that during winter *T. carteri* from Amsterdam Island disperse from their breeding island and migrate in waters off southern and southwestern Australia, with a few birds entering the Tasman Sea (Map 42). The important areas during the non-breeding period are in the southern Australian EEZ, particularly the Great Australian Bight, where the highest values of residence time occur. The waters off southern Australia are not considered highly productive (Poloczanska et al., 2007;Ridgway and Condie, 2004). However, these areas of high residence time matches with areas of locally enhanced productivity and known feeding aggregations of other species (Alderman et al., 2010), including bluefin tuna *Thunnus thynnus* (Willis and Hobday, 2007) -in particular the Kangaroo Island Canyons, the Eyre Peninsula and Cape Mentelle upwellings, and meso-scale eddies along the shelf break (Ward et al., 2006).



Map 42. *Yellow-nosed albatross, Amsterdam Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

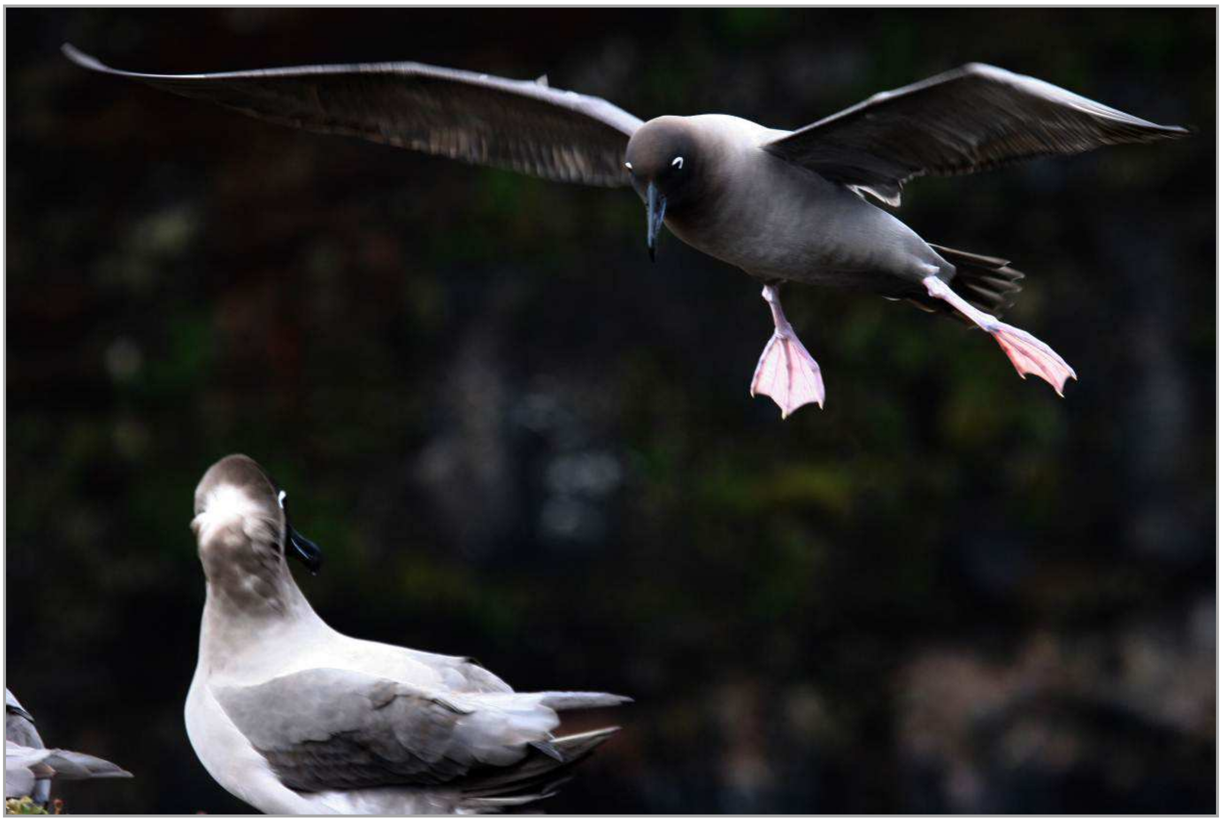
Threats. Amsterdam Island is the key breeding site for this species (65% of the world population). Therefore, threats impacting at this breeding site have the most significant impacts for the species overall. On Amsterdam Island the decline in *T. carteri* numbers is likely a result of the combined impacts of disease and interactions with longline fishing across their range. *T. carteri* overlap with fishing operations targeting tuna species in waters off West Australia, as well as in sub-tropical waters (Gales et al., 1998;Huang and Liu, 2010b;Rolland et al., 2009a;Weimerskirch and Jouventin, 1998), as well as diseases.
According to ACAP (ACAP 2010d), this species is known to be killed in longline fishing operations targeting Patagonian Toothfish *Dissostichus eleginoides* in the waters adjacent to the Prince Edward Islands (Ryan and Boix-Hinzen, 1999). Recently, incidental capture was reported on tuna longline fishing (Huang and Liu, 2010a) and on demersal longline off the east coast of the lower North Island, New Zealand (New Zealand Department of Conservation, unpublished).

Gaps & Stakes. Further information on the distribution of birds of different breeding colony sites (particularly the Crozet Islands breeding colonies), at different stages of the annual cycle (especially different migratory periods) is required to better assess the distribution of the species and its overlap with fishing operations.

Albatrosses/Light-mantled albatross

Phoebetria palpebrata

CRITICALLY ENDANGERED | ENDANGERED | VULNERABLE | NEAR THREATENED | LEAST CONCERN | NOT LISTED



@G. Dorémus

TAXONOMY

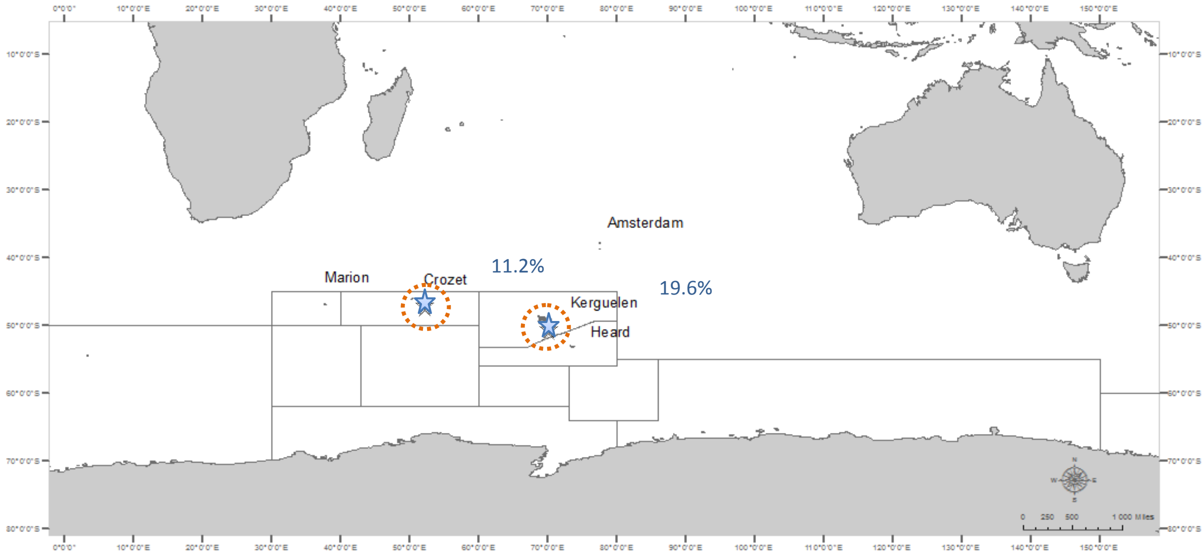
Order Procellariiformes / Family Diomedeidae / Genus *Phoebetria* /Species *P.palpebrata*

Biennial breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 17. *Breeding cycle and availability of tracking data (blue arrow) of* P.palpebrata

Regional Breeding Sites. *Phoebetria palpebrata* nest solitarily or in small groups, building pedestal nests along sheltered vegetated cliff edges. This species is considered a biennial breeder when successful, although unsuccessful breeders may breed the following year with an average 59% success rate (Jouventin and Weimerskirch, 1988).



P. palpebrata breeds on Heard and Macquarie Islands (Australia), South Georgia, Prince Edward and Marion Islands (South Africa), Kerguelen and Crozet Islands (France), and Auckland, Campbell and Antipodes Islands (New Zealand; ACAP 2010e). Counts tend to be inaccurate at some sites, given difficulties in detecting nests in inaccessible terrain and scanning from a distance. In 1998, the global population was estimated to be about 21,600 breeding pairs on 14 islands or approximately 140,000 individual birds (Gales, 1998). However, the only estimates considered to be of medium or high accuracy are for Possession Island (Crozet), Marion, Prince Edward and Macquarie Islands (ACAP 2010e).

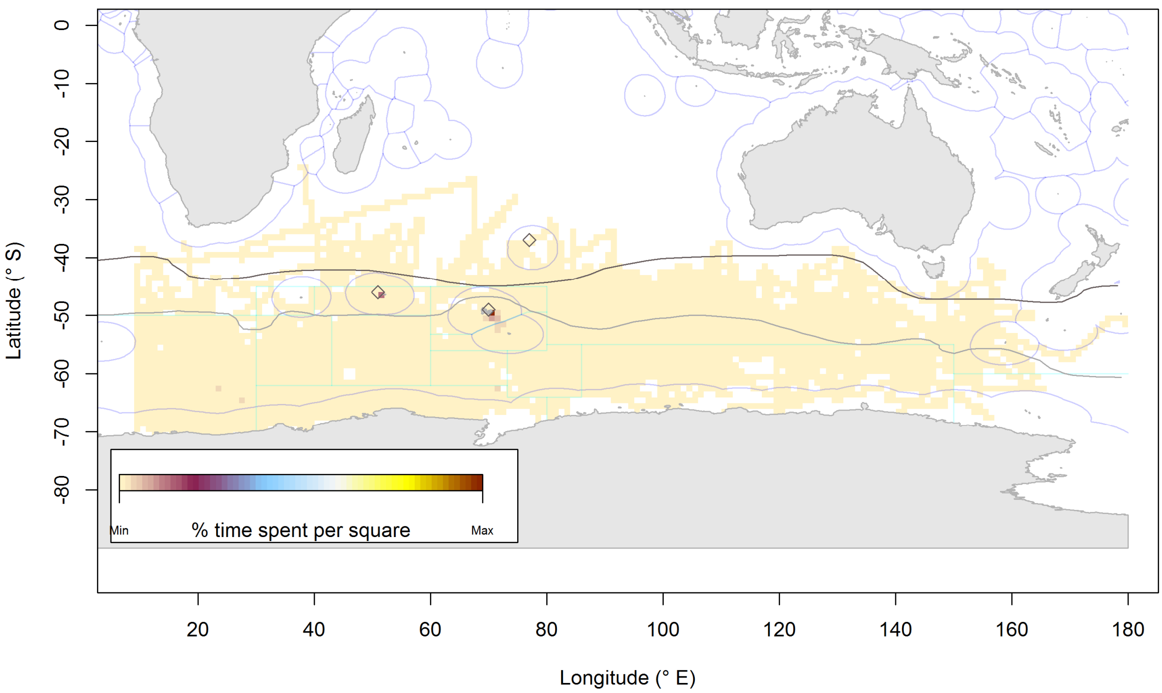
Population trends. Little information is available to determine population trends for *P. palpebrata*. Between 1980 and 2005, the breeding population on Possession Island (Crozet) increased by 1.1% per year or about 49% in total (Delord et al., 2008). The population appeared stable between 1980 and 1999 before increasing at an annual rate of 6.8% from 1999 to 2005 (Delord et al., 2008). However, interannual variation in numbers is high, such that a decrease of 1.7% per year between 1980 and 1995 was reported in an earlier study (Weimerskirch and Jouventin, 1998). The at-sea abundance of this species in Prydz Bay of East Antarctica is reported to have decreased significantly since between 1980 and 1981 (Woehler et al., 2001). Reported declines at these and other locations were considered to be the result of incidental mortality associated with fisheries (Gales, 1998), particularly during the non-breeding season (Weimerskirch and Jouventin, 1998).

Diet and stable isotopes. Chick food at Crozet is dominated by cephalopods (56% by mass), with carrion and crustaceans ranking second (16-17%) and fish fourth (11%) (Ridoux, 1994). The chick diet was not investigated at Kerguelen Islands, but collection of regurgitated casts allowed determining cephalopod prey (unpublished data). At both Crozet and Kerguelen Islands, light-mantled sooty albatrosses feed on oceanic squids, with the most abundant species being the cranchiid *Galiteuthis glacialis*. The ommastrephid *Martialia hyadesi* is also an important dietary item at Kerguelen Islands. The regular occurrence of beaks of *Psychroteuthis glacialis* (Crozet and Kerguelen) together with the

presence of Antarctic krill *Euphausia superba* in food samples (Crozet) indicate foraging at least in part in high-Antarctic waters during the breeding period.
Feather isotopic ratios are similar for birds from Crozet and Kerguelen Islands. Chick $\delta^{13}C$ values are intermediate between those from subantarctic and Antarctic organisms, thus suggesting adults forage in the two zones during the chick-rearing period. The $\delta^{13}C$ values of adult feathers indicate moulting over a wide latitudinal range, from the subtropics to Antarctica, with a focus on subantarctic waters. The light-mantled sooty albatross is the only albatross species that moult in part in high-Antarctic waters where it feeds on low trophic level prey, most likely Antarctic krill (Blévin et al., 2013;Cherel et al., 2013;Jaeger et al., 2010a).

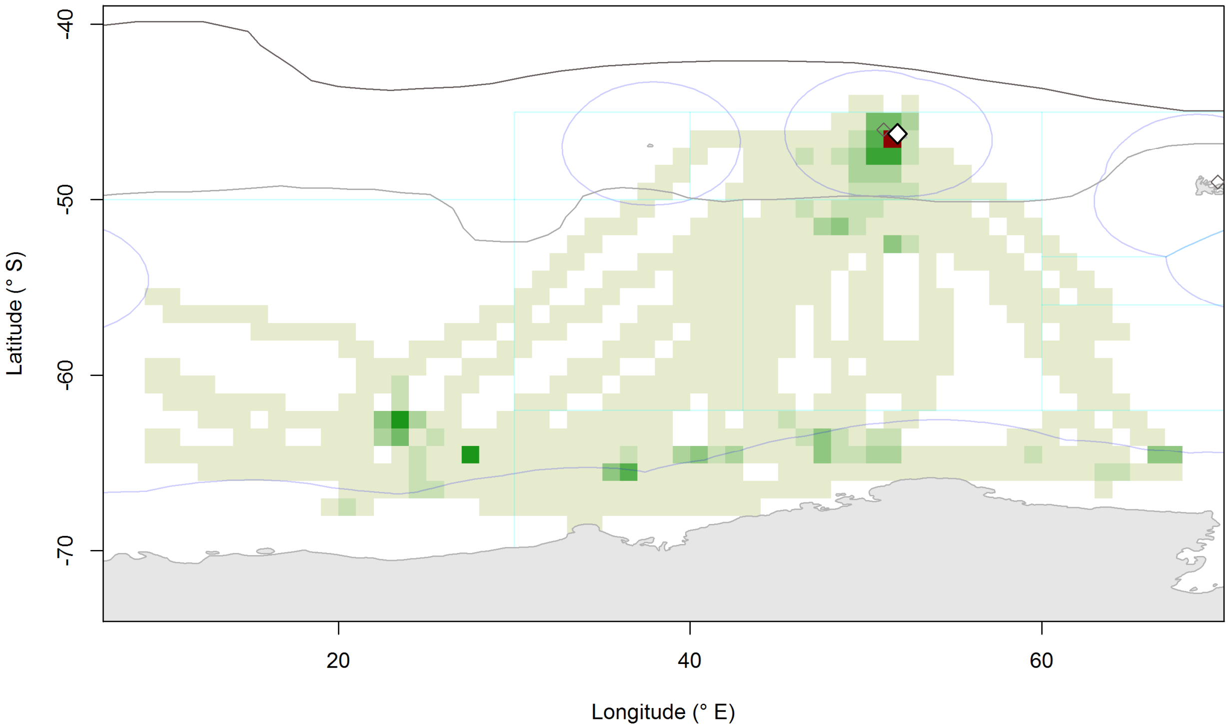
Marine distribution. *Phoebetria palpebrata* have a circumpolar distribution over the Southern Ocean and exhibit the most southerly distribution of all the albatross species. Although common between 40°S and 60°S, they disperse as far south as pack ice and 77°S in the Ross Sea (Weimerskirch et al., 1986).

Important areas

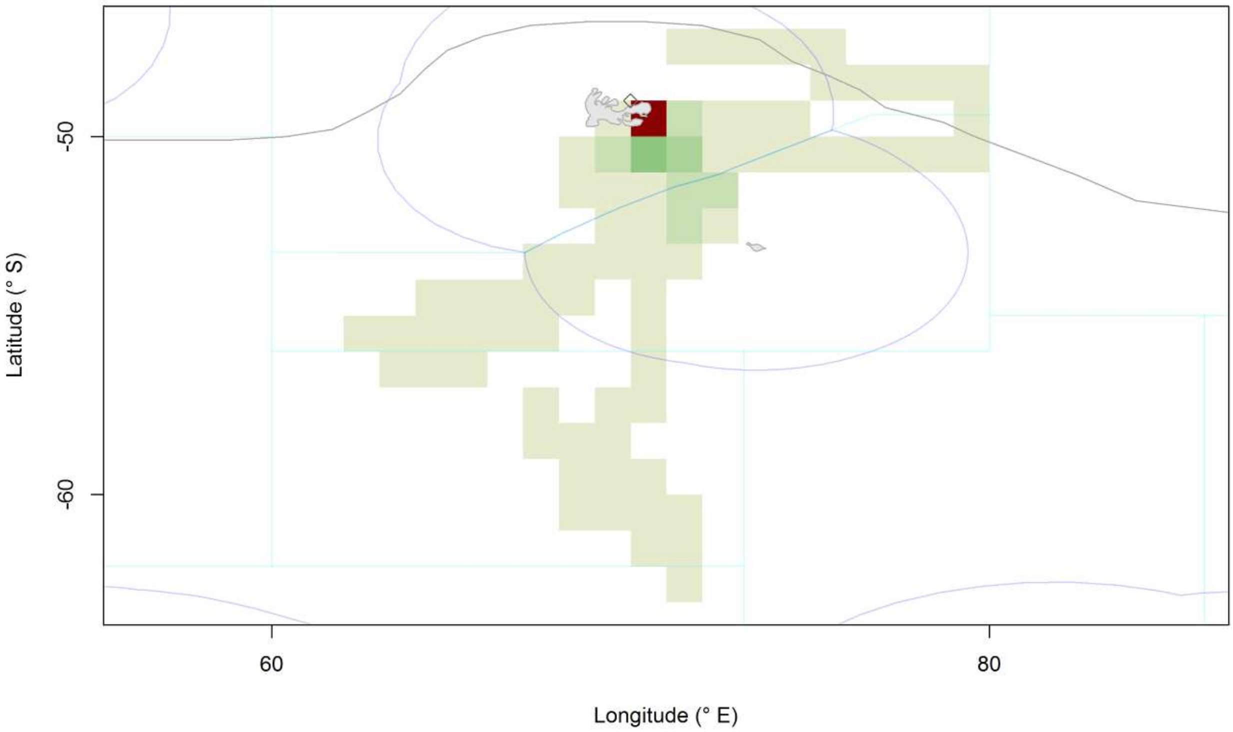


Map 43. *Light-mantled albatross,* Crozet Islands and Kerguelen Island. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Based on satellite-tracking data, breeding birds from Crozet and Kerguelen Islands forage in the surrounding shelf waters as well as into subantarctic and Antarctic areas (Maps 44 & 45). Breeding birds from Crozet Islands forage in subantarctic waters during incubation and in Antarctic waters during chick-rearing (unpublished data). Satellite-tracked birds revealed that birds tend to fly directly to Antarctic and subantarctic foraging sites assisted by prevailing winds (Marchant and Higgins, 1990;Weimerskirch, 1998). Consequently, important residence times occur in Antarctic waters and in the French EEZ of Crozet and Kerguelen during breeding period.



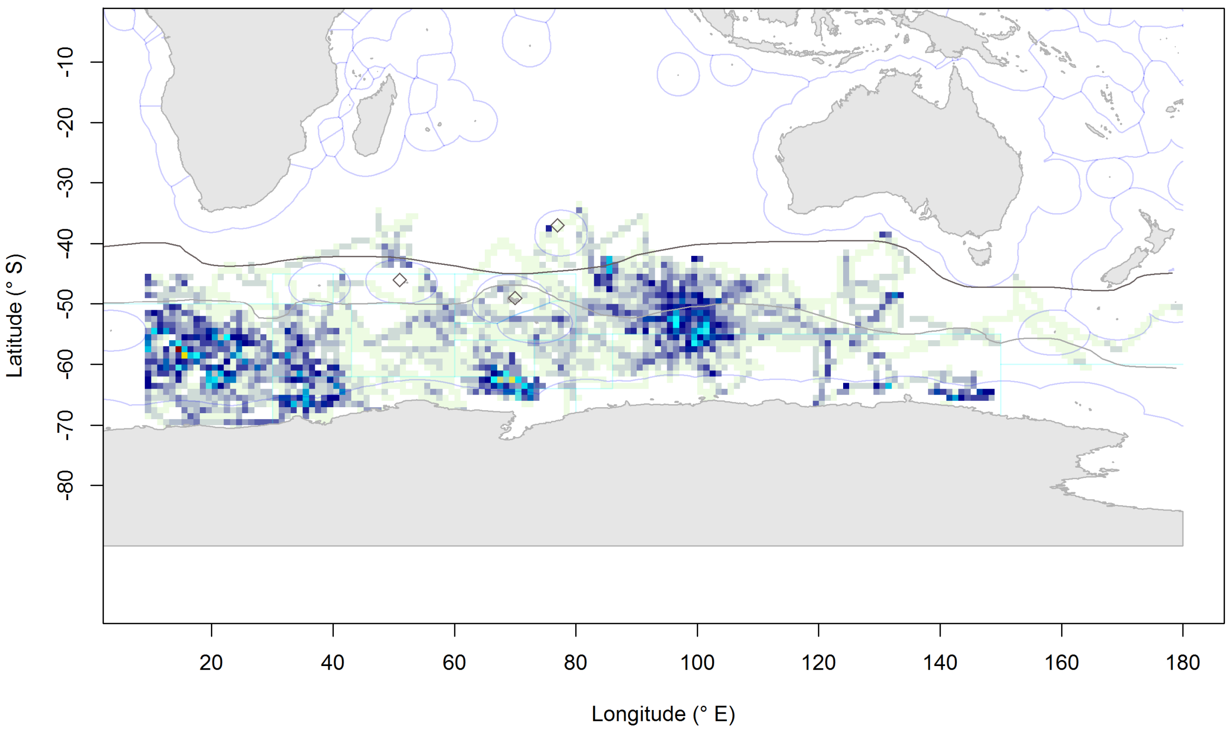
Map 44. *Light-mantled albatrosss, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



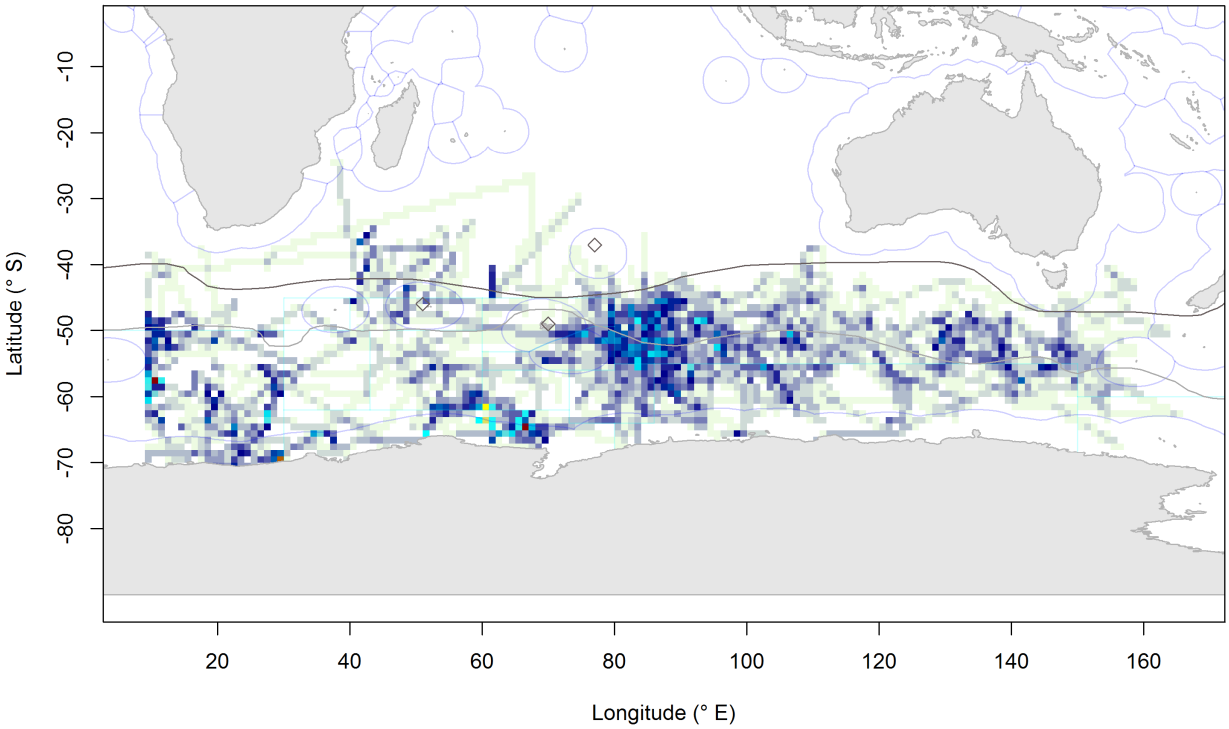
Map 45. *Light-mantled albatross, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structure is shown: the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During inter-nesting period (including moulting period) the birds spend a large amount of time in subantarctic and Antarctic waters (Maps 46 & 47). They tend to aggregate on the east part of southern Indian Ocean (south and north of the southwest Indian Ocean ridge, eastward of Bouvetøya Island), in the Prydz Bay area (East Antarctica). Important area appears also outside the area of interest in the southern East Atlantic Ocean (East of Bouvetøya Island).

Some of these area are already known to be important for seabirds, namely *P. palpebrata*, especially the area of Prydz Bay (60°E – 90°E) (Woehler, 1997a;Woehler et al., 2003) and the area west of Prydz Bay (30°E – 80°E) (Woehler et al., 2010).



Map 46. *Light-mantled albatross, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 47. *Light-mantled albatross, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. According to ACAP (ACAP 2010e), the primary threat to *P. palpebrata* is mortality associated with fisheries, specially longlining (Gales, 1993;Gales, 1998). While less inclined to following fishing vessels than most other albatrosses, their diving capabilities allow them larger access to baited hooks than most albatross species (Gales, 1998). Breeding birds travel to Antarctic waters to forage (Weimerskirch et al., 1986); however, these birds tend to move northward during the nonbreeding period, particularly in the eastern part of southern Indian Ocean, and consequently come under threat as bycatch (Gales, 1998;Weimerskirch and Jouventin, 1998). *P. palpebrata* represented 6% of total seabird bycatch from tuna longliners 1988-1997 in the New Zealand EEZ, whereas "*small numbers*" were reported caught in the Australian EEZ (Taylor, 2000). An estimated ≈ 4 000 *P. palpebrata* were caught annually in the Southern Ocean by the Japanese longline industry based on the number of hooks set between 1981 and 1986 (Schulz and Amey, 2004). Plastics were cited as present in stomach contents and pellets of this species in an earlier review, but extent and recent impact are unknown (Cherel and Klages, 1998).

Gaps & Stakes. More information is needed on movements of adults breeding at Crozet Islands and Kerguelen Islands, particularly during the incubation period and late chick rearing period, the non-breeding period and migratory period. Given the threats to this species are predominately sea-based, there is a need to better assess overlap with fishing operations and document levels of bycatch, so that programmes and mitigation measures can be targeted (Huang and Liu, 2010b).

Albatrosses/Sooty albatross

Phoebetria fusca

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@G. Dorémus

TAXONOMY

Order Procellariiformes / Family Diomedeidae / Genus *Phoebetria* /Species *P.fusca*

Biennial breeder

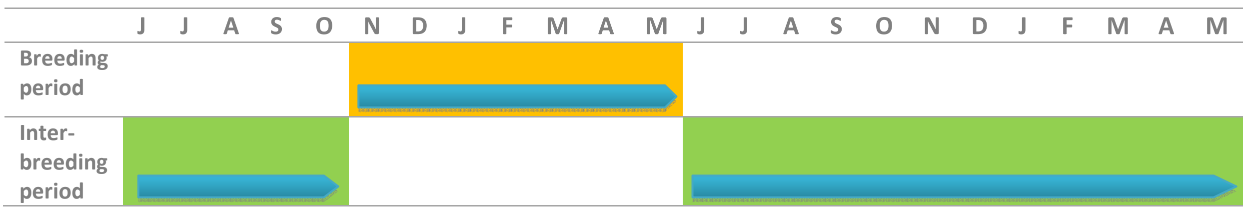
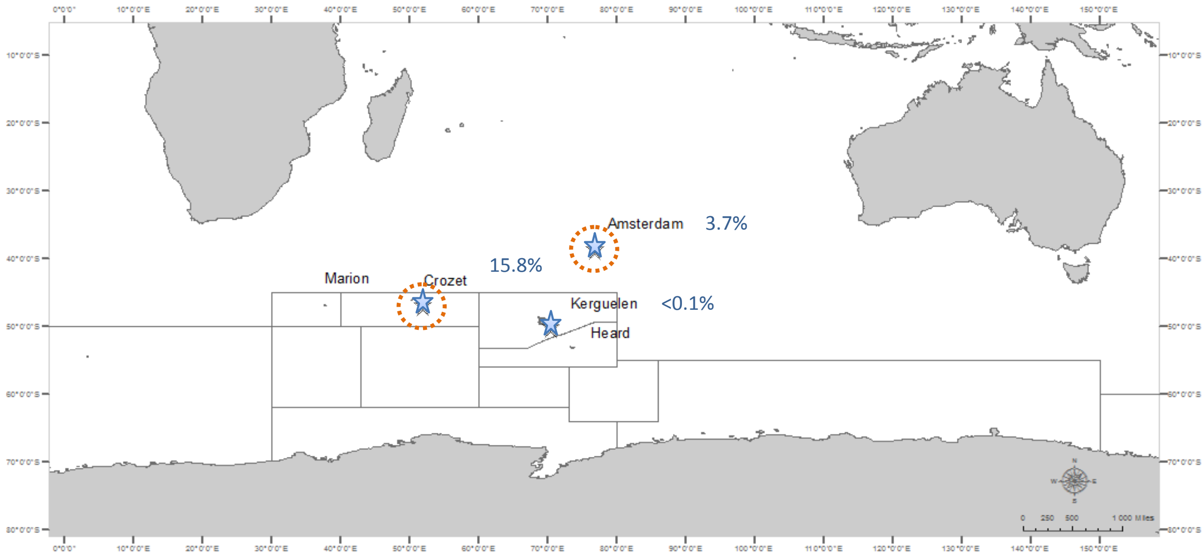


Table 18. *Breeding cycle and availability of tracking data (blue arrow) of* P.fusca

Regional Breeding Sites. *Phoebetria fusca* is a biennial breeder and lays a single egg with no replacement laying. This species nests solitarily or in small colonies or clusters, building pedestal nests along sheltered cliff edges (Berruti, 1979;Weimerskirch et al., 1986).



P. fusca breeds on Prince Edward and Marion Islands (South Africa), Kerguelen Islands, Crozet Islands, Amsterdam and Saint Paul Islands (France), as well as Gough and Tristan da Cunha Islands (United Kingdom) which are thought to hold over 60% of the global population (ACAP 2010f).
In the late 1990's, the global population was estimated to be about 15 655 breeding pairs on 15 islands or approximately 100 000 individual birds (Gales, 1998).

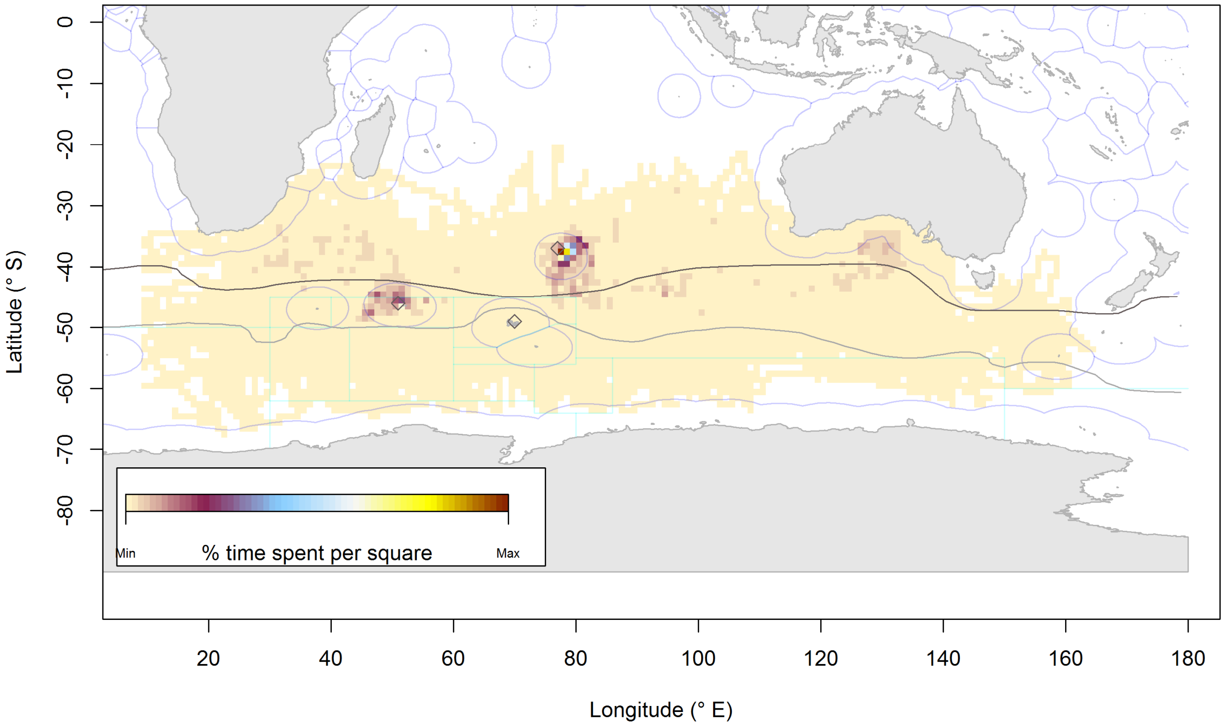
Population trends. Partial information is available to determine population trends for *P. fusca*, but declines have been reported at all sites where repeated surveys have been carried out. On Possession Island (Crozet), the breeding population declined by 58% between 1980 and 1995 (Weimerskirch and Jouventin, 1998) and by 82% between 1980 and 2006 at an average rate of 4.2% per year (Delord et al., 2008).
These drastic decreases are the result of low survival of adult and immature birds (Jouventin et al., 1984), supposed to be caused by at-sea mortality associated with fisheries, mainly longline fishing vessels (Delord et al., 2008;Gales, 1998;Huang and Liu, 2010b;Weimerskirch and Jouventin, 1998).

Diet and stable isotopes. Preliminary analysis shows that chick food at Amsterdam Island is dominated by fish (63% by mass), with cephalopods ranking second (37%) (unpublished data). In contrast, bird carrion amounts to a major part of the chick diet at Crozet (51% by mass), followed by cephalopods (41%) and fish (5%). Bird carrion includes crested penguins (*Eudyptes* sp.) and prions (*Pachyptila* sp.) (Ridoux, 1994). Fish, squid and crustacean prey are pelagic organisms, mainly from the oceanic domain (unpublished data).
Feather δ^{13}C and δ^{15}N values show that adults from Amsterdam and Crozet Islands caught prey for their chicks in subantarctic and subtropical waters, respectively, and this can be related to the different oceanographic locations of the two breeding sites (Jaeger et al., 2010a), unpublished data).
In contrast to the breeding period, feather δ^{13}C values indicate that adults from both Amsterdam and Crozet Islands moult in oceanic subtropical waters, but with population-related differences in the main foraging zones (Cherel et al., 2013).

Marine distribution.

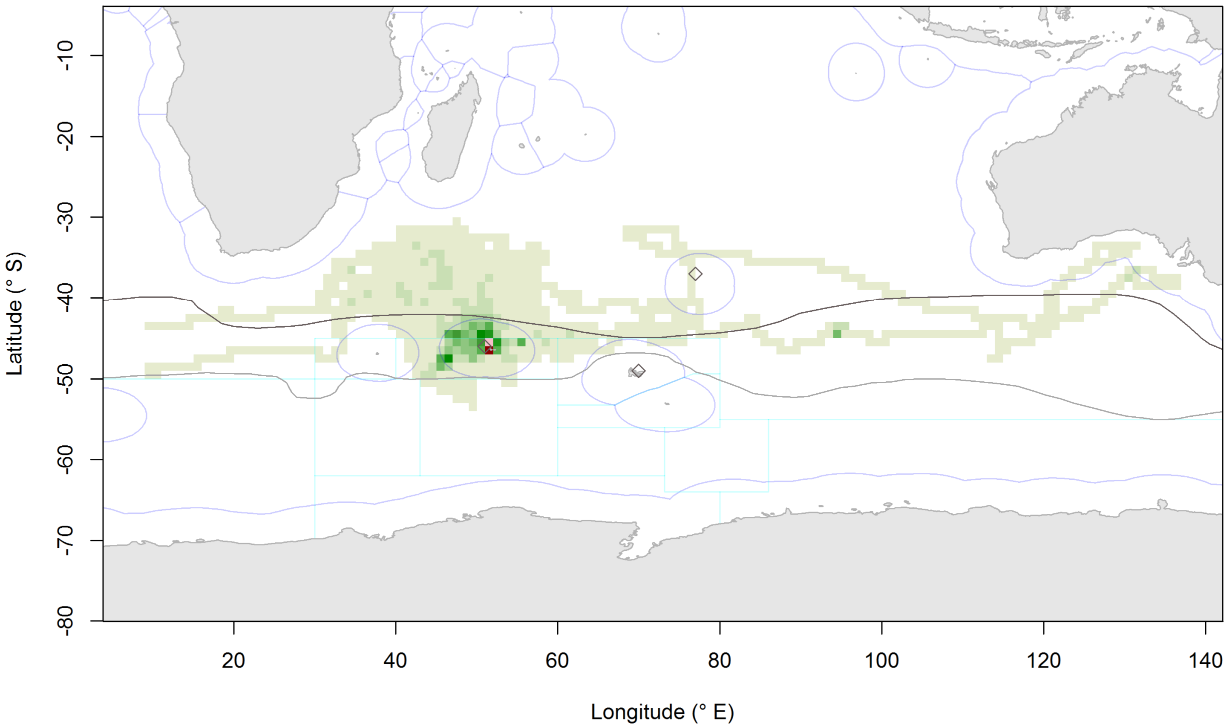
Important areas

Compared to his sibling species (*P. palpebrata*), *P. fusca* exhibits more northern distribution, foraging over subtropical and subantarctic waters (Map 48). The pelagic distribution is mainly between 30°S and 60°S in the southern Indian and Atlantic Oceans, with a southern limit of c. 65°S near Antarctica and a northern limit of c. 20°S (Berruti, 1979;Weimerskirch et al., 1986).
For the Crozet and Amsterdam birds, the higher residence time occurs around the breeding colonies (French EEZs of Crozet Island and Amsterdam Island). Relatively high values of residence time are also found north of southeast Indian Ocean ridge and in the Great Australian Bight during the inter-nesting period.

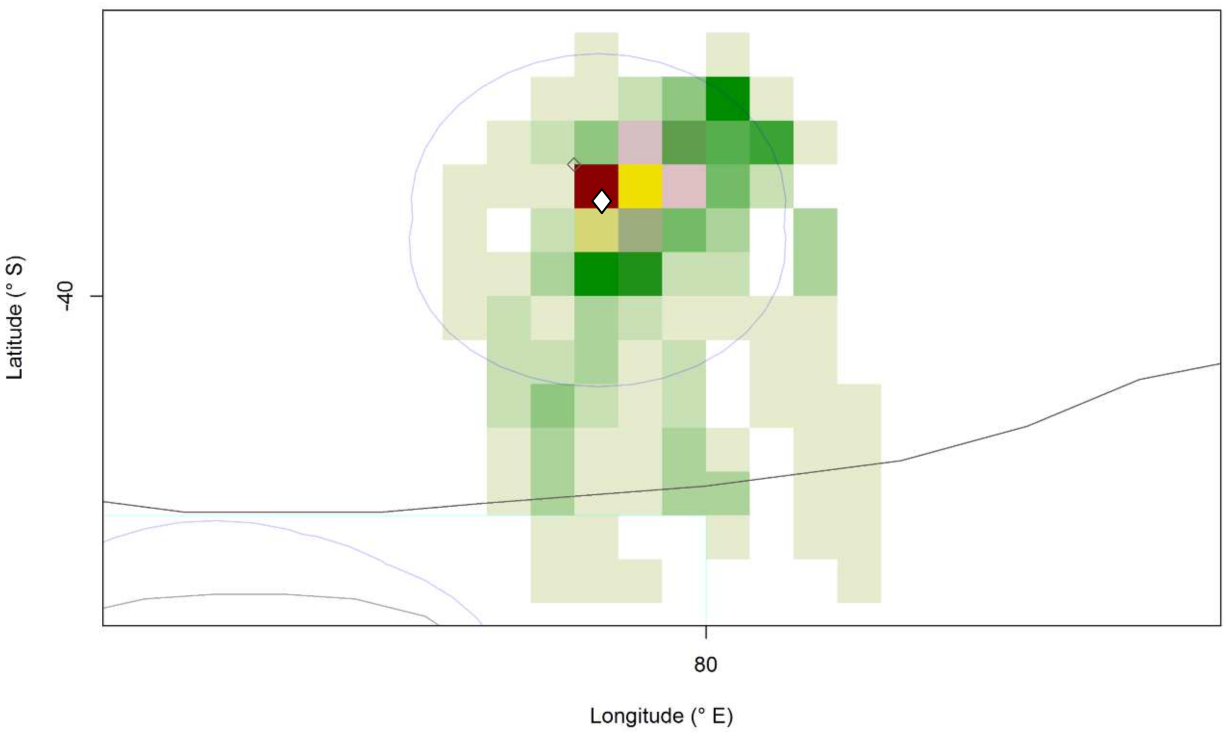


Map 48. *Sooty albatross*, Crozet and Amsterdam Islands. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding period the residence times are highly influenced by location of breeding colonies and are mainly distributed around the Crozet and Amsterdam Islands in the French EEZs (Maps 49 & 50). Birds from Crozet tend also to distribute in subtropical waters, on the southwest Indian Ocean, on the north of the spreading ridge flank of the southwest Indian ridge (Map 49).



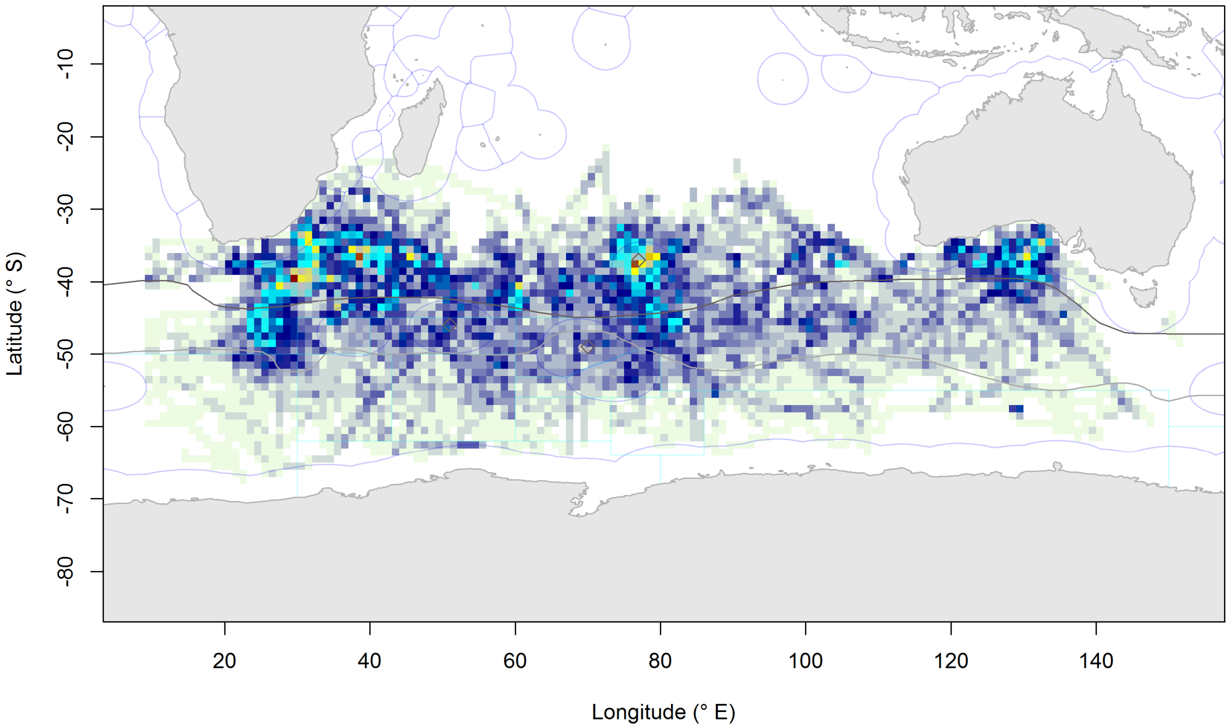
Map 49. ***Sooty albatross, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



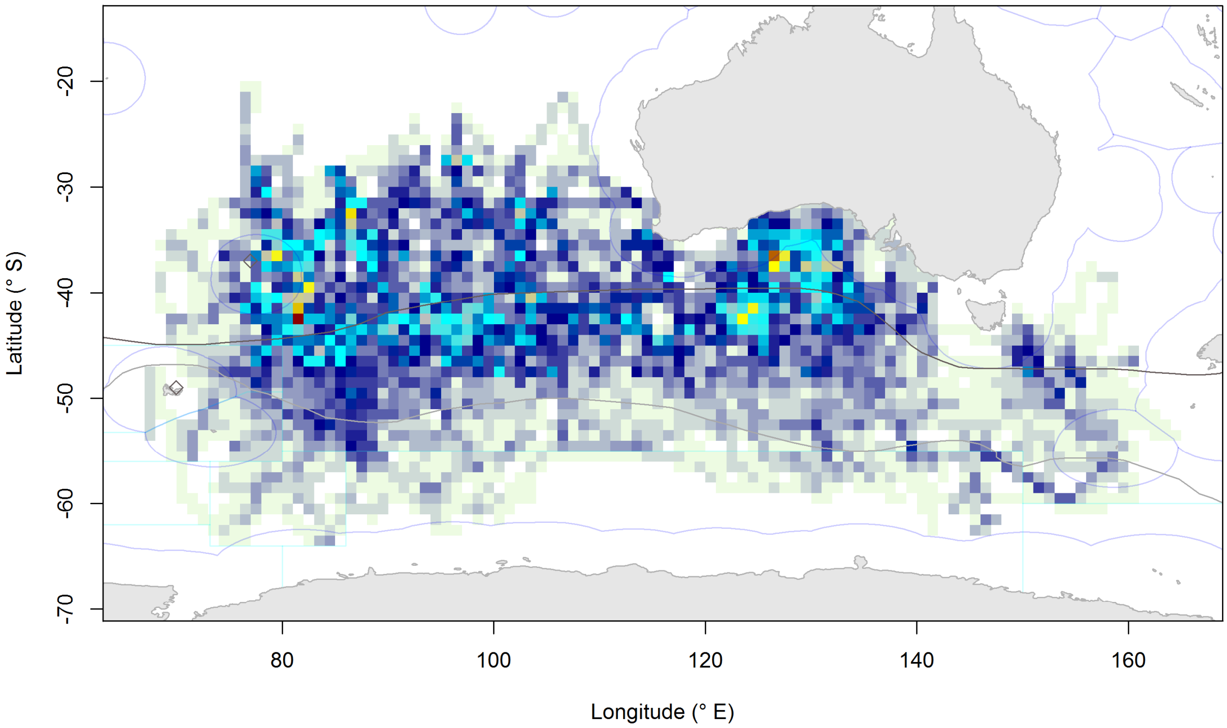
Map 50. ***Sooty albatross, Amsterdam Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Oceanographic frontal structures is shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003).

Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Adults move north in winter from subantarctic to subtropical seas (Weimerskirch and Guionnet, 2002), whereas immature birds tend to remain in subtropical waters year round (Stahl, 1987). Adults tend to disperse throughout the Indian Ocean during the inter-nesting period whatever the colony (Crozet Island or Amsterdam Island; Maps 51 & 52). Nonetheless, birds from Crozet Island tend to disperse in the southwestern Indian Ocean and in the vicinity of Amsterdam Island, while birds from Amsterdam Island distribute more easterly, to the north in subtropical waters and in the Great Australian Bight, where high residence times are observed.



Map 51. *Sooty albatross, Crozet* I*sland.* Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 52. *Sooty albatross. Amsterdam Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. According to ACAP (ACAP 2010f), **t**he major threat to *P. fusca* is mortality associated with fisheries, particularly longlining, and is likely to be the reason driving population decreases (Delord et al., 2008;Gales, 1998;Weimerskirch and Jouventin, 1998). An estimated maximum of 161 *P. fusca* per year was caught by the Japanese tuna fleet in the Australian Fishing Zone during 1989-1995 (Gales et al., 1998). However, because of the pelagic nature of this species, it can be suspected that proportionally higher numbers are killed on the high seas than in EEZ fisheries (Gales, 1998;Huang and Liu, 2010b). These birds forage in subtropical seas frequented by Asian longline fishing vessels and accordingly come under threat as bycatch (Huang and Liu, 2010b;Yeh et al., 2013). Lack of band returns indicate reflects a lack of observers in these feeding areas rather than a low mortality rate (Delord et al., 2008;Weimerskirch and Jouventin, 1998). However, the first documented band recovery of this species was reported from a Taiwanese longline vessel (Delord et al., 2008). Some plastic debris were detected present in stomach contents and pellets (Cherel and Klages, 1998).

Gaps & Stakes. Given the strong population decline observed at several colonies, more information is urgently required on movements and foraging distribution of adults, chiefly during the breeding period for birds breeding on Amsterdam Island, but also during the non-breeding period, as well as the extent of overlap with fisheries together with estimates of incidental mortality rates.

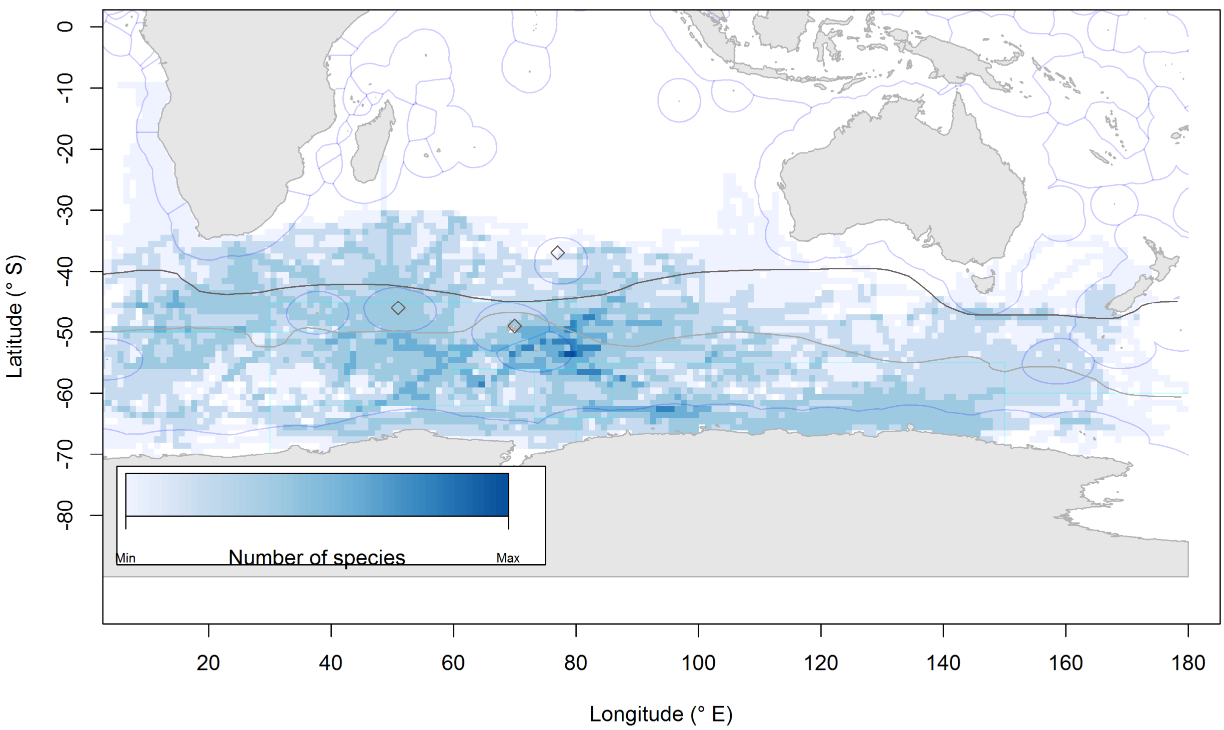
PETRELS

Petrels of French Southern Territories in the southern Indian Ocean

The southern Indian Ocean is commonly used by at least 23 petrel species of which 11 large petrel species – heavier than 200 g (cf Table 1), and visited less frequently by other seven or so species. A total of 21 species breed in the French Territories and most of these suffer from crucial lack of distribution data for adults during and/or outside the breeding period.

The Atlas focuses on seven species breeding in the French Southern Territories or Adélie Land (Antarctica), for which the available tracking data showed they forage within the southern Indian Ocean: the Northern giant (*M. halli*), Southern giant (*Macronected giganteus*), Grey (*Procellaria cinerea*), White-chinned (*P. aequinoctialis*), Snow (*Pagodroma nivea*) and Cape (*Daption capense*) petrels and the Southern fulmar (*Fulmarus glacialoides*). The Northern and Southern giant petrels and the Grey petrel breed in the area and are resident year-round in the southern Indian Ocean. The other species such as the White-chinned, Snow and Cape petrels and Southern fulmar, breed on some islands or colony sites, but they migrate throughout the Southern Ocean.

The breeding populations of several of these species are undocumented or in decline and are included on the IUCN Red List as threatened species (Table4; Vulnerable) as a main consequence of incidental mortality in trawl and longline fisheries.



Map 53. Specific diversity of petrels. Observed cumulated *Presence* distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds for 7 species of petrels (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line;

SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Petrels/Southern giant petrel

Macronectes giganteus

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@JB .Thiebot

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Macronectes* /Species *M. giganteus*

Annual breeder

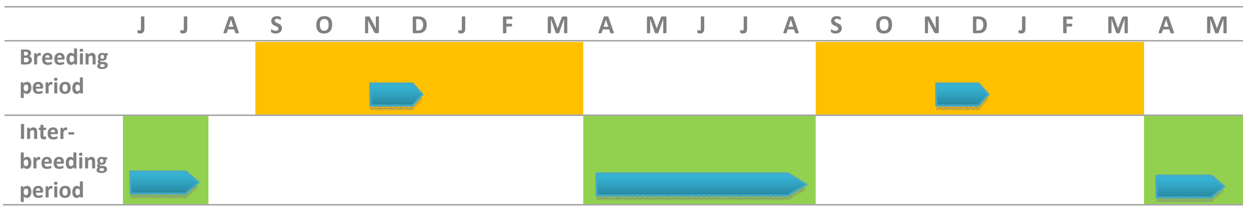
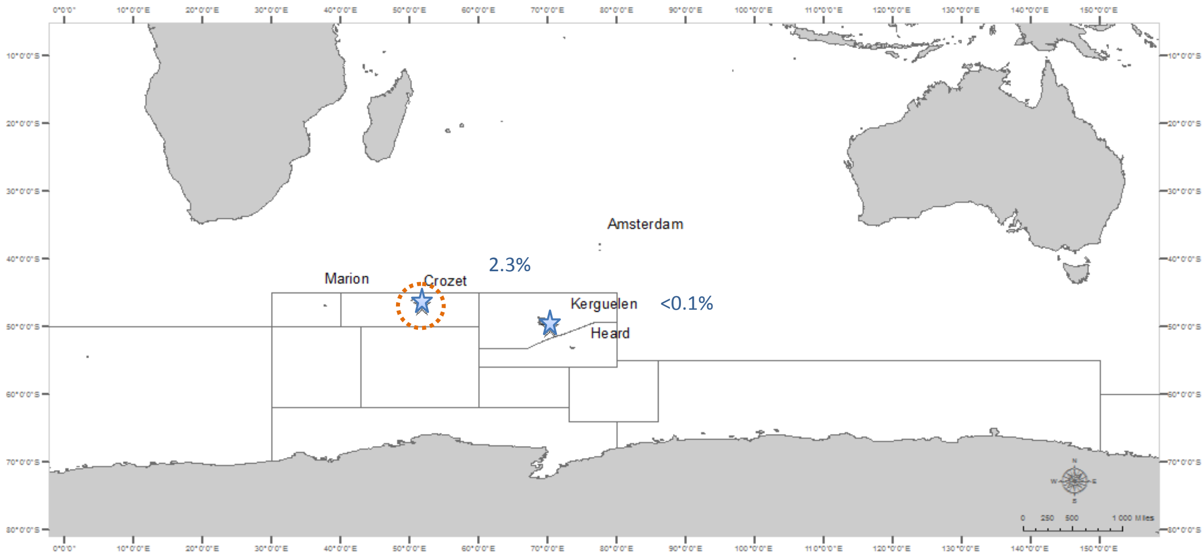


Table 19. *Breeding cycle and availability of tracking data (blue arrow) of* M. giganteus

Regional Breeding Sites. *Macronectes giganteus* breeds annually in loose colonies. Colonies of *M. giganteus* occur on 10 oceanic islands or island groups between 40°S and 60°S, six islands off South America, four locations in East Antarctica, and numerous sites on the Antarctic Peninsula (ACAP 2010g).

It is currently difficult to estimate the sizes of the breeding populations of *M. giganteus* at some locations for numerous reasons, including small and widely dispersed colonies, and an extensive part of the breeding population absent in any one year as birds can take years off from breeding. The latest assessment estimated a total of 46 800 breeding pairs equivalent to approximately 100 000 mature individuals, with about 40% of the global breeding population found on the Falkland Islands (ACAP 2010g, BirdLife International 2012).
The three island groups in the Indian Ocean sector (Prince Edward, Crozet and Kerguelen) account for approximately 7% of the global population ((Delord et al., 2008;Derenne et al., 1976;Jouventin et al., 1984;Weimerskirch et al., 1989). Approximately 1 100 pairs, or 2% of the total population, breed on Crozet Islands with a few tens of pairs breeding on Kerguelen Islands.



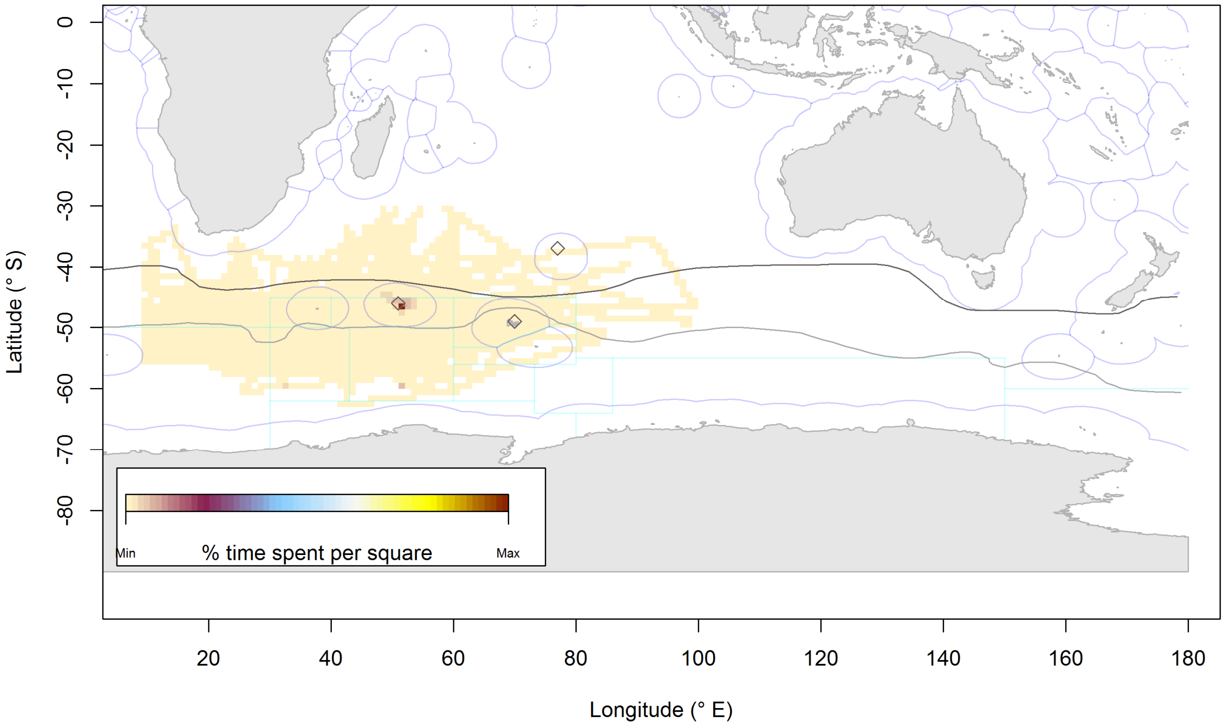
Population trends. The population on Possession Island (Crozet) increased at an average rate of 9.2% per year during 1999-2004, following a period of stable population between 1980 and 1999 (Delord et al., 2008).

Diet and stable isotopes.
Chick food at Crozet Islands includes mainly bird carrion (89% by mass) complemented by other marine organisms. Penguins are by far the major dietary items (84%), followed by small Procellariiforms (5%) (Ridoux, 1994). Field observations show giant petrels feeding on birds and pinnipeds on land, and on fishery bycatch and offal at sea (Delord et al., 2005;Le Bohec et al., 2003;Ridoux, 1994).
Feather $\delta^{13}C$ and $\delta^{15}N$ values indicate that chicks are fed mainly with subantarctic prey and that the species occupies a high trophic position, respectively (unpublished data). No feather isotopic data is available for adult birds.

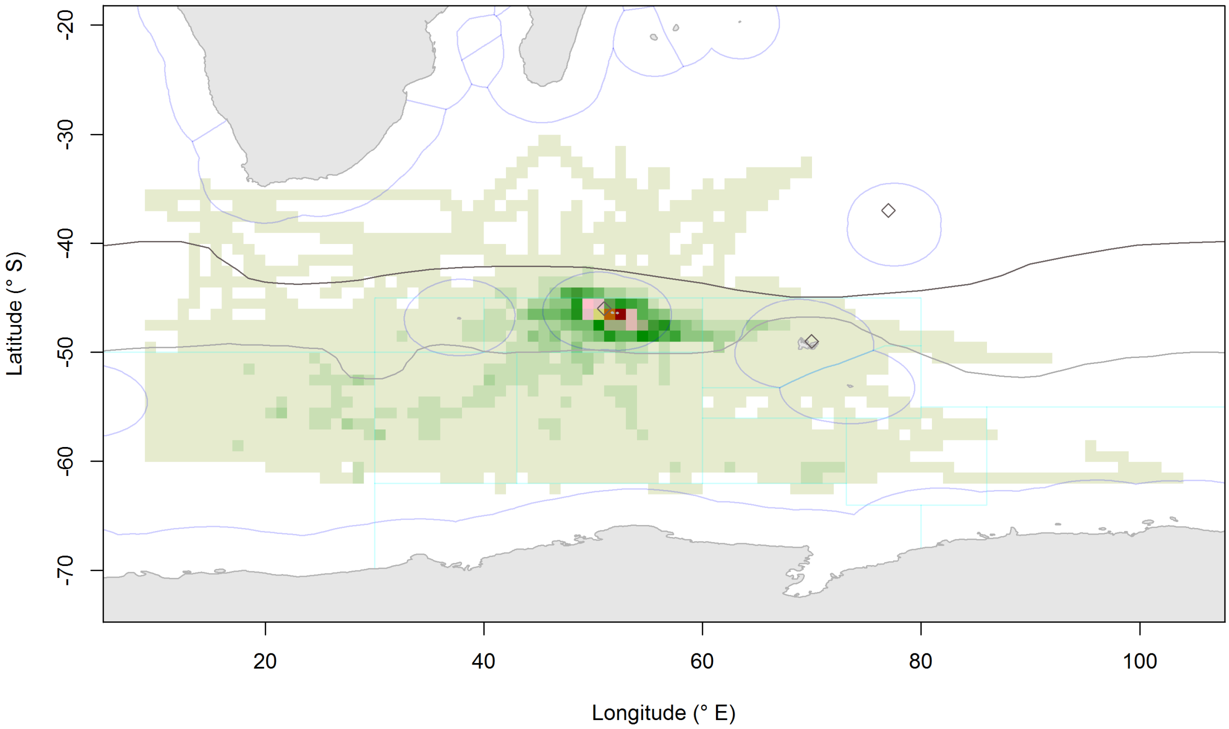
Marine distribution

Tracking data reveal that adults stay in the southern Indian Ocean whatever the period, from subantarctic to polar waters (Map 54), with birds moving into the southern Atlantic Ocean (Thiers et al., 2013).

Important areas

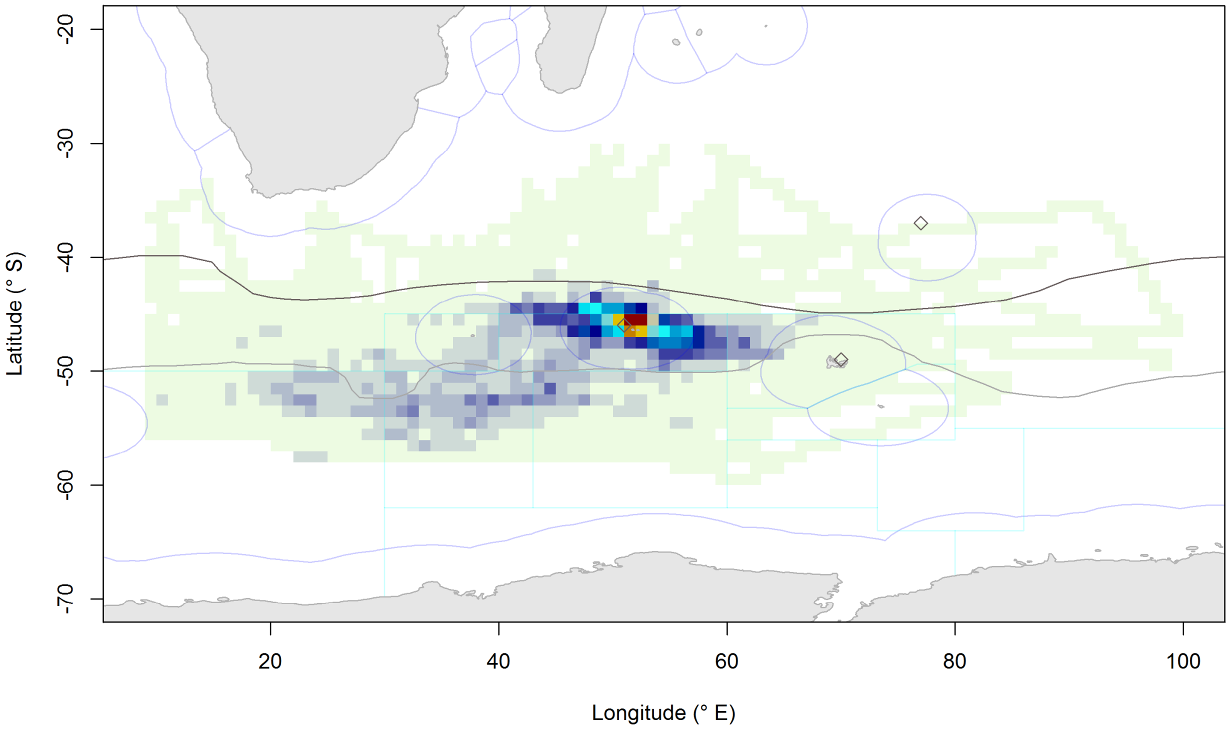


Map 54. *Southern giant petrel, Crozet Islands*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 55. *Southern giant petrel, Crozet Islands*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Although adult breeders at Crozet have high residence times within the Crozet EEZ, mainly over the Crozet Shelf, densities remain high south to the Antarctic circumpolar current front (Map 55). Incubating adults forage over the Polar front and the Antarctic circumpolar current front and up to the Antarctic ice edge, whereas during the chick provisioning phase breeding birds concentrate their activity closer to colonies. Males and females exhibit different foraging patterns: males forage mainly onland, but also over the shelf, whereas females dispersed more widely (Thiers et al., 2013).



Map 56. ***Southern giant petrel, Crozet Islands.*** **Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the inter-nesting period, in winter, birds remain restricted to the eastern part of southern Indian Ocean (Map 56). The higher residence times of adults occur within the Crozet EEZ. Male and female show different patterns: females are localized between the northern subantarctic front and the southern part of the polar front, while males tend to remain close to their colony, just as they do during the breeding season (Thiers et al., 2013).

Threats. According to ACAP (ACAPg), in the 1990s the numbers of *M. giganteus* reported killed in legal commercial fisheries in the Southern Ocean were low (CCAMLR, 1999;Nel et al., 2002c). However, the number of *M. giganteus* killed in illegal, unregulated and unreported (IUU) fisheries was considered to be much higher. The Commission for the Conservation of Antarctic Living Resources (CCAMLR) estimated that potentially several thousands of these birds were killed incidentally by IUU vessels from 1997 to 1999, particularly in sub-Areas 58.6 and 58.7 (Indian Ocean; (CCAMLR, 1999). Since 2004, the bycatch of seabirds including *M. giganteus* in the convention area has been virtually eliminated in the legal Department of Environment and Heritage fisheries (Agnew and Kirkwood, 2005;Department of Environment and Heritage, 2006). No Southern giant petrel has been reported killed in the CCAMLR area since 2005. With regard to IUU fishing, new estimates indicate that IUU fishing effort and, hence, seabird bycatch has significantly decreased in recent years (Otley et al., 2007) although some areas may remain more vulnerable than others. In New Zealand fisheries (longlines and trawls), very few *M. giganteus* were observed killed from October 1996 to September 2005 (New Zealand Department of Conservation, 2008).
Recent tracking data reveal that adults breeding at Crozet exhibit differences in their potential interactions with fisheries. Males overlap to a large extent with toothfish longline fisheries in shelf areas within Exclusive Economic Zones, whereas females (and juveniles) are more likely to encounter high sea longline fleets targeting tuna in subtropical waters (Thiers et al., 2013). The circumpolar

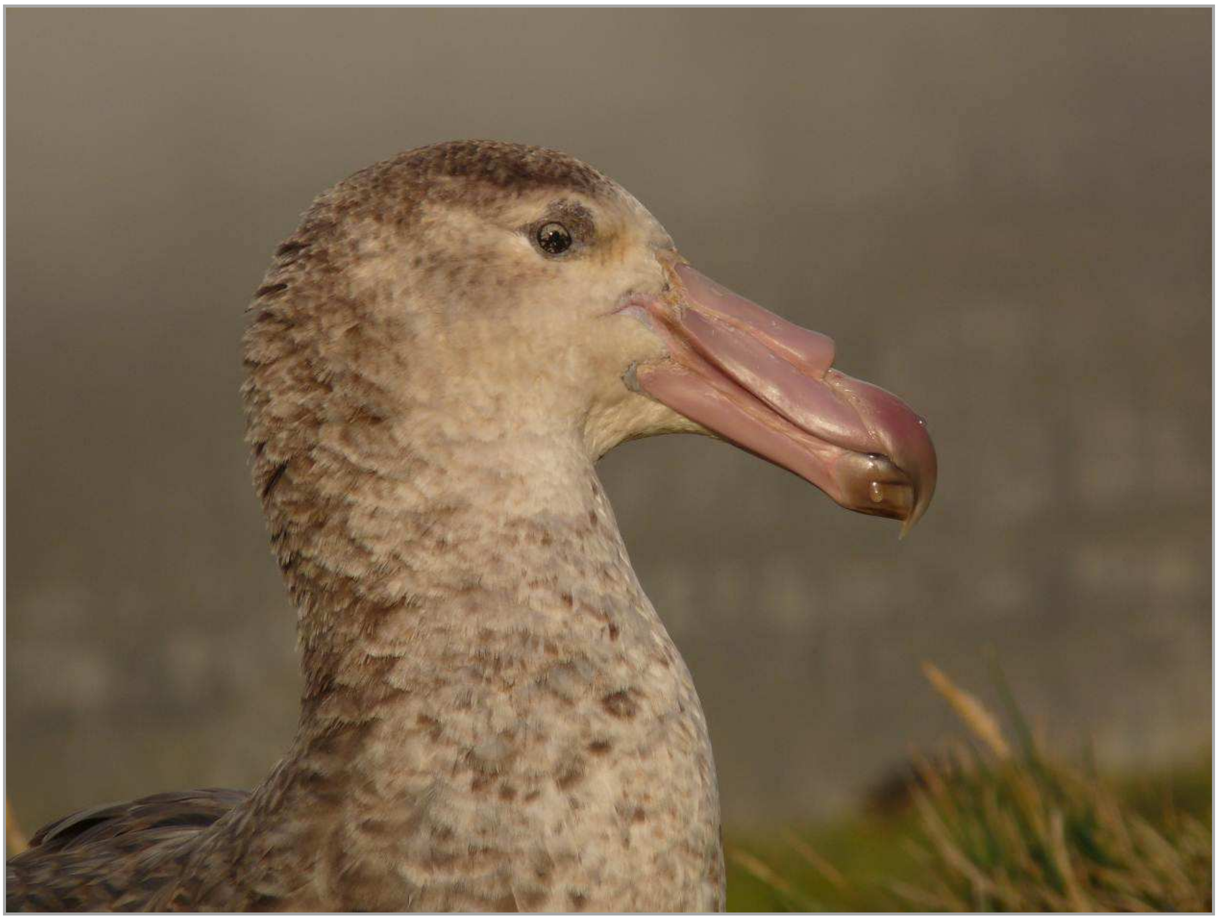
wide ranging behavior of naïve juvenile birds makes them particularly susceptible to interaction with a wide range of long line fisheries (Thiers et al., 2013), but in the zones of legal fishing where conservation measures are taken, mortality is very limited.
Other marine threats experienced by *M. giganteus* include injuries from nets or other fishing gear (Nel and Nel, 1999;Petry and Fonseca, 2002), swallowing of debris and entanglement in fishing gear. The global impact of these threats is unknown.

Gaps & Stakes. Further information on the distribution of birds at different stages of the annual cycle (especially different breeding stages) and during different breeding cycles is required to better assess overlap with fishing operations.
Southern giant petrels interact with both longline and trawl fisheries and more inclusive information on rates of incidental mortality would assist with the assessment of the impacts of interactions. Similarly, rates of secondary ingestions of hooks are poorly known.

Petrels/Northern giant petrel

Macronectes halli

CRITICAL ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED



@Y.Charbonnier

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Macronectes* /Species *M. halli*

Annual breeder

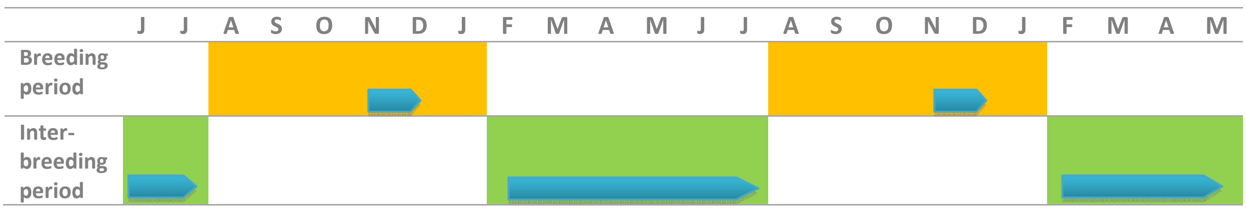
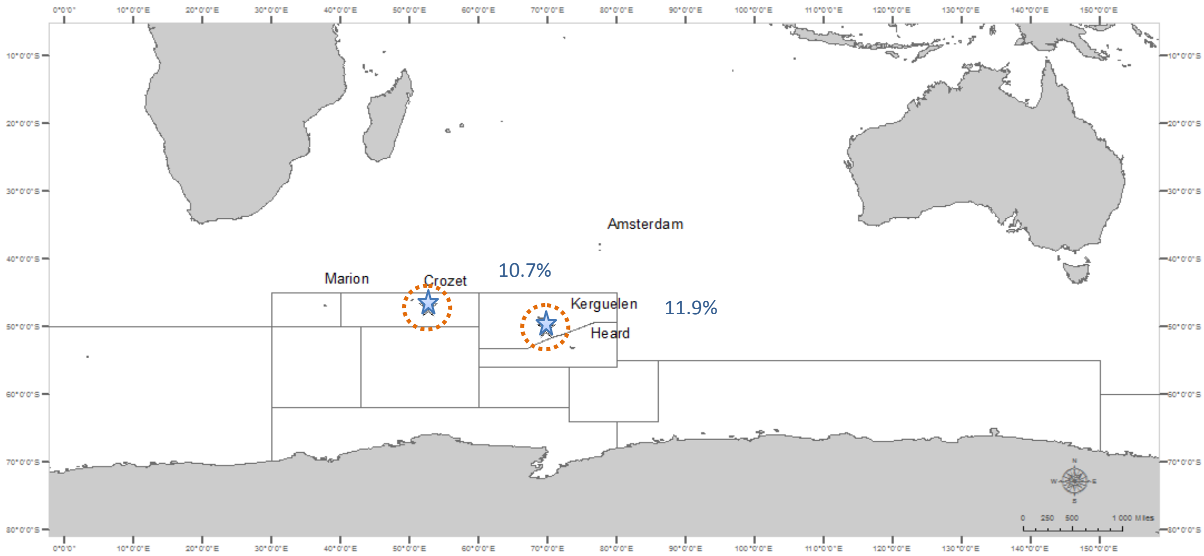


Table 20. *Breeding cycle and availability of tracking data (blue arrow) of* M. halli

Regional Breeding Sites. *Macronectes halli* are surface-nesting colonial or solitary annual breeders. No difference in seasonal or gender plumages exists, but males are larger with heavier bills (Nico De Bruyn et al., 2007).



The breeding range of *M. halli* encompasses the subantarctic zone and convergence, including South Georgia, Prince Edward Islands, the Crozet and Kerguelen archipelagos, Macquarie Island and the New Zealand islands of Auckland, Campbell, Antipodes and Chatham (ACAP 2010h).
South Georgia holds the largest *M. halli* breeding population, over one third of the global total. French Southern Territories holds 23% of the global total breeding population. In the late 1990s, the total breeding population was estimated as 11 210 pairs (Patterson et al., 2008).

Population trends. The populations of *M. halli* have shown both decreases and dramatic increases across their breeding range. At many sites, however, census data are infrequent and/or of low accuracy, preventing detailed assessments of population trends. On Possession Island (Crozet), the population increased from 150 to 560 breeding pairs between 1966 and 1980 (Voisin, 1988), declined during the 1980s, increasing again in the late 1990s and decreasing since 1998 (Delord et al., 2008). These increases are likely a result of increases in king penguins *Aptedonydtes patagonicus* and fur seals *Arctocephalus spp.* (source of carrion) numbers and increased pelagic food sources such as waste available from commercial fishing operations (González-Solís et al., 2000;Voisin, 1988). Conversely, the at-sea abundance of *M. halli* in the Prydz Bay area of East Antarctica has apparently decreased by 75% since 1980/81 (Woehler, 1996).

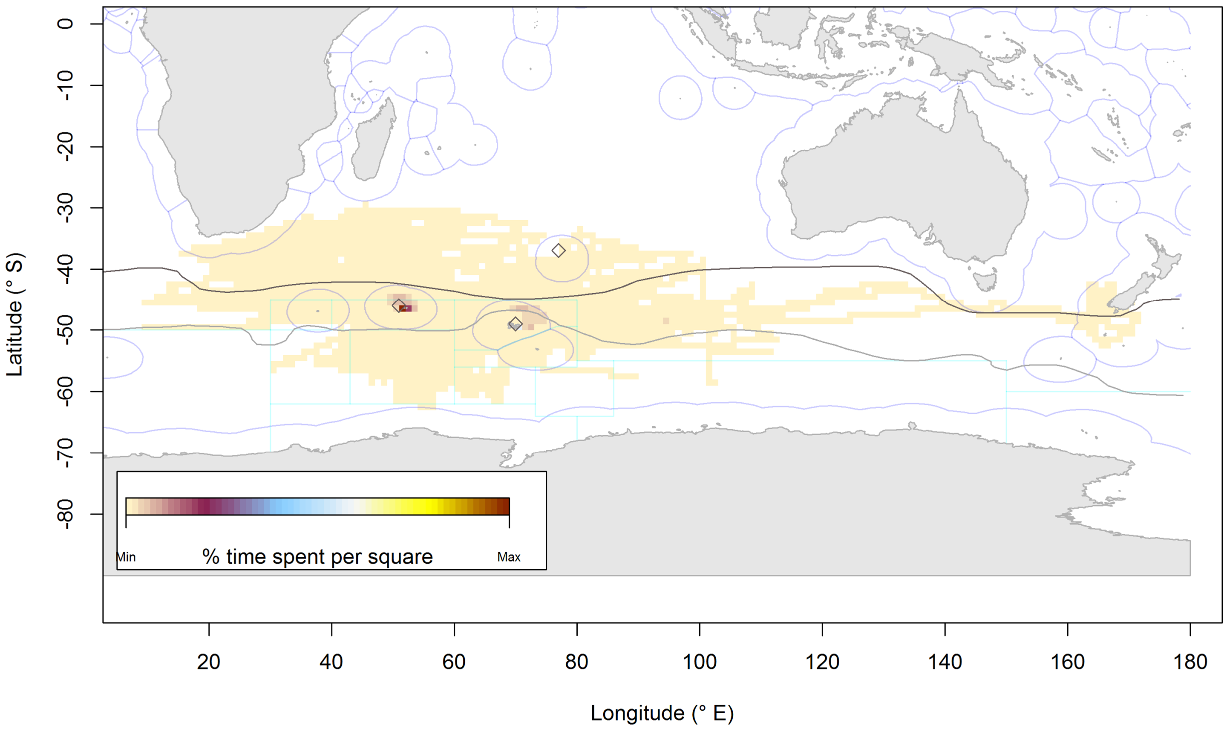
Diet and stable isotopes. Chick food at Crozet Islands includes almost exclusively bird carrion (99% by mass), with penguins being the major dietary items (81%), followed by small procellariiforms (18%) (Ridoux, 1994). No dietary data is available at Kerguelen Islands. Field observations at both localities show giant petrels feeding on birds and pinnipeds on land, and on fishery bycatch and offal at sea (Delord et al., 2005;Le Bohec et al., 2003;Ridoux, 1994;Weimerskirch et al., 2000).
At the two localities, feather δ^{13}C and δ^{15}N values indicate that chicks are fed mainly with subantarctic prey and that the species occupies a high trophic position, respectively (Blévin et al., 2013), unpublished data). No feather isotopic data is available for adult birds from Crozet islands.

Since adult giant petrels begin to moult during the breeding period, special care was made to collect fully grown old feathers from the lower back on Kerguelen birds. Preliminary analysis shows that adults mainly moult in the subantarctic zone, with a high trophic position. No gender differences occur in feather $\delta^{15}N$ values, but females have slightly higher $\delta^{13}C$ values than males suggesting some degree of sex-related spatial segregation during moult.

Marine distribution. *Macronectes halli* are pelagic and circumpolar, generally found between 30-64°S, but the extent is imprecise given the difficulty in distinguishing *M. halli* from *M. giganteus* (Voisin, 1988) at sea. In summer, they range in subantarctic to Antarctic open oceans and in winter to early spring throughout subtropical seas to 28°S (González-Solís et al., 2008).
Tracking data reveal that adults stay in the southern Indian Ocean whatever the period, from sub-tropical, as far as the coast of South Africa, to subantarctic waters.

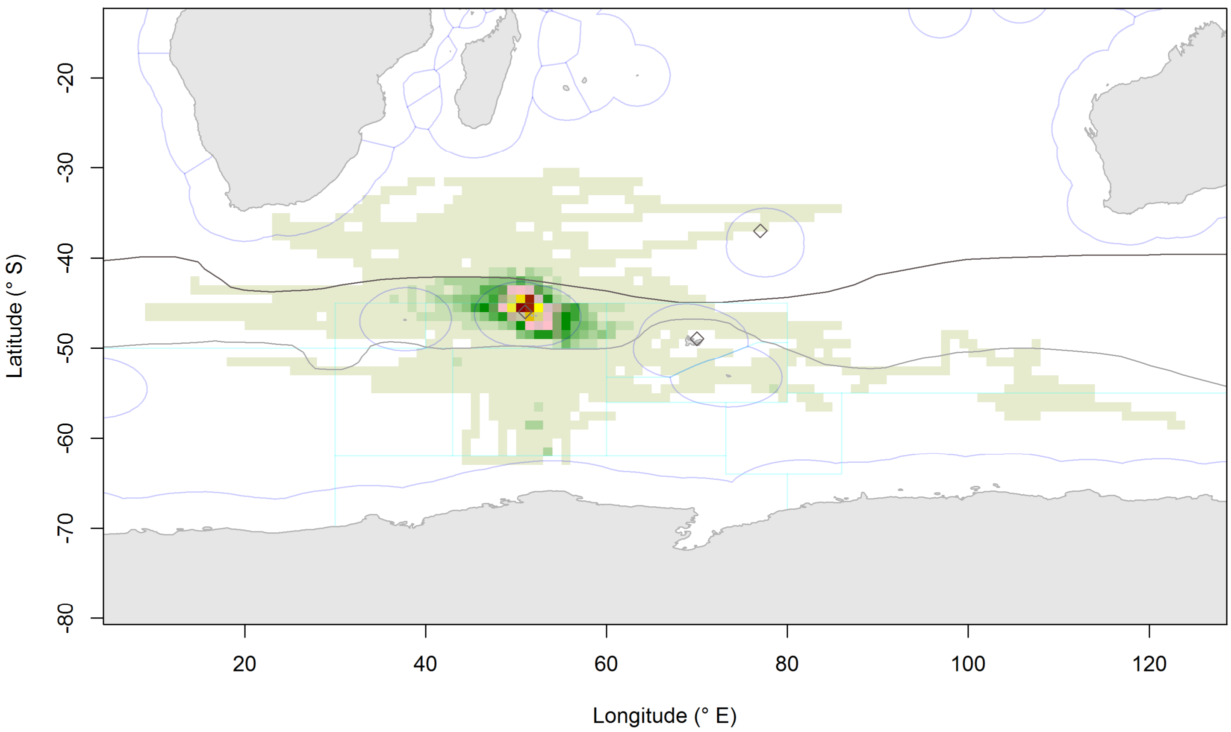
Important areas

The adults from Crozet and Kerguelen tend to spend a higher amount of time around their colony and in waters within the French EEZs whatever the period.

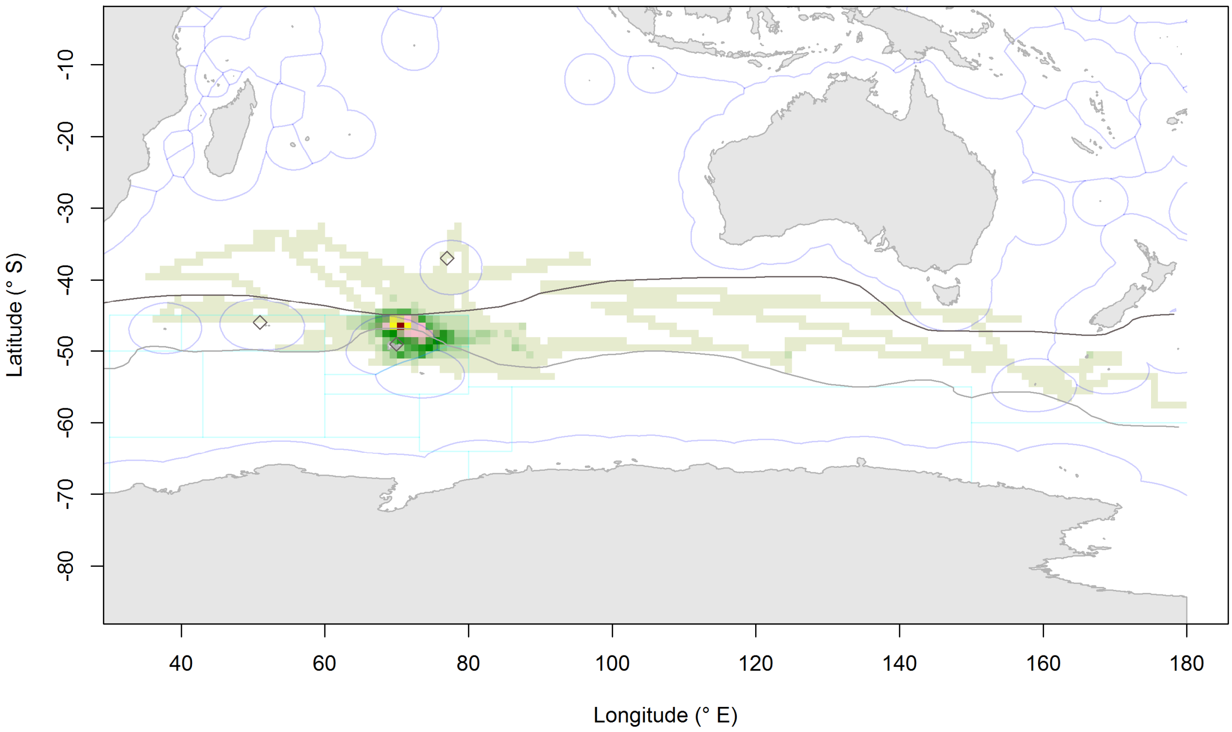


Map 57. *Northern giant petrel, Crozet Islands and Kerguelen Islands*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Adult breeders at Crozet and Kerguelen showed a wide distribution over the islands shelves and south to the Polar Front (Map 57). During the breeding period higher residence times of adults occur within the Crozet (Map 58) and Kerguelen (Map 59) EEZs. During the chick provisioning phase breeding birds concentrate their activity close to breeding colonies, with males remaining in shallow shelf waters close to the islands or on land. Males and females exhibit different foraging patterns: females dispersed more widely than males (Thiers et al., 2013).

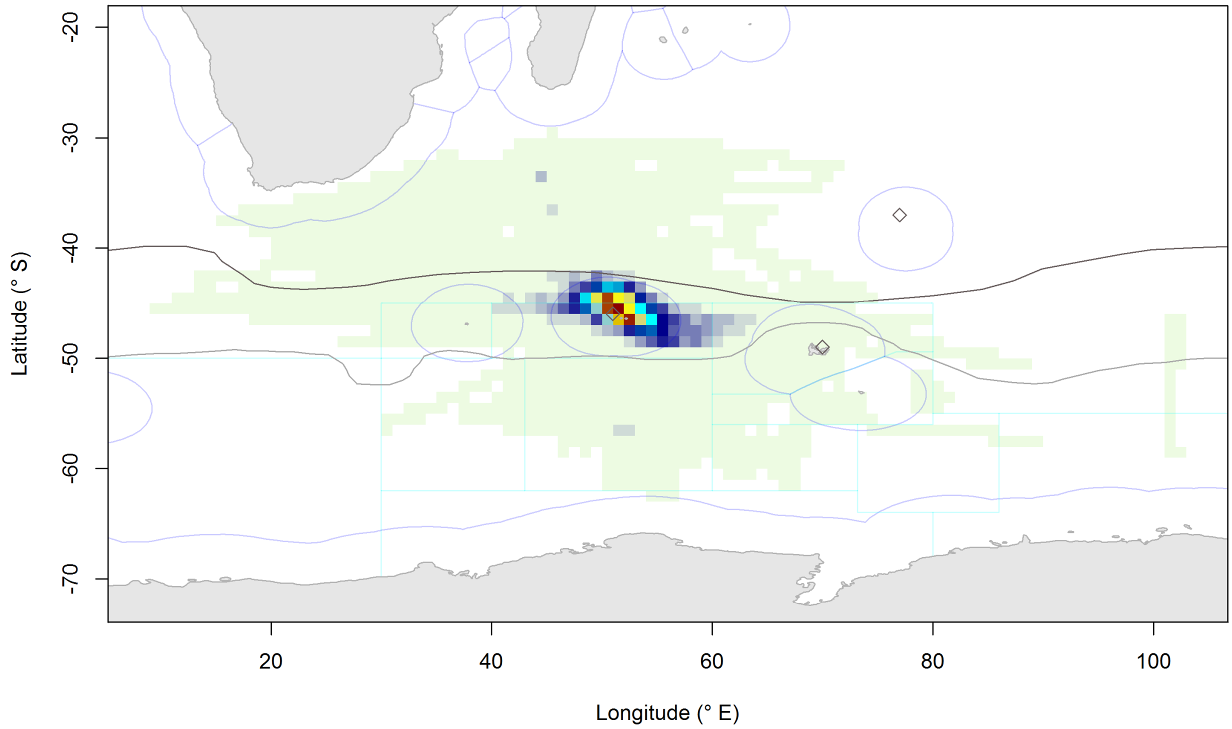


Map 58. *Northern giant petrel, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

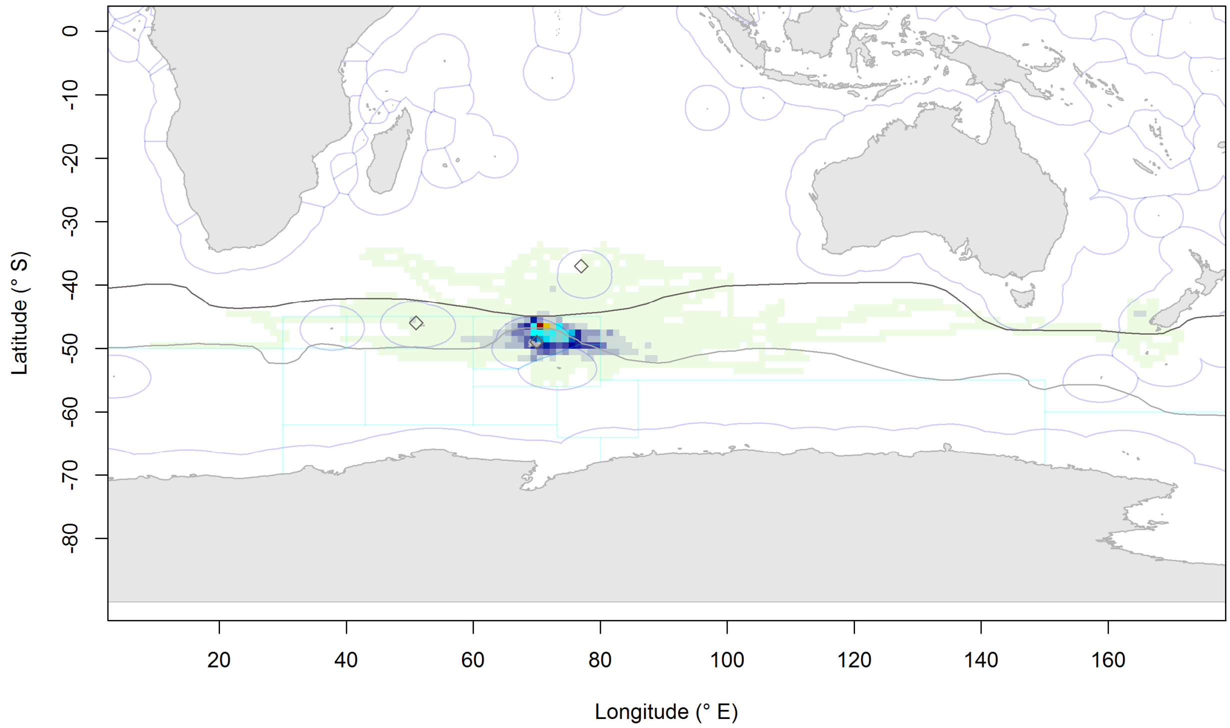


Map 59. ***Northern giant petrel, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding season adult birds are restricted to the vicinity of the breeding grounds, where birds, especially males, forage on land or in offshore waters. Some birds forage in more distant waters, especially females (Maps 58 & 59).



Map 60. *Northern giant petrel, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 61. *Northern giant petrel, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin,

1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The distribution of adults was wider during the inter-nesting than the breeding period, although birds remained restricted to the eastern part of the southern Indian Ocean (Map 60 & 61). The higher residence times of adults, especially males, occur within the French EEZs of Crozet and Kerguelen. Females from Kerguelen disperse more widely than males, targeting waters located between the northern subantarctic front and the polar front, with birds reaching the Tasman Sea. Females from Crozet disperse over a large latitudinal range (from 30°S to 65°S; (Thiers et al., 2013).

Threats. According to ACAP (ACAP 2010h), the greatest threat to *M. halli* is commercial fishing activities in the Southern Ocean. Longline fishing for Patagonian toothfish (*Dissostichus eleginoides*) is of particular concern as this demersal fishery tends to be restricted to shelf areas around subantarctic breeding islands. Possibly 7-16% of the breeding *M. halli* population may have been killed by longliners operating around Prince Edward Island in 1996-2000 (Nel et al., 2002c). Females may experience higher mortality in this fishery as they tend to have larger pelagic ranges and longer foraging trips than males. Additionally, females have greater overlap between foraging territories and longline fishing areas (González-Solís et al., 2008;Thiers et al., 2013). Trawl fisheries may also injure or kill *M. halli* through collisions with netsonde cables and trawl warps (New South Wales Department of Environment and Climate Change, 2005).
Other marine threats may include ingestion of or entanglement in marine debris (both plastic and fishery-related) (Nel and Nel, 1999), shooting by commercial fishing vessels to reduce stealing of baits (Hunter and Brooke, 1992).

Gaps & Stakes. Further Information on the distribution of birds of different breeding colony sites, at different stages of the annual cycle (especially different breeding stages) and during different breeding cycles is required to better assess overlap with fishing operations.
Data on *M. halli* are lacking in key areas including the diet and foraging areas. Additionally, the extent and effects of at-sea threats such as plastic debris ingestion are currently unknown.

Petrels/Southern fulmar

Fulmarus glacialoides

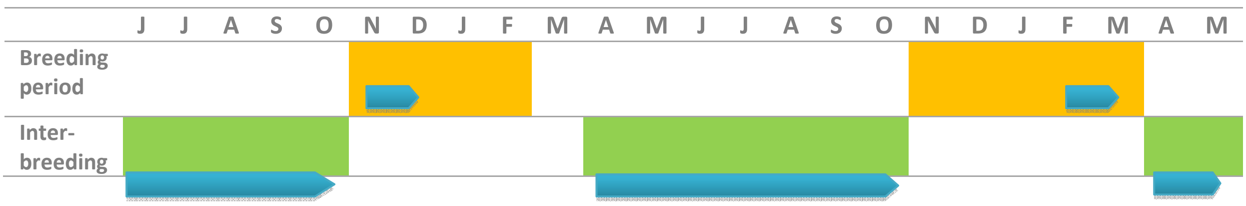
CRITICALLY ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED

@C.Barbraud

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Fulmarus* /Species *F. glacialoides*

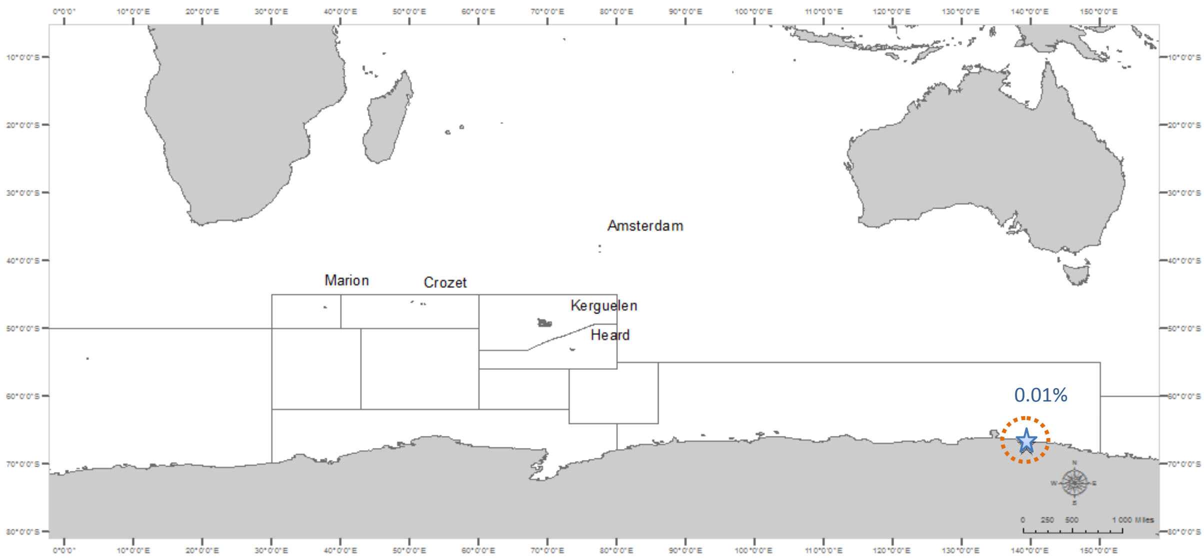
Annual breeder



period	

Table 21. *Breeding cycle and availability of tracking data (purple arrow) of* F. glacialoides, Adélie Land

Regional Breeding Sites.
This colonial species breeds on the coast and offshore islands of the Antarctic continent and Antarctic Peninsula and on the islands of South Orkney, South Shetland, and Bouvetøya (Creuwels et al., 2007). The species breeding stronghold is the Antarctic Peninsula, South Orkney, South Shetland, and Bouvetøya islands. Adélie Land hosts at most 0.01% of the world breeding population that is estimated (with low accuracy and underestimation) to be at least 400 000 breeding pairs (Creuwels et al., 2007). The nearest colonies are situated ≈ 170 km east of Pointe Géologie (Adélie Land) and hosts 6 500 to 7 200 breeding pairs (Barbraud et al., 1999).



Population trends. In Adélie Land, the small population (from ≈ 20 to 55 breeding pairs) is monitored annually and has been increasing at c. 1% per annum between 1963 and 2012, with high interannual fluctuations in the number of breeding pairs ((Jenouvrier et al., 2003); unpublished data). This slight increase seems due to immigration from colonies elsewhere. There is no information on trends in other breeding sites due to a lack of regular surveys.

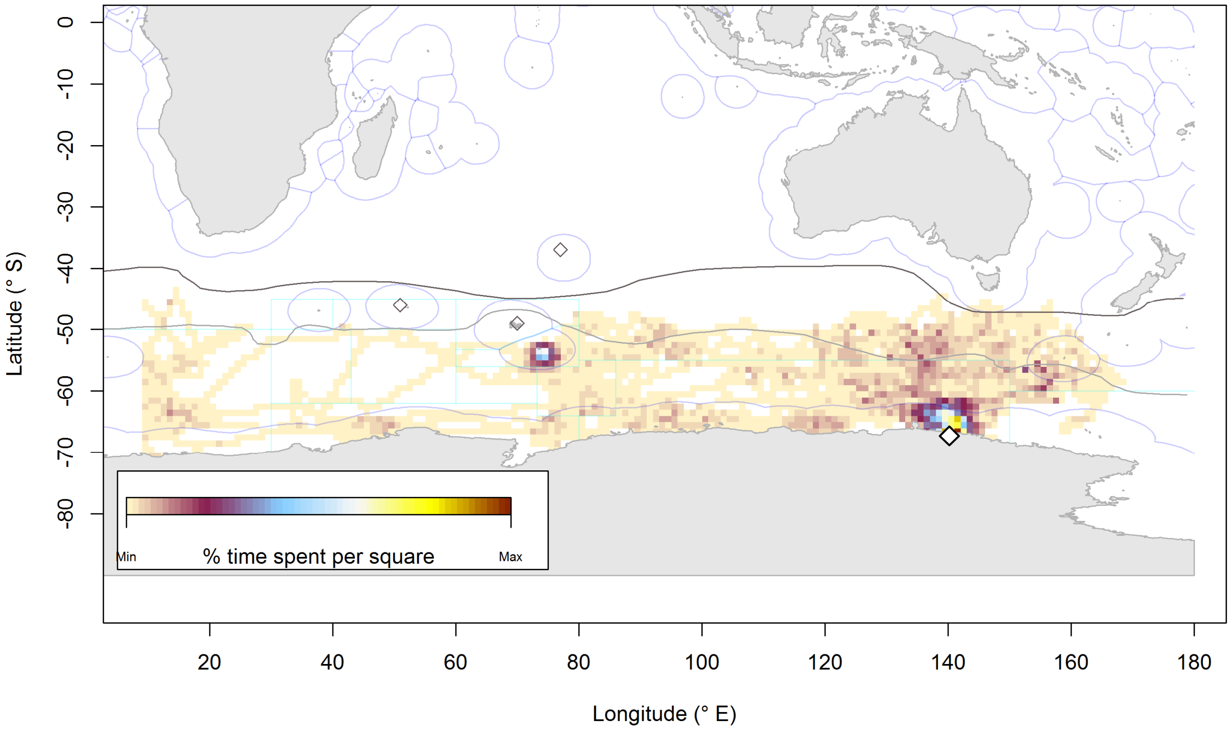
Diet and stable isotopes. Chick food in Adélie Land is dominated by crustaceans (64% by mass), with carrion ranking second (20%) and fish third (16%). Euphausiids form the bulk of the diet, with the oceanic Antarctic krill *E. superba* (62%) being by far the main dietary item. Carrion and fish prey were not determined (Ridoux and Offredo, 1989), but the Antarctic silverfish *Pleuragramma antarcticum* was identified from several spontaneous regurgitations collected in 2001 (unpublished data). Feather $\delta^{13}C$ and $\delta^{15}N$ values show that adults caught prey for their chicks in high-Antarctic waters, where the species occupies an intermediate trophic position (mixed crustacean and fish diet) within the seabird community. The $\delta^{13}C$ and $\delta^{15}N$ values of adult feathers indicate moulting in high-Antarctic waters where individuals feed opportunistically from low- to high-trophic level prey (unpublished data).

Marine distribution.

% ?

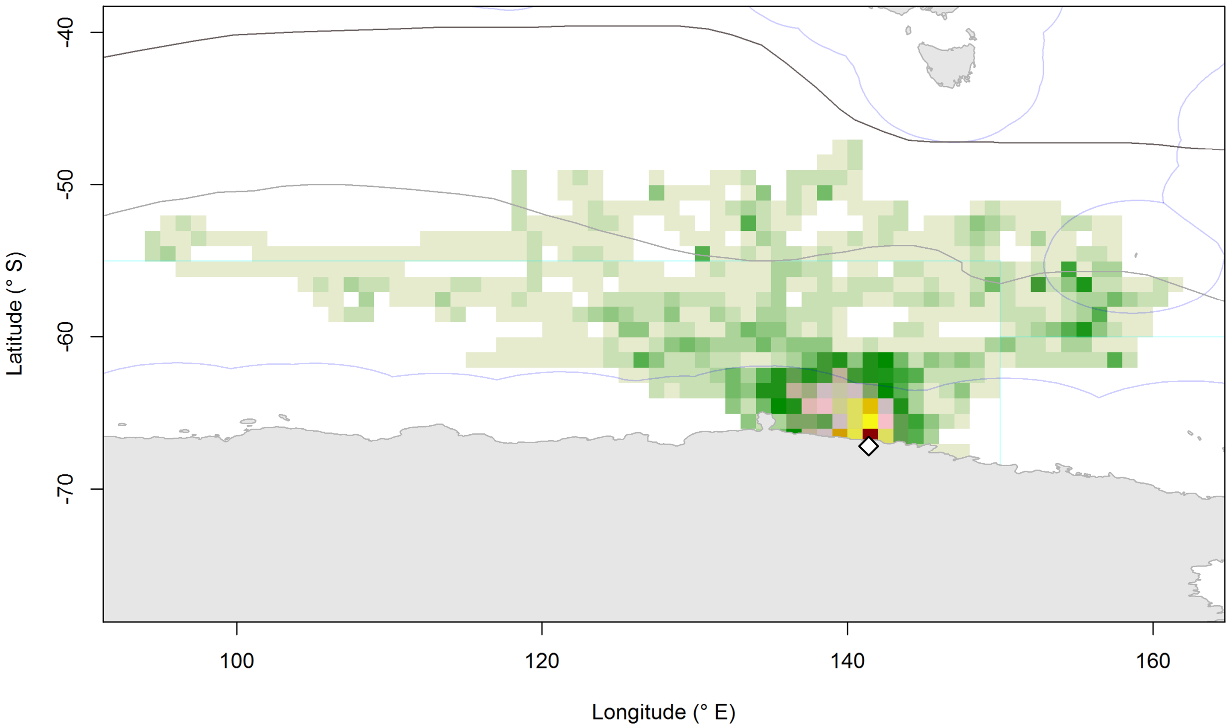
The southern fulmar has a circumpolar distribution, with the majority of birds found in Antarctic and subantarctic waters, some birds being found further north along cold upwelling currents (Marchant and Higgins, 1990). *F. glacialoides* tend to prefer open waters (Fraser and Ainley, 1986) but also forage in pack ice (Ainley et al., 1992;Ainley et al., 1993b). Few breeding birds have been tracked but information from Adélie Land suggests that birds forage in loose pack ice when rearing their chick (unpublished data).

Important areas



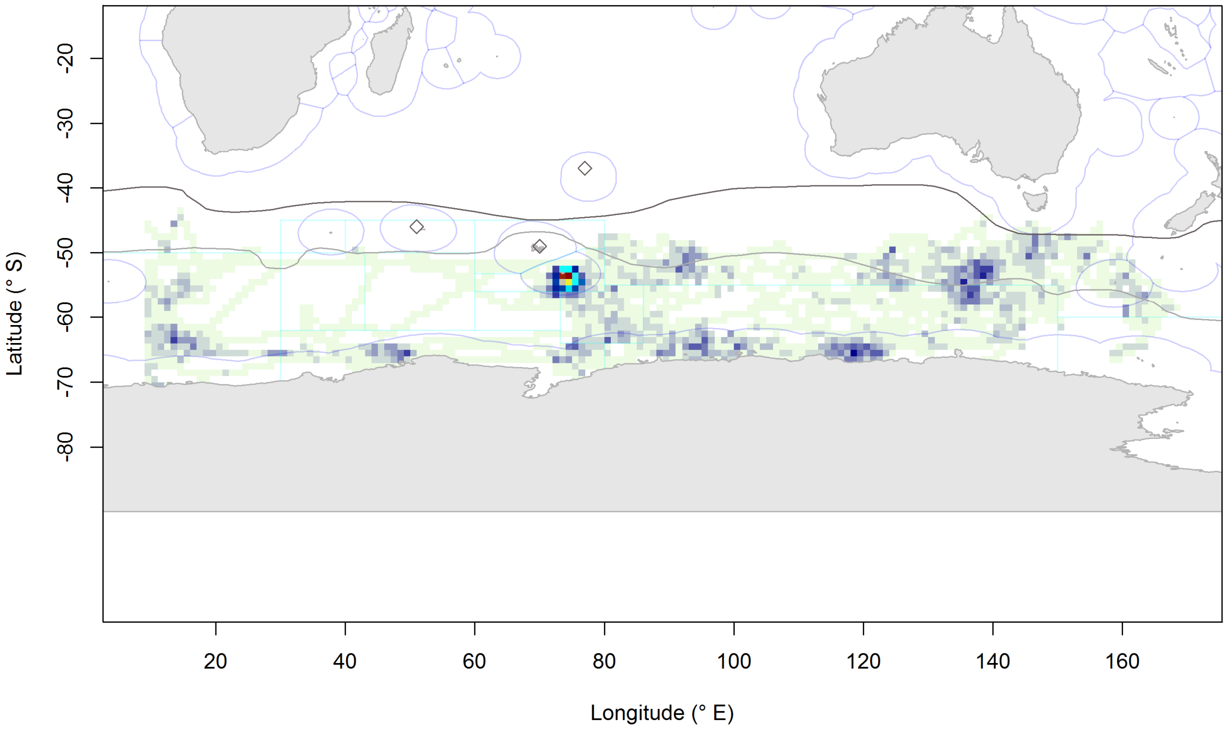
Map 62. *Southern fulmar, Adélie land*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Tracking data are available for the colony of Pointe Géologie (Adélie Land). Birds from Adélie Land are found throughout the southern Indian Ocean and move up to the southern Atlantic Ocean (Map 62).



Map 63. *Southern fulmar, Adélie land*. Observed distribution (GLS data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Tracking data (using GLS) during the breeding period reveal that during the complete breeding season southern fulmars are concentrated around the breeding grounds, with decreasing densities occurring away from the colony (Map 63). This suggests that birds can forage to more than 1000km from the colonies south and north of the Polar frontal zone, probably during the early stage of the breeding season when ice is still extended around the continent. Satellite tracking of birds brooding chicks indicate that southern fulmars move at 200-300km from the colony, foraging in polynias (open water areas), especially close to the Mertz glacier tongue.



Map 64. *Southern fulmar, Adélie land*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

In winter, tracking data (using GLS) reveal that southern fulmars disperse westward from the Adélie Land colony in the Indian and Atlantic part of the Southern Ocean and north of Adélie Land, moving northward to the Polar Frontal zone, mainly over oceanic waters (Map 64). However, highest densities occur around Heard Island, with birds still present in the pack ice zone along the continent.

Threats. Currently there is no evidence of serious threats to *F. glacialoides* populations. Although fishing vessels attract southern fulmars (Whitehouse and Veit, 1994;Wienecke and Robertson, 2002a), accidental mortality in fishing gear is extremely rare (Sullivan, 2004;Wienecke and Robertson, 2002a;Wienecke and Robertson, 2002b). During breeding Antarctic krill is an important food resource for southern fulmars in Adélie Land. Consequently, increasing krill pelagic fisheries close to breeding grounds may have negative effects on reproduction. However no such fisheries are operating at the moment close to Adélie Land. The breeding site in Adélie Land is protected and rarely visited, as are other breeding sites (IAATO, 2012). Levels of mercury and organochlorine compounds in eggs and adults (Luke et al., 1989b;Van den Brink et al., 1998) and rates of occurrence of plastic particles recorded in stomach were low (VanFraneker and Bell, 1988), but should be reassessed.

Gaps & Stakes. More precise information is required on the distribution of breeding birds during the different stages of the nesting season (incubation, chick rearing), as well as larger sample sizes for the non-breeding season. Information is also lacking for juvenile birds when they disperse from the breeding colony. However, the Adélie Land colony remains small to track large numbers of individuals. Southern fulmars from the nearest breeding colony situated in King George V Land hosting several thousands breeding pairs could be tracked to obtain large sample sizes.

While the population breeding in Adélie Land is well monitored, there is a considerable lack of knowledge about the distribution, abundance and trends of other breeding colonies elsewhere. Thus, there is a need for more detailed systematic surveys at other breeding sites. There is also a need to better assess the at-sea distribution of breeding and non-breeding birds in order to be able to assess the overlap with potentially developing krill fisheries so that mitigation measures can be targeted if necessary.

Petrels/Cape petrel

Daption capense

CRITICALLY ENDANGERED ENDANGERED VULNERABLE NEAR THREATENED LEAST CONCERN NOT LISTED

@C.Barbraud

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Daption* /Species *D. capense*

Annual breeder

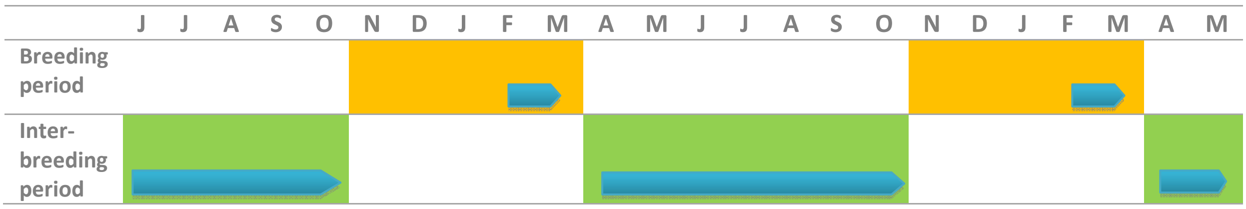
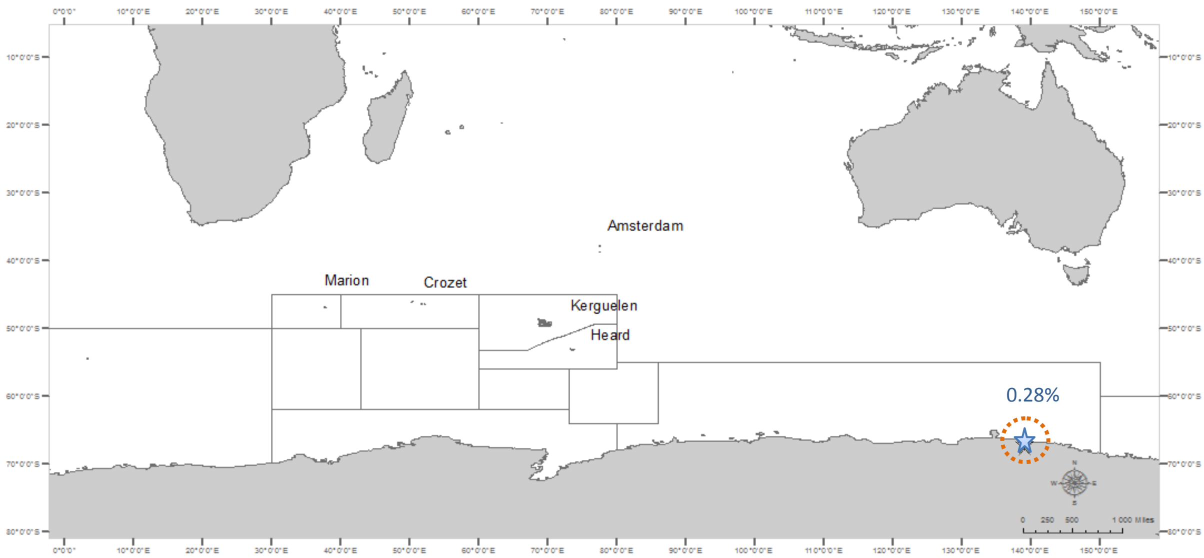


Table 22. *Breeding cycle and availability of tracking data (purple arrow) of* D. capense, Adélie Land

Regional Breeding Sites.
The Cape petrel breeds between 44° and 70°S on the coast and offshore islands of the Antarctic continent and Antarctic Peninsula and on numerous subantarctic islands (Brooke, 2004;Hodum, 2007). The species breeding stronghold is the Antarctic Peninsula and Scotia Sea. Adélie Land hosts at

most 0.28% of the world breeding population that is estimated to be at least 175 000 breeding pairs (Brooke, 2004;Hodum, 2007). However, this is an underestimate since at-sea survey's in Prydz Bay alone suggested an estimate of 1.8 million birds (Cooper and Woehler, 1994). The nearest colonies are situated ≈ 170 km east of Pointe Géologie (Adélie Land) and hosts ≈ 200 breeding pairs (Barbraud et al., 1999).

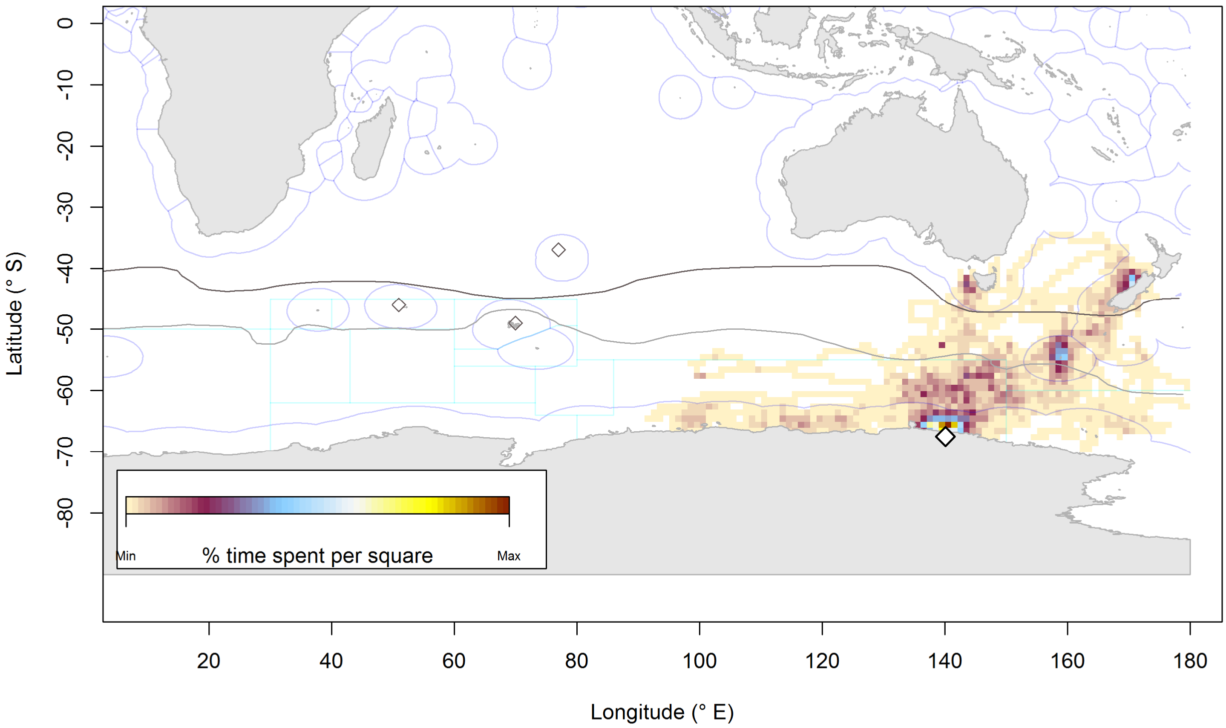


Population trends. In Adélie Land, the population (≈ 450 breeding pairs) is monitored annually and has been stable between 1984 and 2012, with high interannual fluctuations in the number of breeding pairs (unpublished data). There is no information on trends in other breeding sites due to a lack of regular surveys.

Diet and stable isotopes. Chick food in Adélie Land is dominated by crustaceans (71% by mass), with fish ranking second (29%). Euphausiids form the bulk of the diet (64%), with two species being involved almost equally, the neritic ice krill *Euphausia crystallorophias* (35%) and the oceanic Antarctic krill *E. superba* (29%). Fish prey were not identified (Ridoux and Offredo, 1989). Feather $\delta^{13}C$ and $\delta^{15}N$ values show that adults caught prey for their chicks in high-Antarctic waters, where the species occupies the lowest trophic position (crustacean diet) within the seabird community. The $\delta^{13}C$ and $\delta^{15}N$ values of adult feathers indicate moulting in high-Antarctic waters where individuals feed opportunistically from low- to high-trophic level prey (unpublished data).

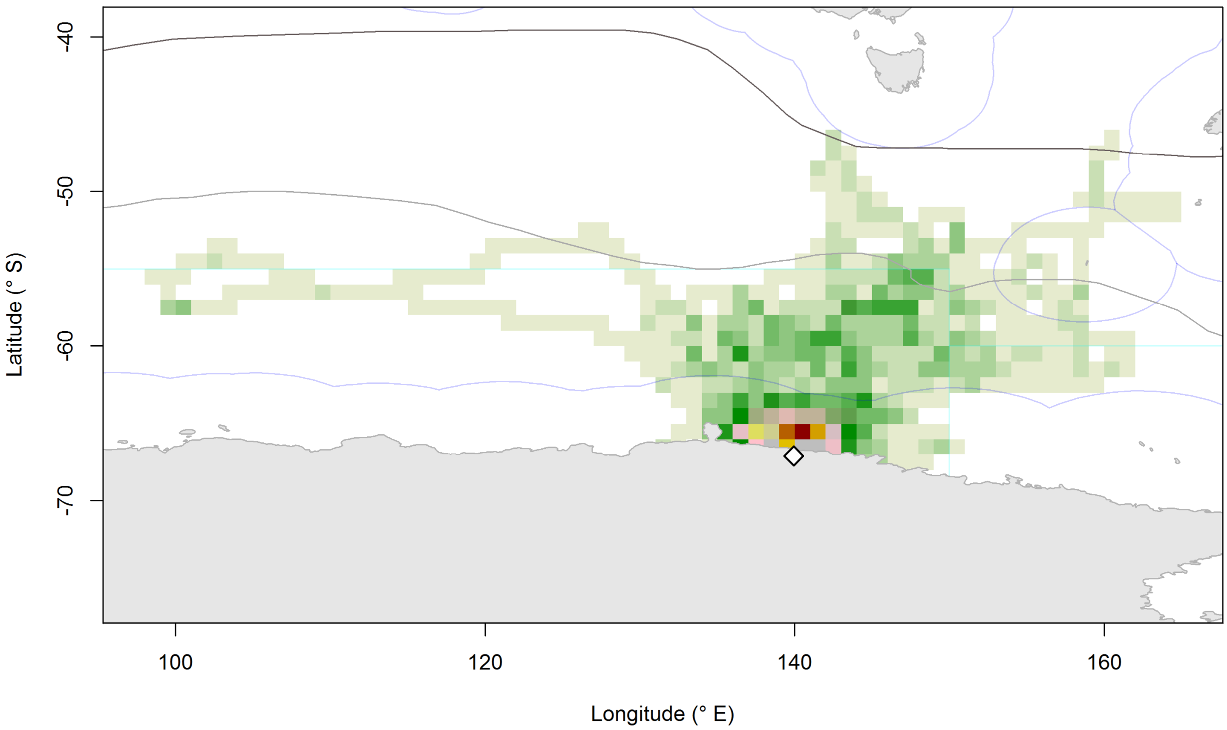
Marine distribution. Cape petrel has a circumpolar distribution, with the majority of birds found in Antarctic and subantarctic waters in summer, and birds move north along cold upwelling currents up to 25°S (Marchant and Higgins, 1990). *D. capense* tend to prefer open waters and avoids pack ice (Fraser and Ainley, 1986) but also forage in pack ice (Ainley et al., 1992;Ainley et al., 1993a).

Important areas



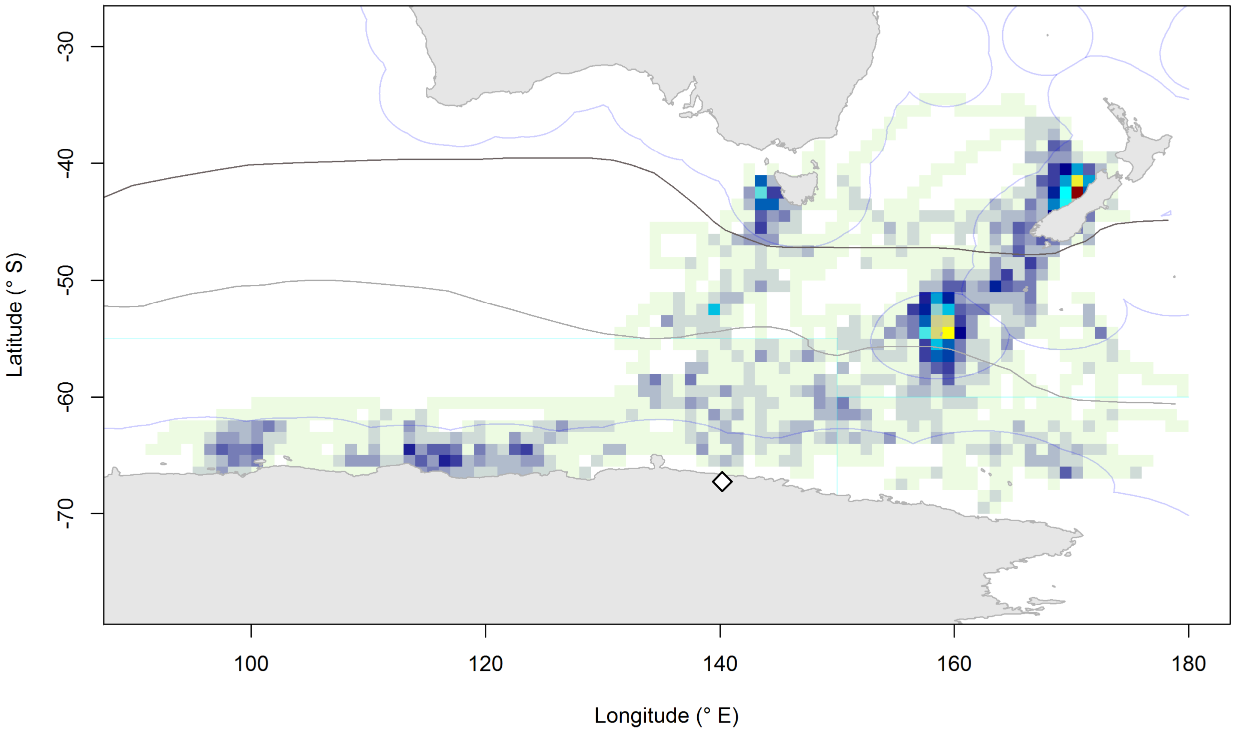
Map 65. ***Cape petrel*, Adélie land Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

GLS tracking data are available for the colony of Pointe Géologie (Adélie Land). The overall distribution of Cape petrels from Adélie land is restricted to the eastern Indian Ocean and the southern Tasman Sea (Map 65).



Map 66. *Cape petrel, Adélie Land*. Observed distribution (GLS data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding season, highest densities of birds breeding in Adélie Land are concentrated in the vicinity of the colonies, with low densities occurring as far as 1000km (Map 65).



Map 67. Cape *petrel, Adélie Land*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Band recovery data suggested non-breeding birds dispersed in the Tasman Sea and New Zealand waters during winter (Weimerskirch et al., 1985). This was confirmed using GLS data: during winter non-breeding birds leave the vicinity of Adélie Land and concentrate especially around Macquarie Island, western Tasmania and the west coast of South Island in New Zealand, with lowest densities occurring in oceanic waters (Map 67). Cape petrels are well known to associate with fishing vessels (Murray et al., 1993;Weimerskirch et al., 2000), and the zones of concentration in offshore waters of oceanic islands or New Zealand and Tasmania might be explained by this behavior.

Threats. Owing to its widespread distribution, large global population, and remote breeding colonies, there are few major threats to *D. capense*. Although Cape petrels and attracted by and interact with fishing vessels, associated mortalities of Cape petrels remain limited (Richard and Abraham, 2013). During breeding Antarctic krill is an important food resource for Cape petrels in Adélie Land. Consequently, increasing krill pelagic fisheries close to breeding grounds may have negative effects on reproduction. However no such fisheries are operating at the moment close to Adélie Land. Levels of organochlorine compounds in eggs and tissues of adults were relatively high (Luke et al., 1989a;Van den Brink, 1997), and plastic particles were commonly found in stomachs of Cape petrels (VanFraneker and Bell, 1988) and could represent a hazard.

Gaps & Stakes. More accurate data based on GPS or Argos transmitters on the distribution of Cape petrels during the breeding season would be necessary. Information is also lacking for juvenile birds when they disperse from the breeding colony.
While the population breeding in Adélie Land is well monitored, there is a considerable lack of knowledge about the distribution, abundance and trends of other breeding colonies elsewhere. Thus,

there is a need for more detailed systematic surveys at other breeding sites. There is also a need to better assess the at-sea distribution of breeding and non-breeding birds in order to be able to assess the overlap with potentially developing krill fisheries so that mitigation measures can be targeted if necessary.

Petrels/Snow petrel

Pagodroma nivea

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@ C.A. Bost

TAXONOMY

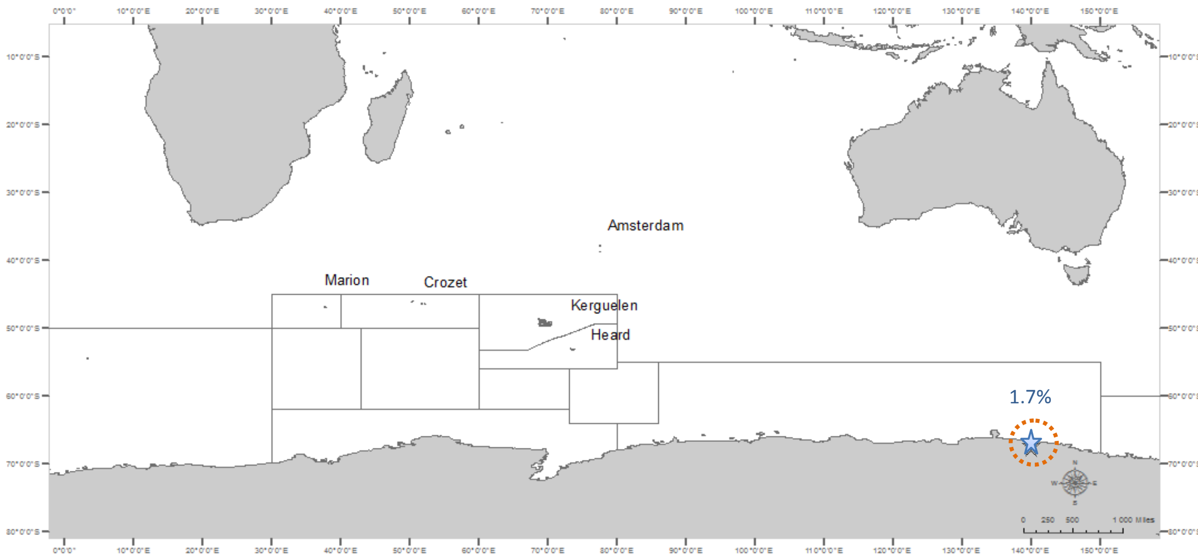
Order Procellariiformes / Family Procellariidae / Genus *Pagodroma* /Species *P. nivea*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 23. *Breeding cycle and availability of tracking data (purple arrow) of* P. nivea, Adélie Land

Regional Breeding Sites. *Pagodroma nivea* breeds on the coast and offshore islands of the Antarctic continent and Antarctic Peninsula and on the islands of South Orkney, South Shetland, Bouvetøya and South Georgia (Croxall et al., 1995). Snow petrels breed in isolated pairs, in loose or dense colonies up to 440km from sea. Adélie Land hosts at most 1.7% of the world breeding population that is estimated to be at least 63 000 breeding pairs (Croxall et al., 1995). However, as for the Cape petrel this is an underestimate since at-sea surveys suggest ≈ 2 millions birds in the Ross Sea (Ainley et al., 1984) and 1.7 million in Prydz Bay (Cooper and Woehler, 1994). The nearest colonies are situated ≈ 170 km east of Pointe Géologie (Adélie Land) and hosts ≈700 breeding pairs (Barbraud et al., 1999).



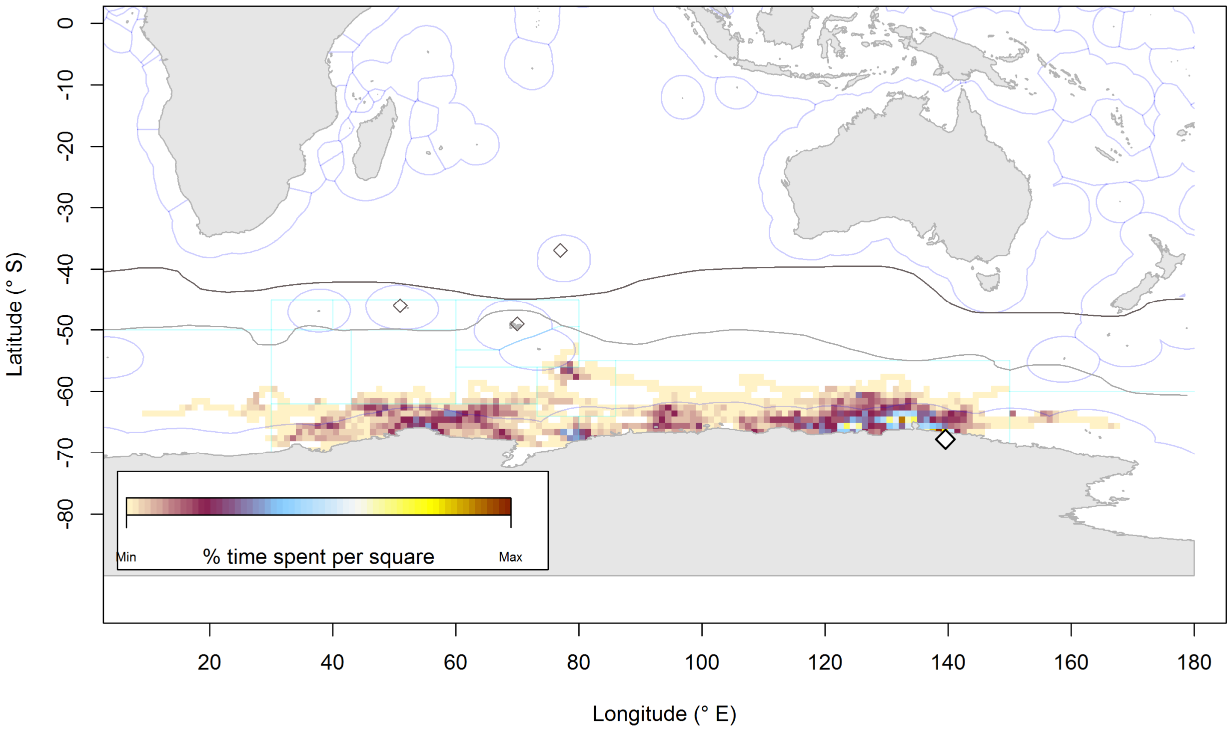
Population trends. In Adélie Land, the population is monitored annually and has been stable between 1963 and 2012, with high interannual fluctuations in the number of breeding pairs (Barbraud et al., 2011;Jenouvrier et al., 2005); unpublished data). There is no information on trends in other breeding sites due to a lack of regular surveys.

Diet and stable isotopes. Chick food in Adélie Land includes almost exclusively fish (95% by mass), with crustaceans and cephalopods being minor items (2% each). Fish prey were not determined (Ridoux and Offredo, 1989), but the Antarctic silverfish *Pleuragramma antarcticum* was commonly identified from spontaneous regurgitations that were opportunistically collected in 1994 (unpublished data).
Feather $\delta^{13}C$ and $\delta^{15}N$ values show that adults caught prey for their chicks in high-Antarctic waters, where the species occupies a high trophic position (fish diet) within the seabird community. The $\delta^{13}C$ and $\delta^{15}N$ values of adult feathers indicate moulting in high-Antarctic waters where individuals feed opportunistically from low- to high-trophic level prey (unpublished data).

Marine distribution. *P. nivea* are almost entirely restricted to cold Antarctic waters and are associated with pack ice, icebergs and ice floes, occuring mainly in areas with 10-50% ice cover (Ainley et al., 1992;Ainley et al., 1993a). The only exceptions are birds from few colonies north of the pack ice zone in South Georgia.

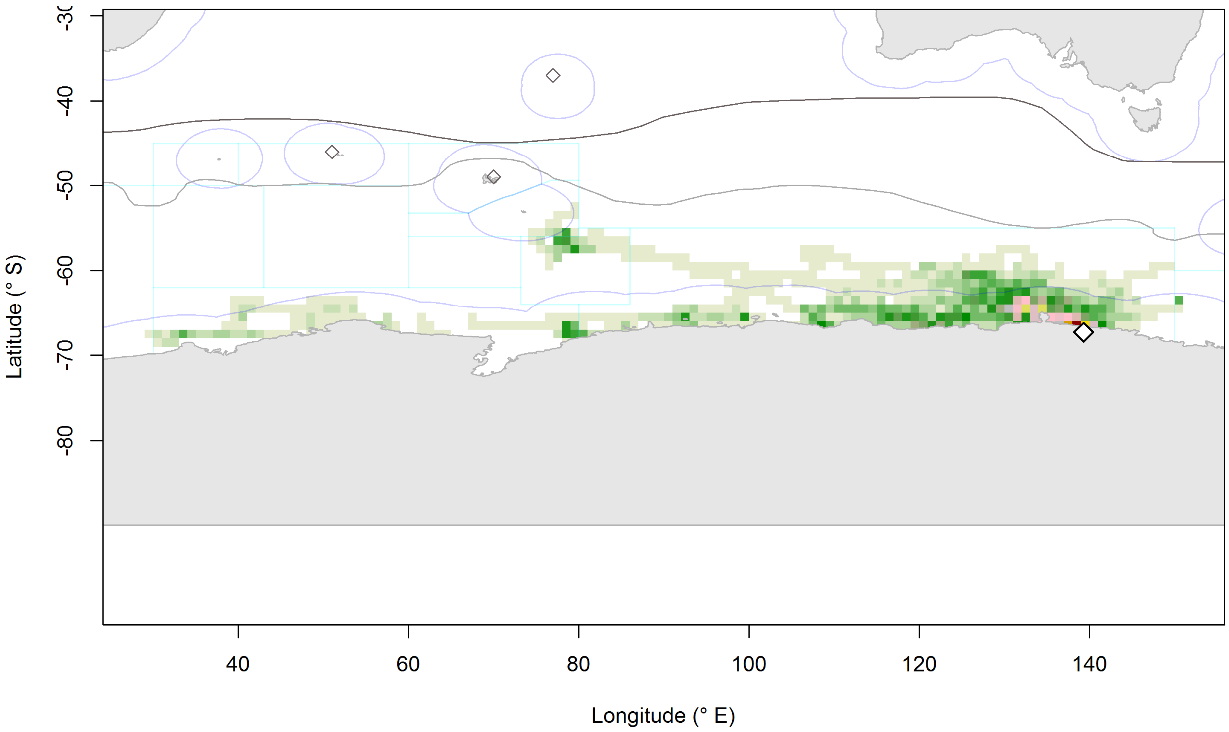
Important areas

GLS tracking data available for the colony of Pointe Géologie (Adélie Land) indicate that *P. nivea* are widely distributed in oceanic, shelf and shelf-slope waters, exclusively in productive Antarctic waters (Map 68). The adults spend most of the times around the breeding colony, off the Adélie Land sector and distribute westward up to eastern part of southern Indian Ocean, off Queen Maud Land sector.



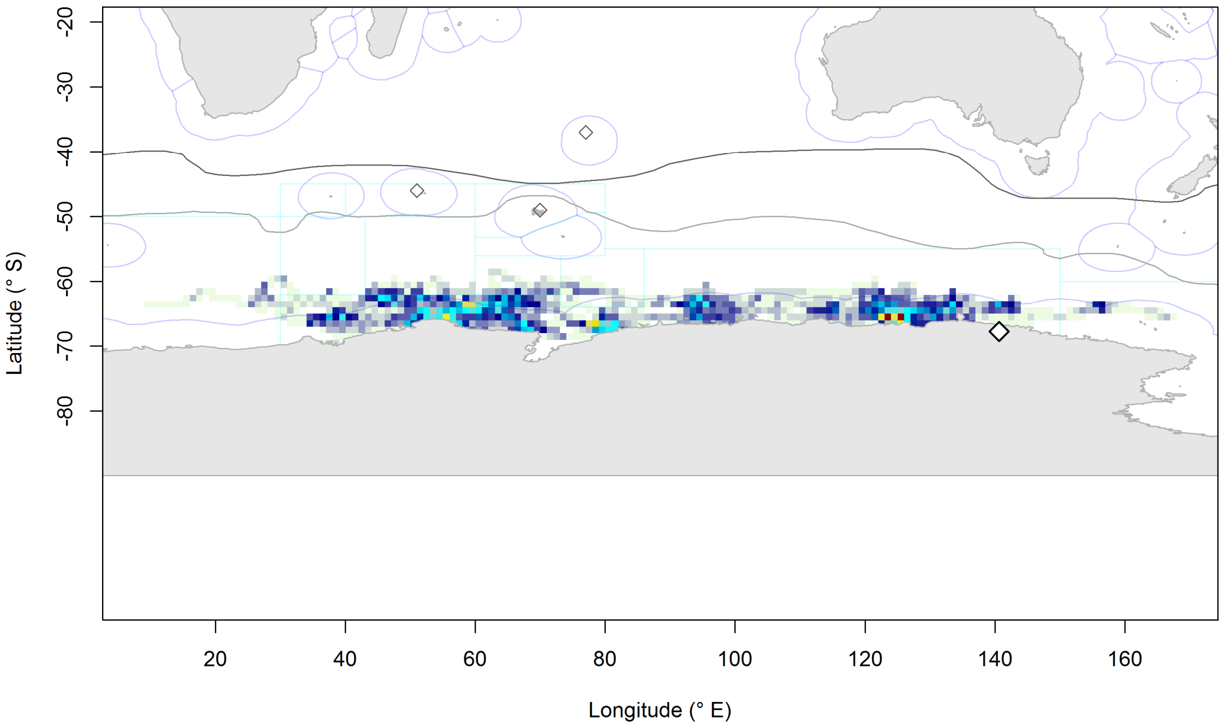
Map 68. *Snow petrel. Adélie Land.* Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Adults of *P. nivea* during breeding period target waters around the colony, off Adélie Land, where the highest values of residence time are observed (Map 69).
During pre-laying exodus adults may reach distant waters, up to Heard and McDonald Islands.



Map 69. *Snow petrel. Adélie Land*. Observed distribution (GLS; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During inter-nesting period *P. nivea* from Terre Adélie move westward from their breeding site (Map 70). Important wintering sites area appeared spread along the coasts of the Antarctic continent between 160°E off Oates Land and 20°E off Dronning Maud Land. The most important zones are located ≈200 km west from Adélie Land, off Enderby Land and in the Prydz Bay area. Birds remain in the pack ice zone in winter, and are not restricted to the edge of the pack ice.



Map 70. *Snow petrel*. *Adélie Land*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. *P. nivea* is an ice dependant species, inhabiting hostile, remote areas, avoiding human persecution and lacking any significant threats to its survival. Climate change and decrease in sea ice extent could, however, threaten this species in the future as its phenology and demographics appear to be sensitive to changes in sea ice concentration (Barbraud and Weimerskirch, 2006). The species is not attracted by fishing vessels and its diet is mainly composed of species not targeted by fisheries (Antarctic silverfish). Low levels of pollutants were found in tissues and eggs of snow petrels (Luke et al., 1989a;Norheim et al., 1982) and few or no plastics in stomachs (Van Franeker and Bell, 1988) but these should be reassessed.

Gaps & Stakes. Further Information on the distribution of birds of different age classes and at different stages of the annual cycle is required to better assess important areas for this species. More accurate data based on GPS or Argos transmitters on the distribution of snow petrels during the breeding season would be necessary.
In the absence of any significant threats to its survival, *P. nivea* has not been the target of any specific conservation measures. There is however a need for more detailed systematic surveys and monitoring at other breeding sites to assess the potential effects of ongoing and future climate change on the species distribution and abundance.

Petrels/White-chinned petrel

Procellaria aequinoctialis

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@N. Gasco

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Procellaria* /Species *P. aequinoctialis*

Annual breeder

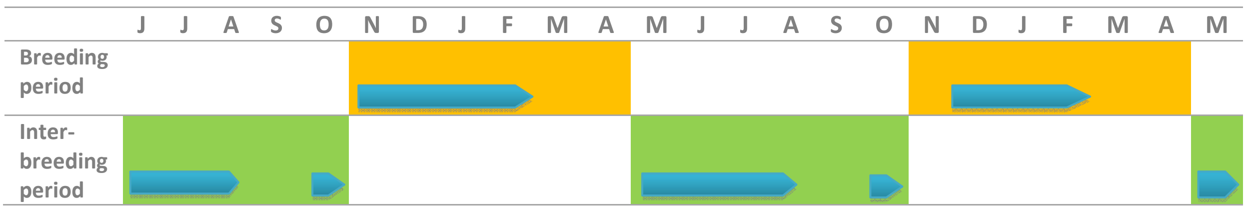
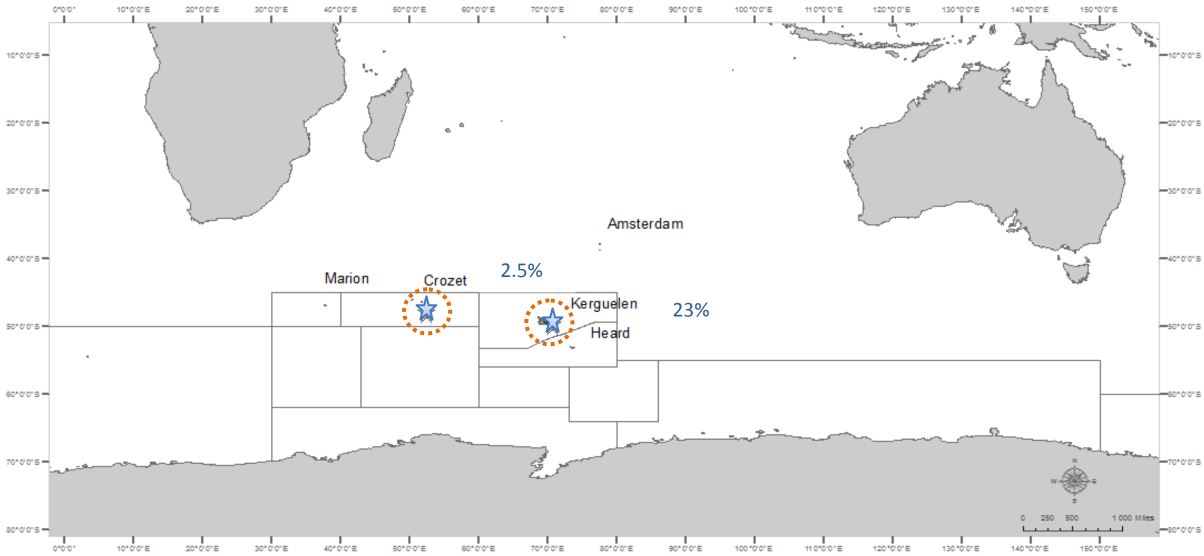


Table 24. *Breeding cycle and availability of tracking data (purple arrow) of* P. aequinoctialis

Regional Breeding Sites. *Procellaria aequinoctialis* is a colonial species that breeds annually, and is the largest of the burrowing petrels (c. 1100 – 1500g). *P. aequinoctialis* has a wide distribution and breed on the French, New Zealand and South African subantarctic islands, as well as on South Georgia and the Falklands (ACAP 2010i). French Southern Territories are thought to hold 25% of world estimated population.



Population trends. There are few data on population trends. Recent surveys indicated overall decline of breeding populations for Bird Island (South Georgia), Marion Island, Crozet and Kerguelen Islands (Barbraud et al., 2009;Barbraud et al., 2008;Berrow et al., 2000;Nel et al., 2002b).
A complete survey of Possession Island (Crozet) in 1983 and 2004 indicated an overall decrease of 37.1% from 8 377 (95%CI: 8,020-8,733) to 5 783 (95%CI: 5,538-6,028) breeding pairs (Barbraud et al., 2008). There was an estimated 186 000 to 297 000 *P. aequinoctialis* burrows at Kerguelen Islands in 2005 (Barbraud et al., 2009), which is similar to an earlier survey that estimated 100 000 to 300 000 breeding pairs in 1985- 1987 (Weimerskirch et al., 1989), although both surveys used different methodologies.

Diet and stable isotopes. Chick food at Crozet and Kerguelen Islands is dominated by fish (50-79% by mass), with cephalopods ranking second (12-25%) and crustaceans third (9-21%) (Catard et al., 2000;Connan et al., 2007;Delord et al., 2010a;Ridoux, 1994). The main fish prey are oceanic species, including myctophids and paralepidids, with some deep-sea macrourids being also eaten at Kerguelen Islands. Stomach oil analysis confirms the dietary importance of myctophids for the white-chinned petrel (Connan et al., 2007). Cephalopod items are oceanic squids, the main species being the brachioteuthid *Slosarczykovia circumantarctica*. Crustacean prey include mainly the hyperiid *Themisto gaudichaudii* and euphausiids. The common occurrence of Antarctic krill *E. superba* in food samples indicates adults forage at least in part in high-Antarctic waters during the breeding period. The presence of fish and squid bait together with offal in the samples underlines the strong relationship of white-chinned petrels with fisheries occurring in Crozet and Kerguelen waters (Catard et al., 2000;Delord et al., 2010a).

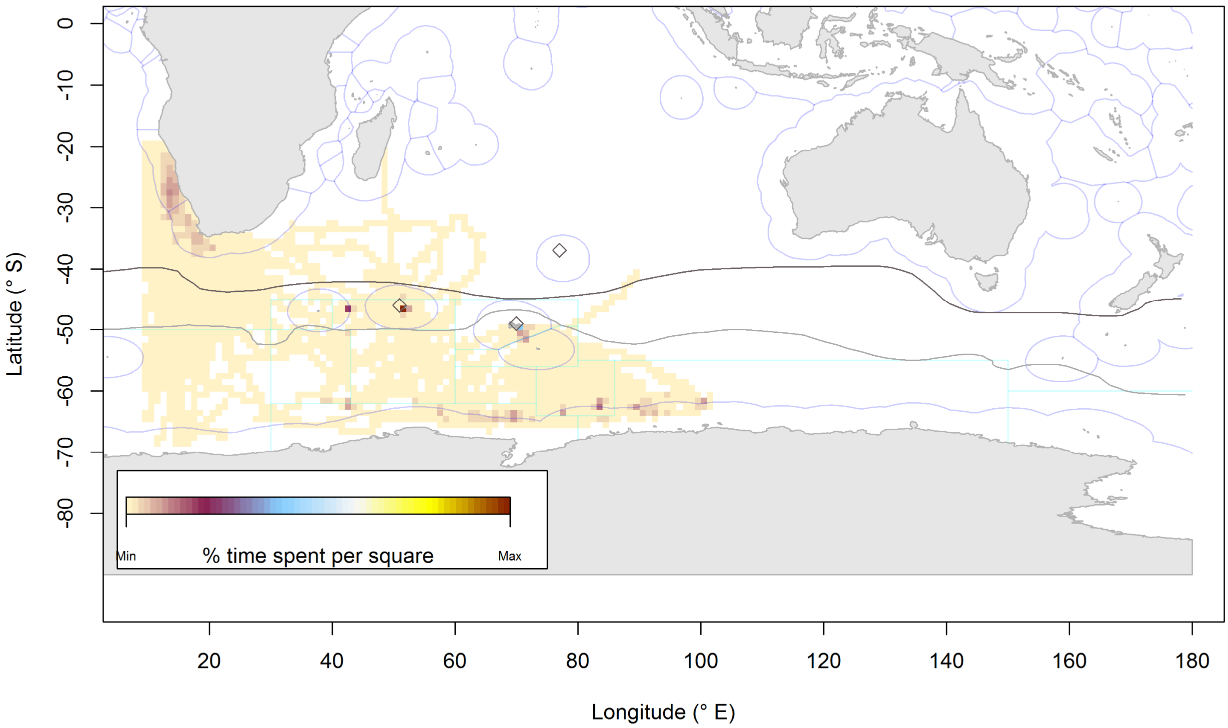
Feather isotopic ratios are almost similar for birds from Crozet and Kerguelen Islands (Blévin et al., 2013;Jaeger et al., 2010a), unpublished data). Chick $\delta^{13}C$ values are low (the lowest $\delta^{13}C$ value for oceanic species from Kerguelen) and intermediate between those from subantarctic and Antarctic organisms. They highlight the importance of Antarctic foraging for parent birds during the chick-rearing period. In contrast, the very positive $\delta^{13}C$ and $\delta^{15}N$ values of adult feathers indicate that

Crozet and Kerguelen white-chinned petrels winter in the Benguela Current. However, lower isotopic values on some Kerguelen birds show they partly moult in subantarctic and Antarctic waters.

Marine distribution.

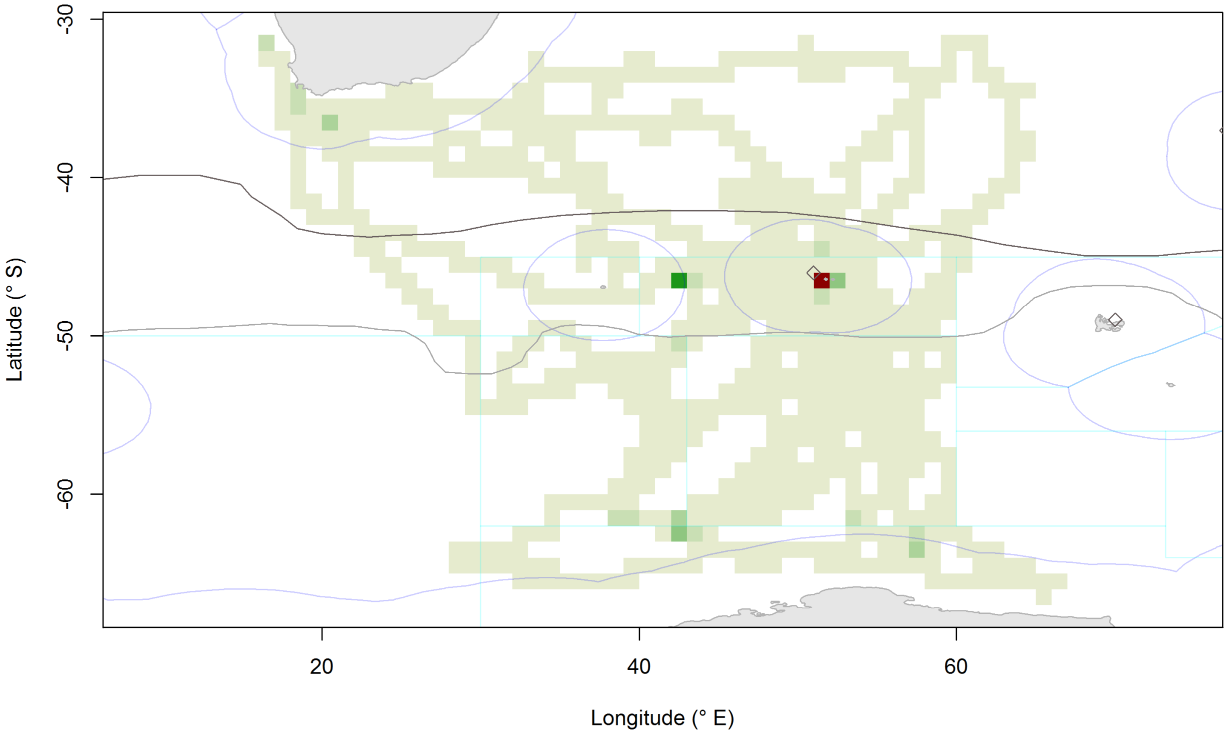
Important areas

The highest residence times for adults are situated around colonies, in Antarctic waters and in the Benguela Current System, off Namibia and South Africa (Map 71).

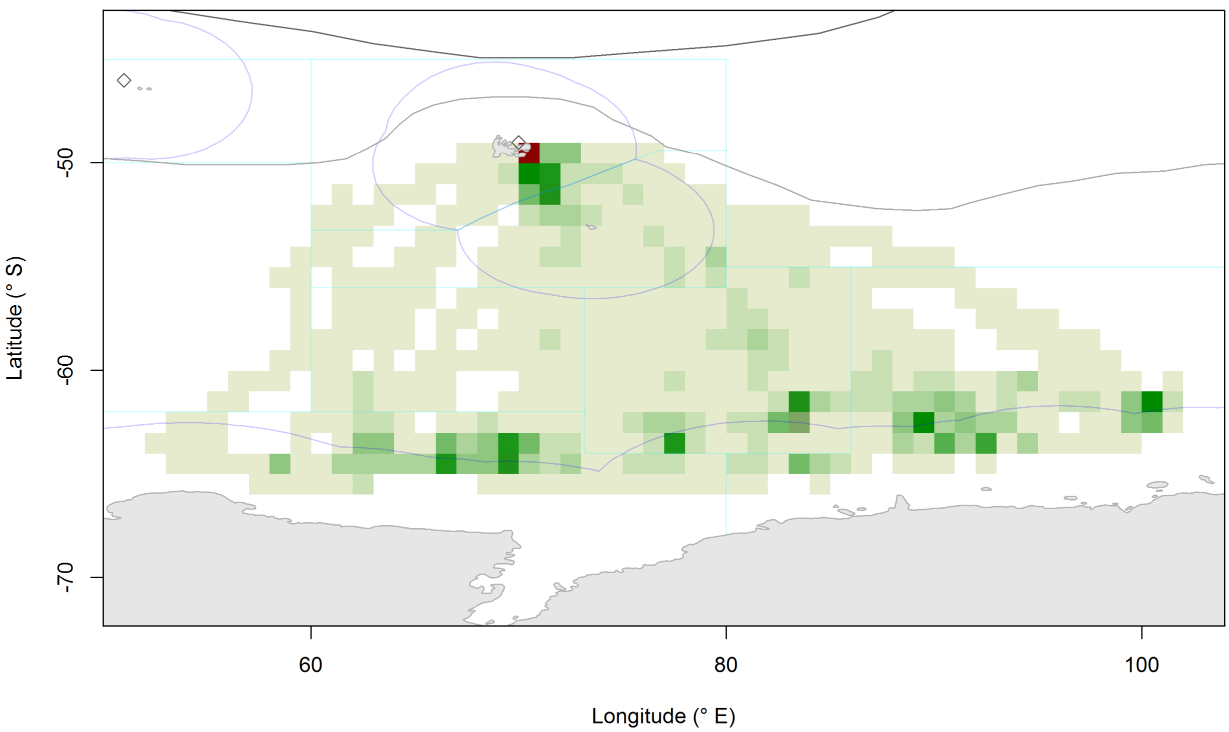


Map 71. *White-chinned petrel, Crozet Islands and Kerguelen Islands*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding season *P. aequinoctialis* from Crozet and Kerguelen are widely distributed in oceanic, shelf and shelf-slope waters (Catard et al., 2000;Péron et al., 2010b;Weimerskirch et al., 1999)(Maps 72 & 73). They concentrate in three distinct water masses: the shelves surrounding the breeding grounds, the productive Antarctic waters along the continent and the Benguela current.



Map 72. *White-chinned petrel, Crozet Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

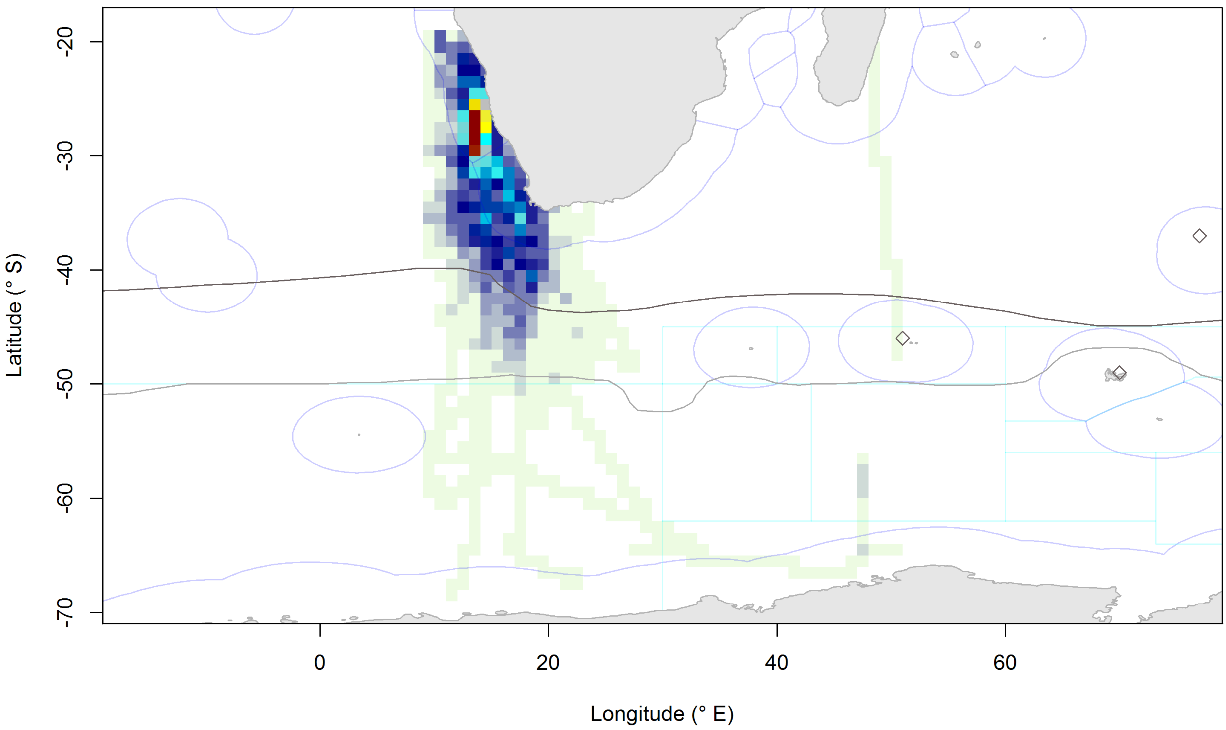


Map 73. *White-chinned petrel, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin,

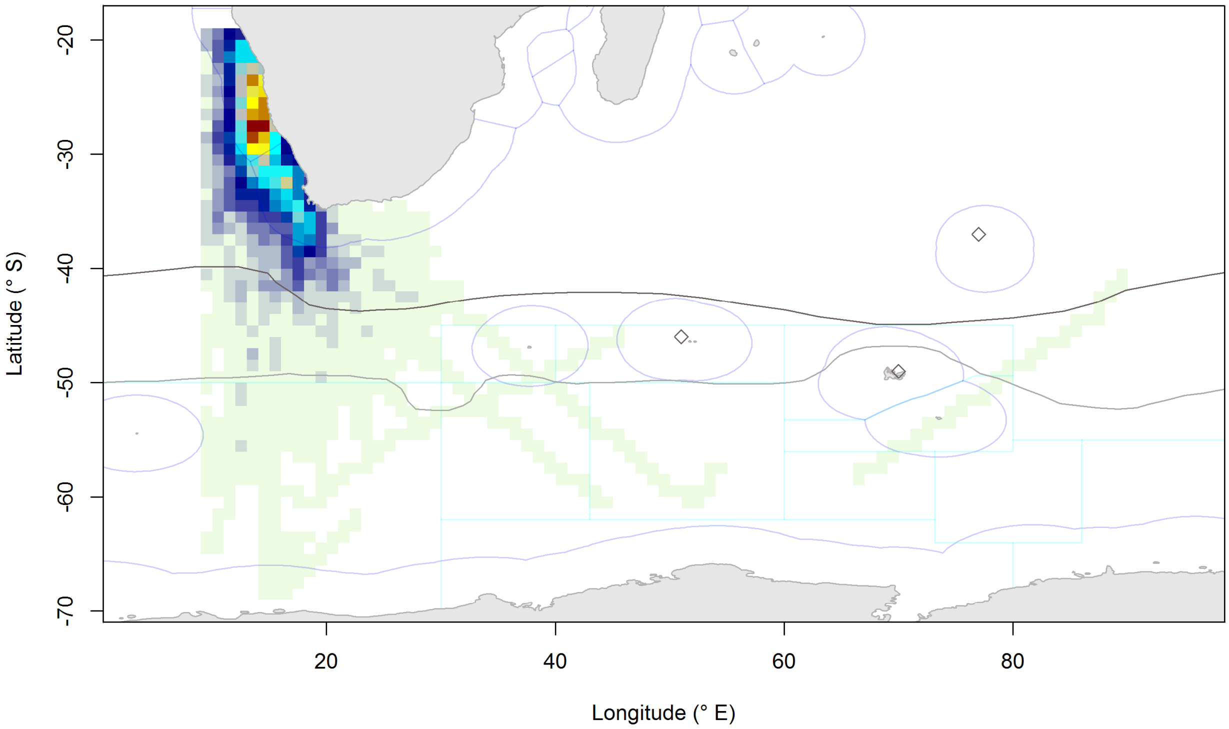
1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding season, white-chinned petrels have a large foraging zone that extend from tropical to Antarctic waters (Weimerskirch et al., 1999). During incubation Crozet birds remain in subtropical to subantarctic waters, whereas Kerguelen birds forage in Antarctic waters. During chick rearing, birds of both sites forage to the south of the colonies tracking the gradual break up of pack ice (Péron et al., 2010b).

During the non-breeding season, white-chinned petrels from Crozet and Kerguelen migrate westwards to the Benguela upwelling system off Namibia and South Africa to spend the winter (Péron et al., 2010b) (Maps 74 & 75).



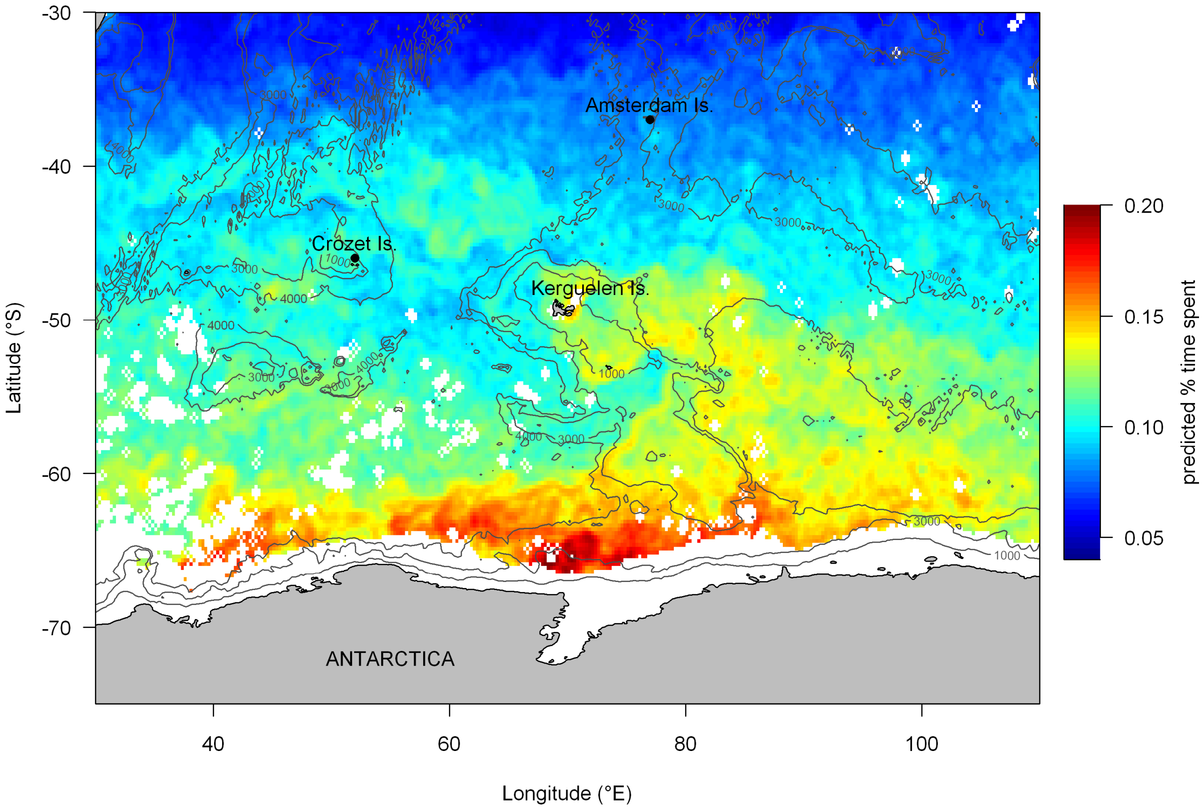
Map 74. *White-chinned petrel, Crozet Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 75. *White-chinned petrel, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

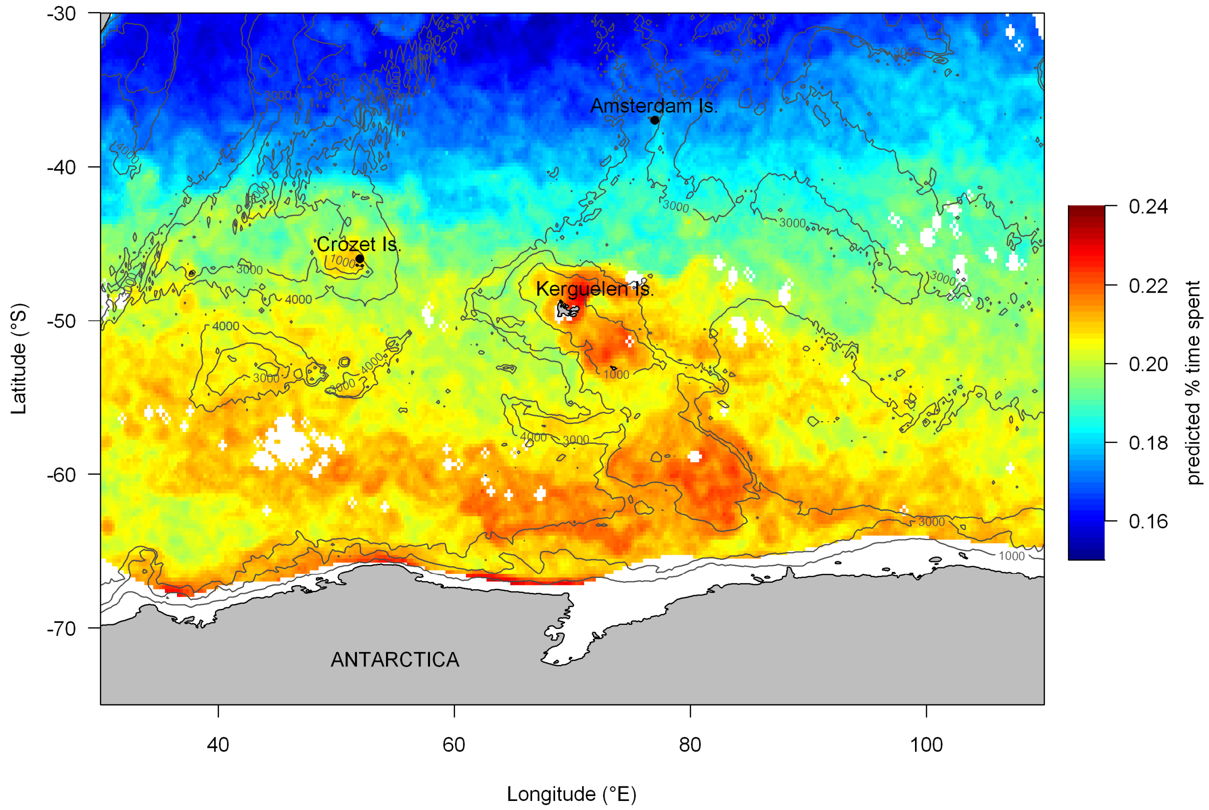
Habitat selection modeling

A hierarchical modeling approach was used to relate oceanographic variables to residence times estimated via Argos data collected during the breeding season (see (Péron et al., 2010b)) for detailed methodology; Annex I). Environmental variables were selected depending on their biological relevance (likely to influence foraging behaviour) and availability in the study area (52 to 102° E, 45 to 66° S) and included bathymetry: BAT; sea surface temperature: SST; chlorophyll-a concentration: CHLA; and their gradients: BATG, SSTG, CHLAG.



Map 76. *White-chinned petrel*. Man spatial predictions of percentage of time spent within each spatial unit obtained by habitat modeling during incubation (Argos data; Time spent per square in each 0.25° cell) of adult. Bathymetry is shown (Péron et al., 2010b).

During chick rearing, residence time was negatively related to SST and positively associated with CHLAG. SST appeared to be a better predictor of residence time than distance to pack ice later in the breeding season. SSTG was retained by the model selection procedure but its influence on residence time was minor during both stages ((Péron et al., 2010b); Table 3). Model ranking indicated that BAT and BATG had weak influences on spatial allocation of time spent at sea. The cross-validation procedure revealed poor predictive performance (r^2 test = 0.28 and 0.30 for incubation and chick rearing, respectively, (Péron et al., 2010b)). However, the averaged spatial predictions of the percentage of time spent matched well with the observed patterns ((Péron et al., 2010b); Maps 76 & 77).



Map 77. *White-chinned petrel*. Man spatial predictions of percentage of time spent within each spatial unit obtained by habitat modeling during chick-rearing (Argos data; Time spent per square in each 0.25° cell) of adult. Bathymetry is shown (Péron et al., 2010b).

During incubation, white-chinned petrel foraging zones were restricted to a narrow latitudinal strip along the pack ice, and zones of maximal CHLAG ((Péron et al., 2010b); Map 76), whereas during chick rearing, seasonal sea ice areas and SST was the most important predictor leading to much larger potential habitat ((Péron et al., 2010b); Map 77). The habitat model for chick-rearing birds identified a key foraging area -the Kerguelen plateau- which was visited during short trips.

Habitat use models revealed an association with distance to sea-ice edge and chlorophyll a gradient during incubation, whereas sea surface temperature and chlorophyll a gradient best explained habitat use during chick rearing.

Threats. According to ACAP (ACAP 2010i), in the southern hemisphere, *P. aequinoctialis* is one of the species most vulnerable to incidental mortality in fisheries (trawl and longline) where seabirds interact with commercial vessels (Barnes et al., 1997;Delord et al., 2005;Delord et al., 2010b;Huin, 1994;Nel et al., 2002d;Watkins et al., 2008;Weimerskirch et al., 2000). *P. aequinoctialis* is known to be killed in longline fisheries off southern Africa and around the subantarctic islands in the Indian Ocean, as well as in trawl fishing operations around the Kerguelen Islands and in New Zealand waters. In trawl fisheries, the birds usually die when they strike warps or get entangled in the mesh of the net; some strike netsonde cables. There are also reports that floating lines from small vessels have been used to target *P. aequinoctialis* in the waters off southern Angola (Roux et al., 2007). The worst mortalities occur in longline fisheries, and a disproportionate number of males to females are killed. Over 26 000 seabirds were reported killed off the Crozet and Kerguelen Islands (CCAMLR Subarea 58.6 and Division 58.5.1) from September 2001 to August 2003, the vast majority (c. 92%)

being *P. aequinoctialis* (Delord et al., 2005). Although from 2003 to 2006 the number of *P. aequinoctialis* killed in that area was reduced from > 14 000 in 2002/03 to c. 2 500 in 2005/06 and further under 100's in the late 2000's, approximately 40 000 *P. aequinoctialis* have been killed incidentally since early 2000's(Delord et al., 2005;Delord et al., 2010b). At the Crozet Islands, mortality is much lower than at Kerguelen in recent years, but a detailed demographic analysis indicates that both climate and fisheries have affected the population and are responsible for its decline (Barbraud et al., 2008).

Gaps & Stakes. Further information on the distribution of birds of different breeding colonies and at different stages of the annual cycle (particularly young adults, non-breeding adults and migration period) is required to better assess overlap with fishing operations.
Very high rates of incidental mortality in longline fisheries have been reported in recent years (Delord et al., 2010b;Watkins et al., 2008). Further information on bycatch levels in all fisheries is needed and effective mitigation measures for this nocturnal foraging and relatively deep-diving species need to be monitored in more detail.

Petrels/Grey petrel

Procellaria cinerea

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@N. Gasco

TAXONOMY

Order Procellariiformes / Family Procellariidae / Genus *Procellaria* /Species *P. cinerea*

Annual breeder

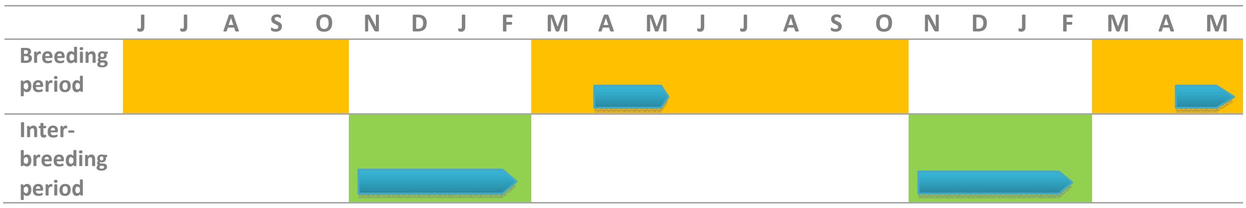
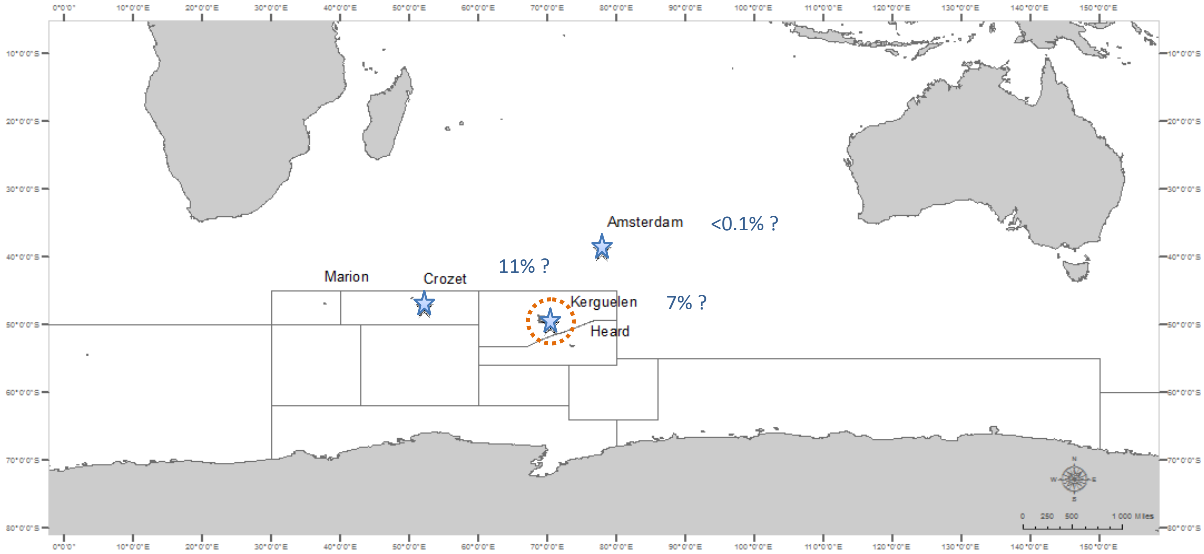


Table 25. *Breeding cycle and availability of tracking data (purple arrow) of* P. cinerea

Regional Breeding Sites. *Procellaria cinerea* is a colonial, winter-breeding species. It is a burrow-nesting, annual breeder. *P. cinerea* has a wide distribution and is known to breed on the South

African, French, New Zealand and Australian subantarctic islands, as well as on Amsterdam Island, and in the Gough and Tristan de Cunha group.



Population data are scarce and accurate census data for most breeding sites are currently lacking (ACAP 2010f). The largest population is thought to occur on Antipodes Island, with a mean of 53 000 breeding pairs estimated in 2001 (Bell, 2002). Over 10 000 pairs have been estimated to breed on Gough Island in 2001 [R. Cuthbert in (Brooke, 2004)], and thousands on Crozet, Kerguelen and on the Prince Edward Islands. Macquarie, Amsterdam, Campbell and Tristan Islands hold much smaller populations.

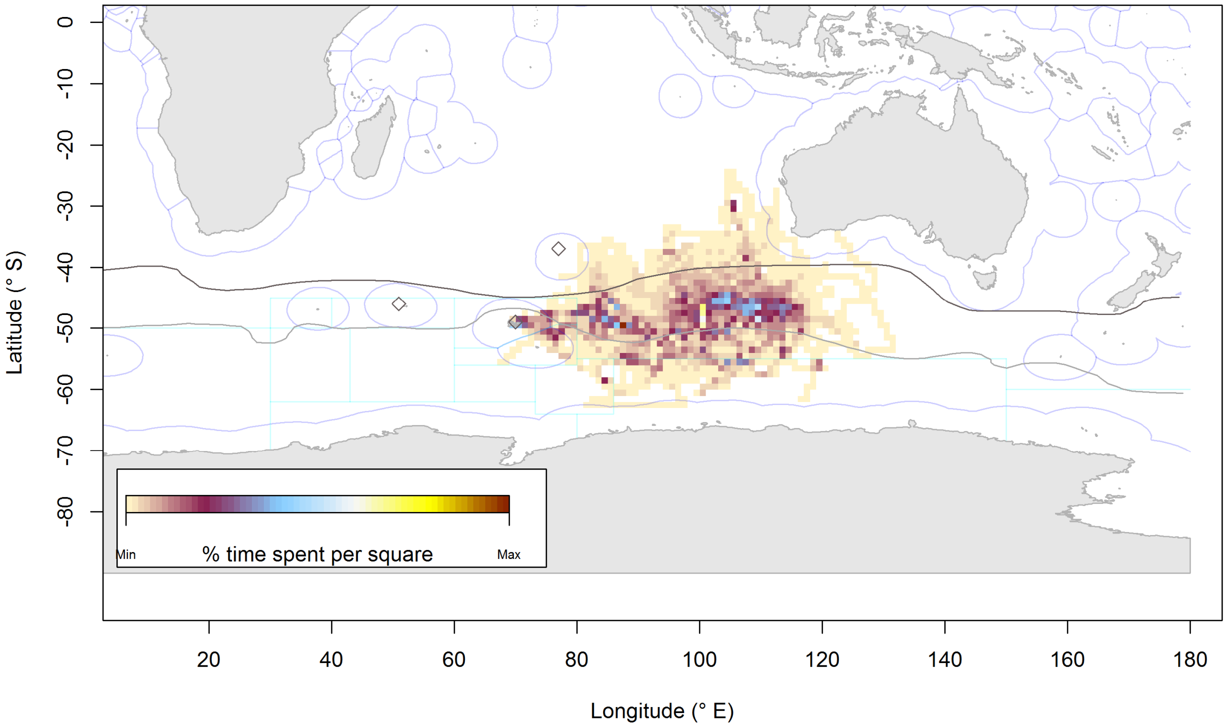
Population trends. There are no data on population trends for most of the breeding sites and no demographic study, with the exception of Kerguelen Islands. An ongoing capture-mark-recapture program has yielded information on demographic parameters since the 1980s. The potential biological removal method suggests that the additional mortality on birds caused by the fisheries operating around Kerguelen can be considered a serious threat for the species at least at the regional scale of the Southern Indian Ocean (Barbraud et al., 2009;Delord et al., 2005;Delord et al., 2010b). The smallest population on Amsterdam Island comprised only 5-10 pairs at the last estimate in the 1980s; however, the fossil record indicates that the island probably once supported one of the largest colonies in the world (Worthy and Jouventin, 1999).

Diet and stable isotopes. Chick food at Kerguelen Islands is dominated by fish (65% by mass), with cephalopods ranking second (27%) and crustaceans being negligible (1%) (unpublished data). Preliminary analysis shown that grey petrels feed on a large diversity of fish that includes neritic, slope and oceanic species, while cephalopod prey are all oceanic squids. The presence of fish bait together with offal in the samples underlines the strong relationship of grey petrels with the Patagonian toothfish longline fishery occurring in Kerguelen waters (Delord et al., 2005;Delord et al., 2010b).
Feather $\delta^{13}C$ and $\delta^{15}N$ values show that adults caught prey for their chicks in subantarctic waters, where the species occupies a high trophic position within the community of oceanic seabirds (Blévin et al., 2013). The $\delta^{13}C$ values of adult feathers indicate moulting from low subantarctic to subtropical waters, including the vicinity of the Subtropical Front (unpublished data).

Marine distribution.

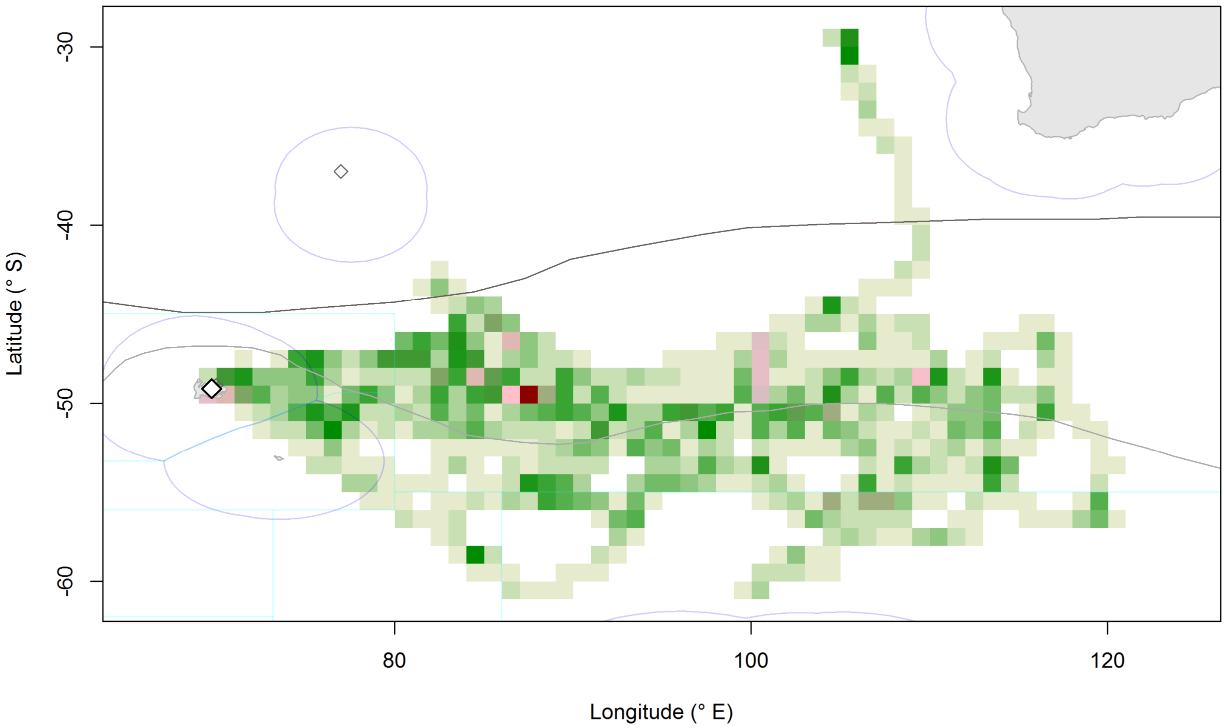
Important areas

Recent studies conducted at Kerguelen Island showed that *P. cinerea* forage in eastern waters of Kerguelen (Map 78), up to 2 000 km from their colonies during winter (breeding period, Map 79), and that grey petrels exploit the same foraging area during summer (non-breeding period; Map 80).



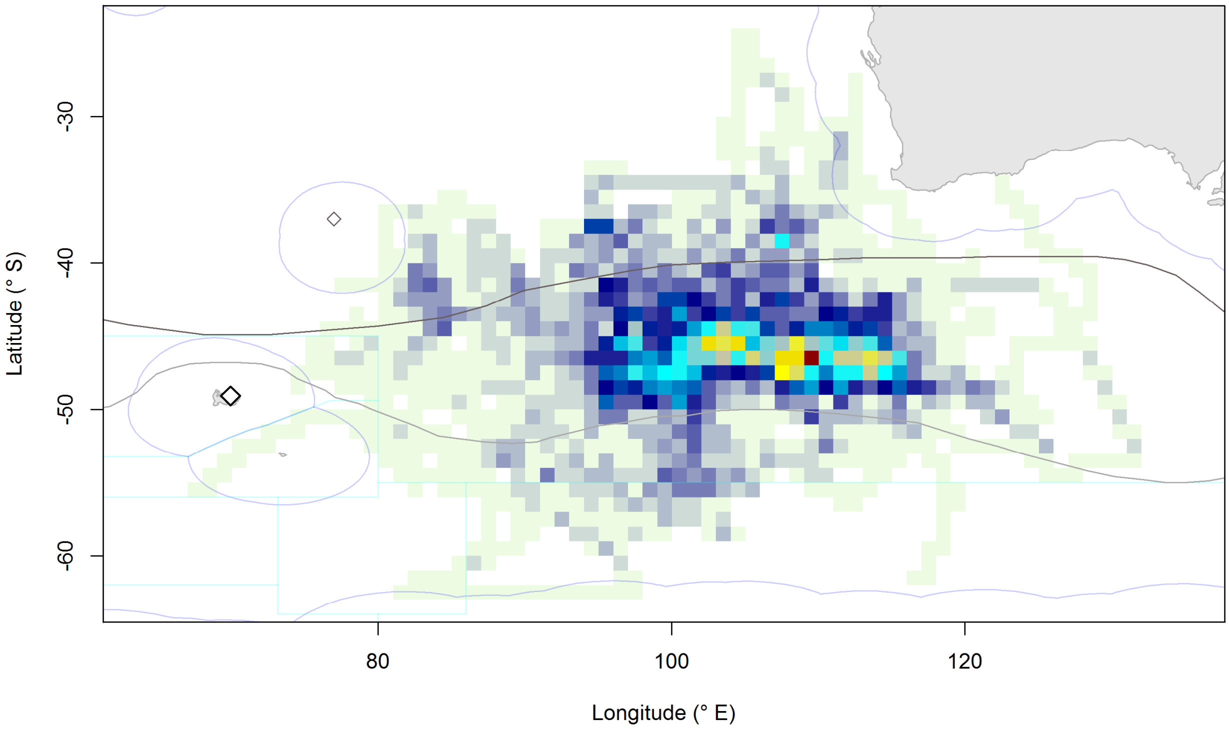
Map 78. *Grey petrel, Kerguelen Island*. Observed distribution (satellite and geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Adults of *P. cinerea* target oceanic waters eastward from Kerguelen, between South Subtropical Front and Polar Front, where they spent a large amount of time throughout the breeding and inter-nesting periods.



Map 79. *Grey petrel, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Although the main foraging grounds are similar during summer and winter, during the inter-nesting period *P. cinerea* distribute over a wider zone, moving to the north, and usingwatersnorth of the sub-tropical front up to 30°N.



Map 80. *Grey petrel, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. According to ACAP, at sea, the key threat to *P. cinerea* is from commercial longline fisheries. *P. cinerea* was the fourth most common species observed killed in New Zealand fisheries between 1998-2004, but the second most common observed killed on bottom longline vessels (after White-chinned petrels)(Waugh et al., 2008).
The species has also been recorded as bycatch in the Patagonian toothfish fishery around the Prince Edward Islands (1% of all seabirds observed killed in 1996-2000), where males made up over 80% of the carcasses examined (Nel et al., 2002d). Substantial incidental mortality may also occur in high seas in the southern Indian Ocean but seabird bycatch information is partial for this region [Huyser et al. 1999 in BirdLife International 2012]. A minimum of 755 *P. cinerea* has been estimated to be killed annually in the legal and illegal Patagonian toothfish fisheries around Kerguelen since 1996 (Barbraud et al., 2009;Delord et al., 2005;Delord et al., 2010b), which is more than double the annual mortality of 300 individuals calculated to result in a decline of the Kerguelen population (Barbraud et al., 2009).

Gaps & Stakes. For Kerguelen, further Information on the distribution of birds at different stages (particularly during the breeding period) of the annual cycle is required to better assess the important areas and the overlap with fishing operations. No information is available for Crozet. Further information on bycatch levels in longline fisheries which operate in international waters is also required to assess the impact of potential interactions with these fisheries on *P. cinerea* populations.

SKUAS

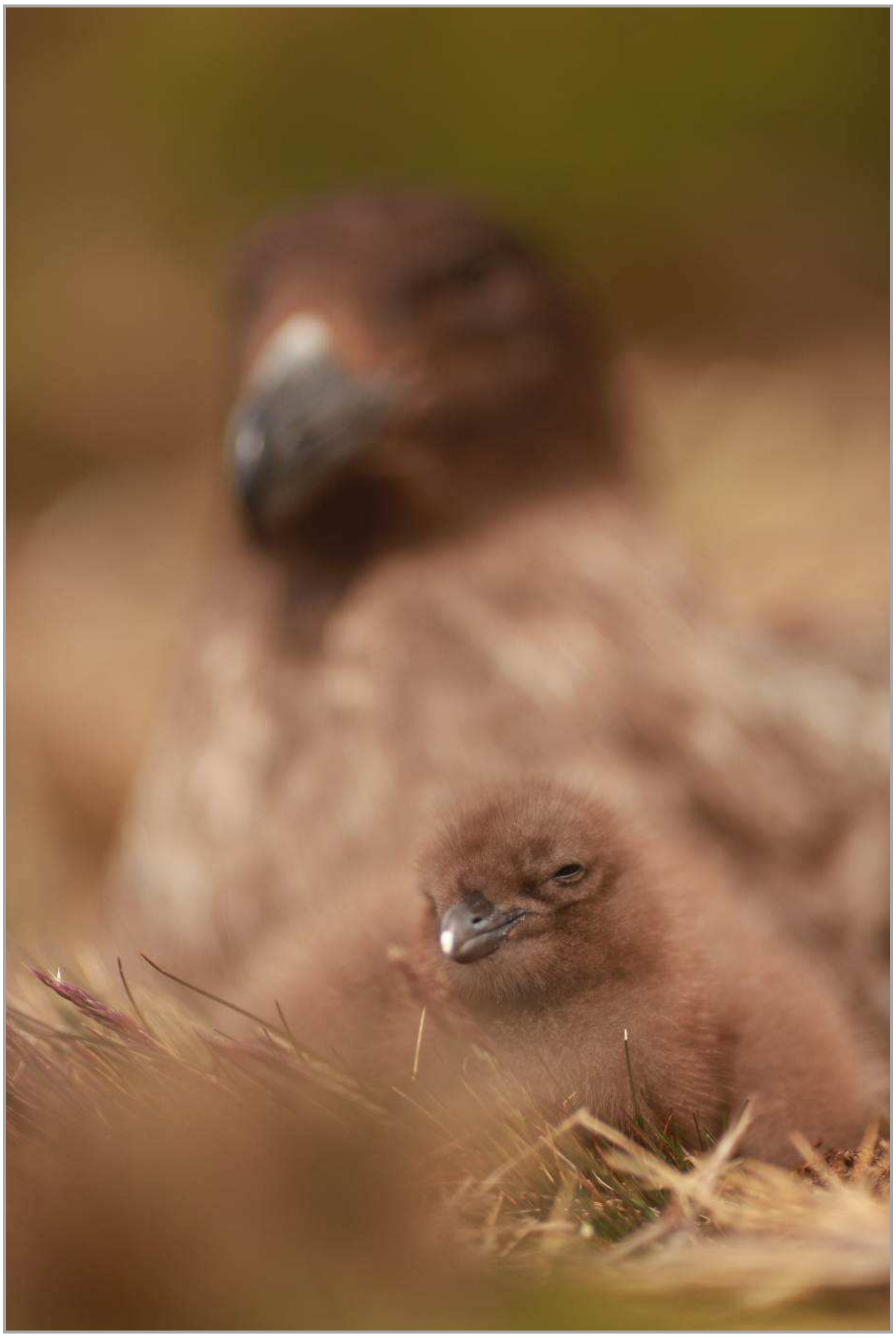
Skuas of French Southern Territories in the Southern Indian Ocean

The systematics of the skua species is debated and currently two genera are recognized: the *Stercorarius* species, which includes three species that breed on some islands or mainland sites in the Arctic and subarctic regions, and migrate in the Southern Indian Ocean during the non-breeding season, and the *Catharacta* species, which includes four species. Of these species, two commonly breed in the Southern Indian Ocean (cf Table 1), the Brown (*C. antarctica*) and South Polar (*C. maccormicki*) Skuas. The Brown Skua is sub-divided into three sub-species (del Hoyo et al., 1996) and the the Atlas focused on one sub-species breeding in the French Southern Territories for which tracking data are available: *C. a. lonnbergi*. The tracking of skuas started recently and consequently tracking data are missing for several important breeding sites for Brown Skuas (e.g. Crozet, Marion and Prince Edward, Amsterdam). The breeding populations of skua species appear to be stable and are included on the IUCN Red List as Least Concerned species.

Skua/Brown skua

Catharacta antarctica lonnbergi

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED



@T. Lacombe

TAXONOMY

Order Charadriiformes / Family Stercorariidae / Genus *Catharacta* / Species *C. antarctica* / Sub-species *C. a. lonnbergi*

Annual breeder

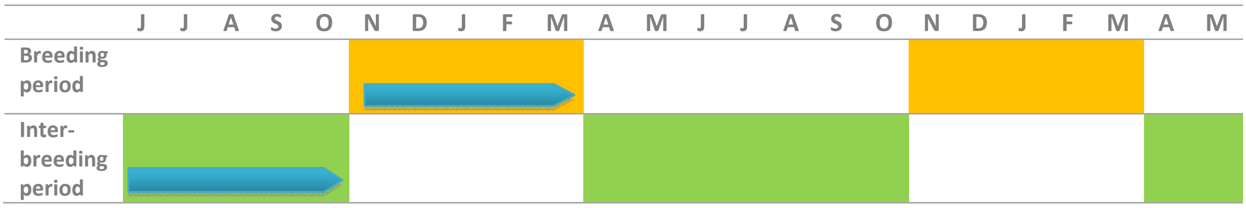
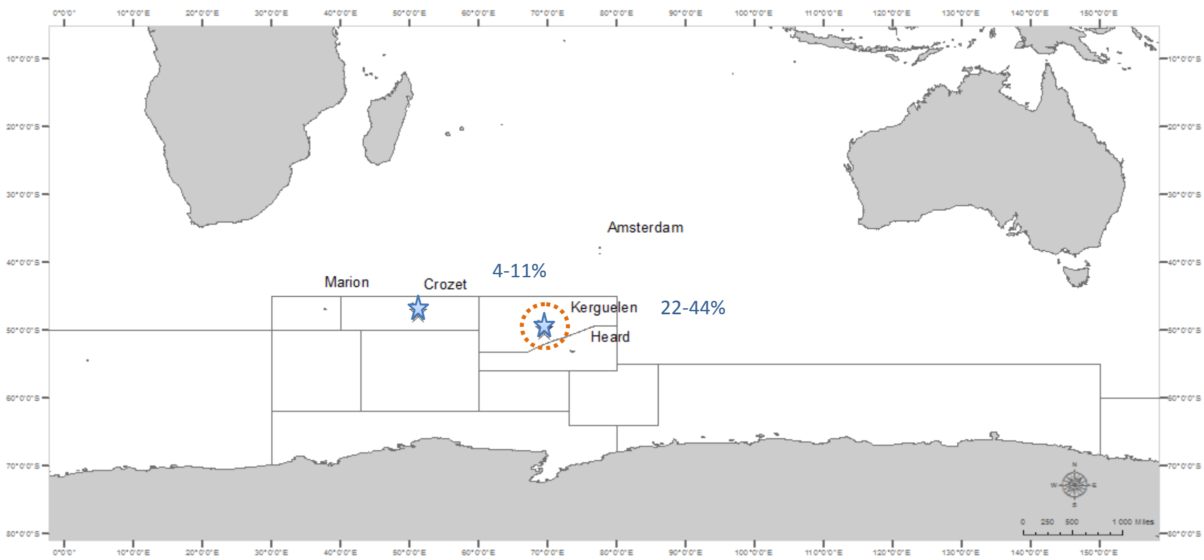


Table 26. *Breeding cycle and availability of tracking data (purple arrow) of* C.a.lonnbergi

Regional Breeding Sites. *Catharacta antarctica lonnbergi* is a loosely colonial species. It has a wide distribution and breeds on the Antarctic Peninsula, subantarctic islands of Atlantic, Indian and Pacific Oceans (del Hoyo et al., 1996). French Southern Territories may hold ≈30-50% of world estimated breeding population (Kerguelen ≈ 2000-4000 breeding pairs, Crozet ≈ 400-1000 breeding pairs), although global and regional breeding population estimates are very imprecise.



Population trends. Regular monitoring of *C. a. lonnbergi* has been conducted on Mayes island, a small island of the Morbihan Gulf (Kerguelen). The breeding population was stable between 1996 and 2012 (unpublished data). On Marion Island the number of breeding pairs decreased between 1987 and 2008 but remained stable in the nearby Prince Edward Island between 2001 and 2008 (Crawford et al., 2003). At South Georgia, the breeding population has increased from the late 1950s to the early 1980s (3.6% per annum), followed by slower growth (0.9 p.a.) (Phillips et al., 2004a).

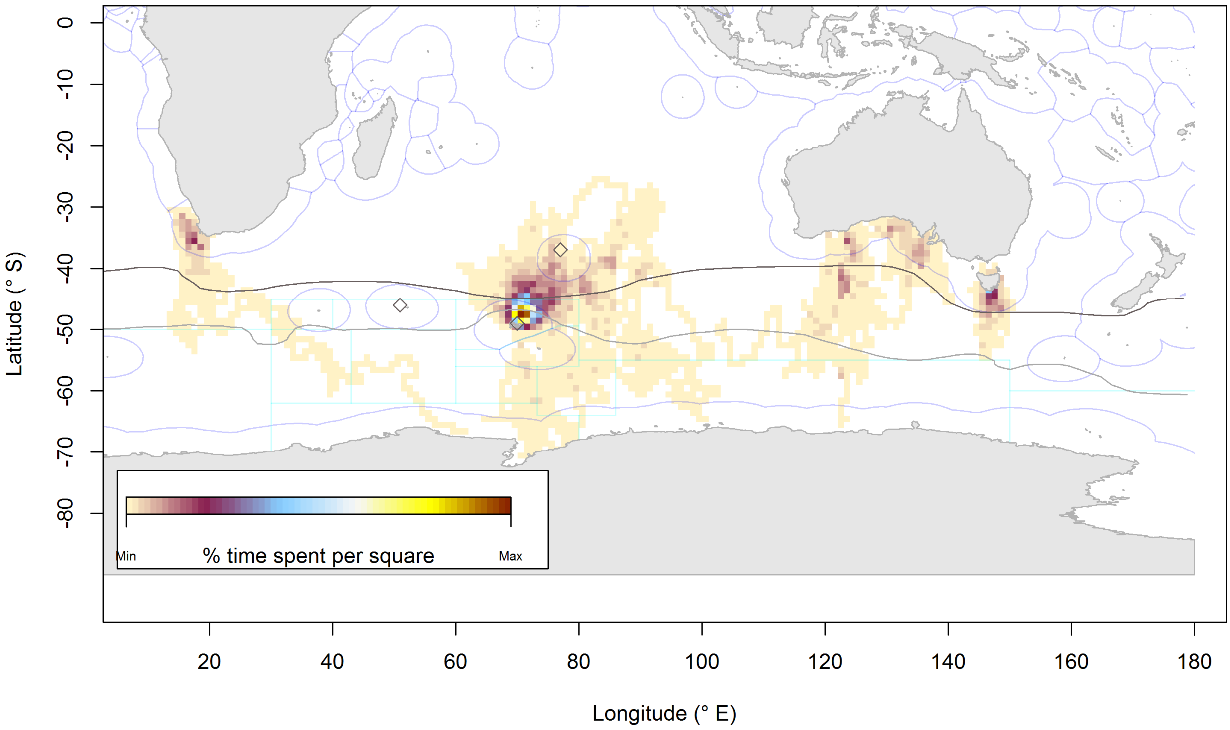
Diet and stable isotopes. Prey items were collected in the vicinity of skua nests during a complete breeding cycle at the study colony of Mayes Island. Only remains of burrowing petrels were found, with blue petrels *Halobaena coerulea* and thin-billed prions *Pachyptila belcheri* accounting for 73% and 19% of the total number of prey, respectively. In a few cases, skuas were observed catching introduced house mice *Mus musculus* (Mougeot et al., 1998). In two nearby islands, the summer diet was also dominated by small petrels, with common rabbits *Oryctolagus cuniculus* being caught when present near the breeding sites (Moncorps et al., 1998).
At Mayes Island, the feather isotopic values of chicks show they are fed with mid-trophic level prey that forage in subantarctic and Antarctic waters, which is consistent with adults catching small

burrowing petrels on land (Blévin et al., 2013). In contrast, $\delta^{13}C$ values of adult feathers indicate moulting primarily in various habitats of the subtropical zone. Feather $\delta^{15}N$ values show adult skuas feed on organisms from three different trophic levels in winter, including amazingly low trophic level prey that remain to be determined (unpublished data).

Marine distribution.

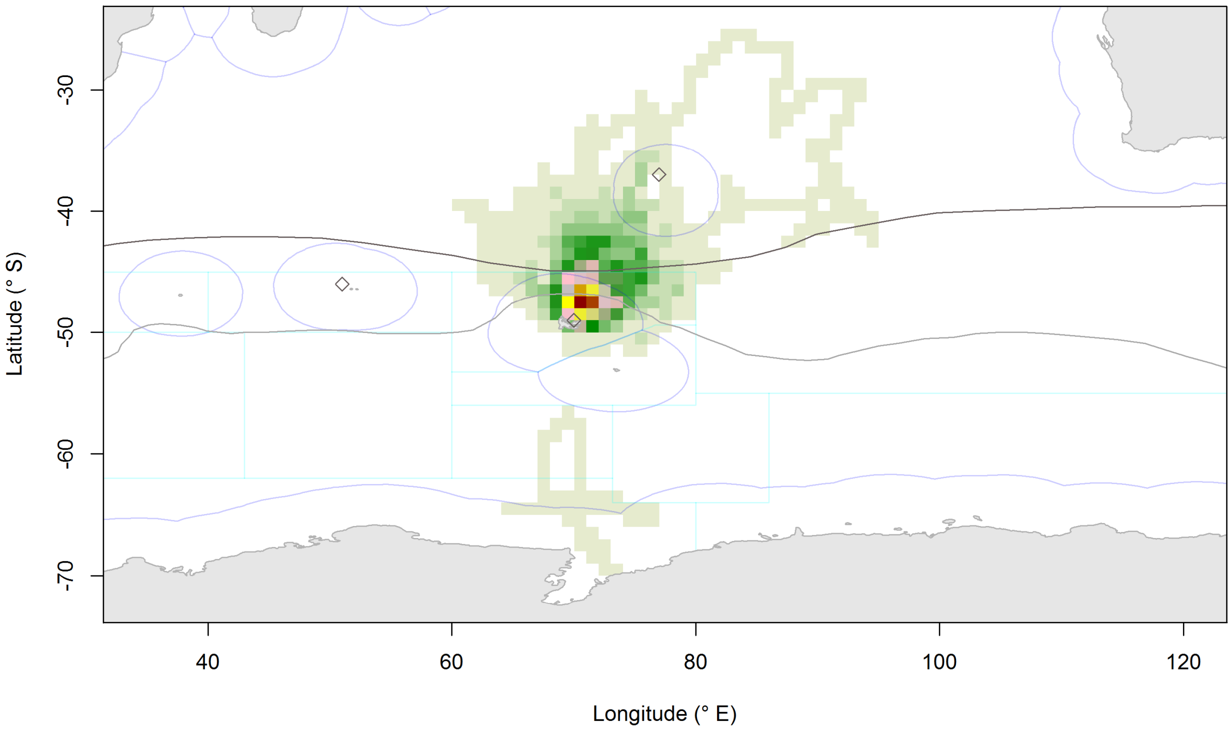
Important areas

Recent studies conducted at Kerguelen Island showed that *C. a. lonnbergi* disperse widely in the Southern Indian Ocean, up to 6 000 km from their colonies during winter (non-breeding period), and that brown skuas remain in the vicinity of Kerguelen during the breeding season (Map 81).



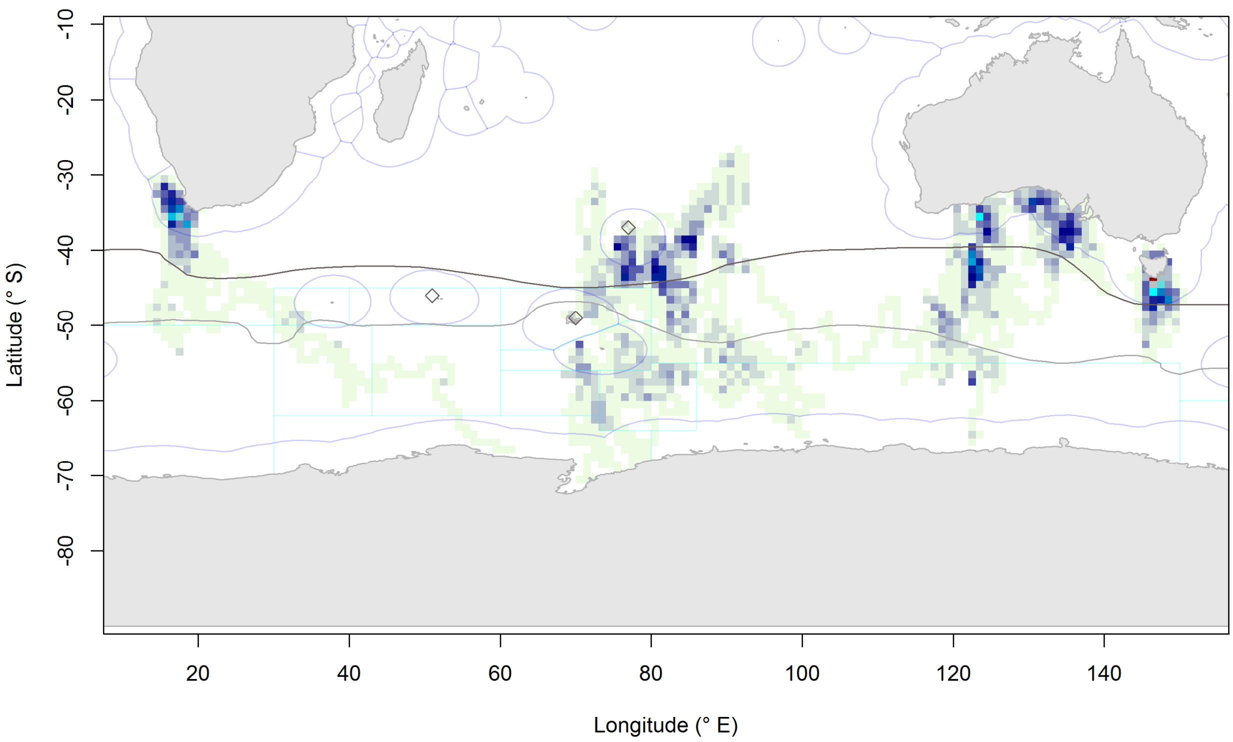
Map 81. *Brown skua, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the breeding season (Map 82), the highest residence time for adults (using GLS) appears to be located northeast of Kerguelen in oceanic waters between South Subtropical Front and Polar Front. Nonetheless, this distribution is not in accordance with field observations showing that adults are sedentary during the breeding period, feeding around colonies, predating small petrels. These observations are corroborated by diet analysis.



Map 82. *Brown skua, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult birds during the breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the non-breeding period individuals from Mayes Island (Kerguelen) disperse widely across the Southern Indian Ocean (Map 83). Tracked individuals moved north, east and west of Kerguelen, some spending the winter in the Benguela upwelling, others in waters northeast of Kerguelen and the rest in the Great Australian Bight and Tasmania. There is however large inter-individual variation in the wintering areas, and some individuals seem to frequent subantarctic and Antarctic waters south of the Polar Front following the breeding season.



Map 83. ***Brown skua, Kerguelen Island*. Observed distribution (geolocator data; Time spent per square in each 1° cell) of adult birds during the inter-nesting period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. The effects of climate change on brown skuas are not documented but given their trophic position and the reported effects of climate change on one of their main preys during the breeding season (Barbraud and Weimerskirch, 2003;Nevoux and Barbraud, 2006), future climate change may affect brown skua population dynamics. There is some evidence that some skua species get caught in longline fisheries, although numbers caught seem relatively low (Anderson et al., 2009;Melvin and Parrish, 2001);(Brothers et al., 2010), and longlining may not represent a serious threat for brown skuas. Because brown skuas are apex predators, they may be particularly sensitive to bioaccumulation and biomagnification of contaminants. High levels of mercury were found in great skuas (*C. skua*) (Thompson et al., 1991) and in the brown skua population at Mayes Island, Kerguelen (Blévin et al., 2013), which could have deleterious effects on breeding and survival. Introduced mammalian predators (rats, cats) on some subantarctic islands may indirectly negatively affect populations of brown skuas by removing some of their main prey species (small burrowing petrels).

Gaps & Stakes. For Kerguelen, larger sample sizes are needed of birds tracked during multiple years given the apparent important inter-individual variations in wintering areas. During the breeding season, data on fine scale movements are lacking since brown skuas were only tracked with GLS. Also tracking data are needed for other breeding sites in the region, including Crozet, Amsterdam and Marion Islands.
Detailed studies are needed on the effects of contaminants (heavy metals, PCBs) and climate change on the demographic parameters and population dynamics of brown skuas. Further information is also needed about the wintering tactics of individuals to help identify the main wintering areas of the populations of this species.

PINNIPEDS

Pinnipeds of French Southern Territories in the Southern Indian Ocean

The Southern Indian Ocean is regularly used by 3 species of pinnipeds, one phocid the Southern elephant seal (*Mirounga leonina*) and 2 species of fur seals the Antarctic (*Arctocephalus gazella*) and Subantarctic (*A. tropicalis*) fur seals (cf. Table 1).

The 3 species are year round residents of the Indian sector of the Southern Ocean, but we lack information on the winter distribution of the two fur seal species. The species were all heavily exploited in the 19th century and up to the 20th century for the elephant seals. Fur seals were hunted for their fur nearly to extinction and recovery started during the second part of the 20th century for all localities from a reduced number of individuals, generally less than 100 per breeding localities. Elephant seals were hunted for their fat until the early 1960's at Kerguelen, but populations while seriously depleted never reached extinction levels for most of the subantarctic localities.

Pinnipeds, and more especially elephant seals, are major consumers of marine resources of the Southern Ocean. The impact of fur seals on the food web is increasing as their populations are recovering, but population sizes for most localities, with the exception of Amsterdam and Saint Paul Islands, are thought to be below pre-exploitation levels. Fur seal and elephant seal females are key predators of mesopelagic myctophids ranging from subtropical to Antarctic waters. The food ecology of males remains poorly described but they are known to be feeding on higher trophic levels than females and therefore on different, but mostly unknown, prey items. While Antarctic and subantarctic fur seals can be benthic as well as mesopelagic predators, elephant seal subadult and adult males are almost exclusively benthic predators.

Breeding population sizes of most populations are increasing or stable depending on the species but mostly on the breeding location. Their sizes are thought to be mainly controlled through density dependence mechanisms and no direct threats related to human activity is currently identified. Entanglement in fishing gears and packing bands are likely the most important anthropogenic threats for fur seals. The three species are classified in Annex II as least concern species (Table 4).

Pinnipeds/Southern elephant seal

Mirounga leonina

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@CA. Bost

TAXONOMY

Order Carnivora / Family Phocidae / Genus *Mirounga* /Species *M. leonina*

Annual breeder

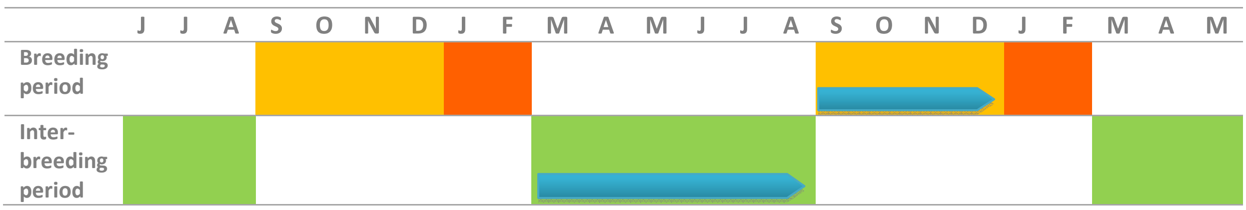
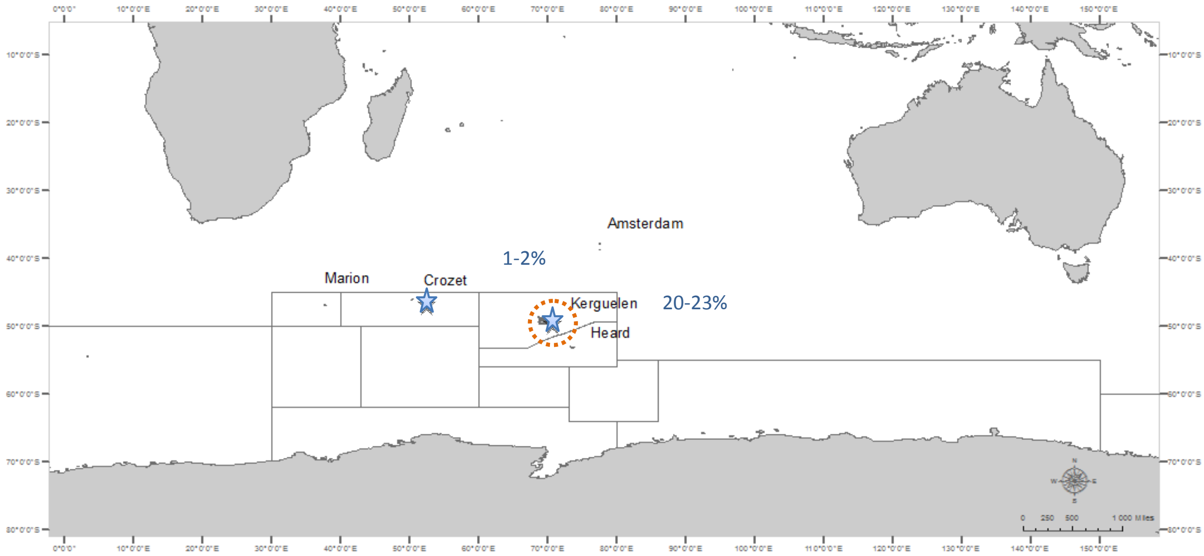


Table 27. *Breeding cycle and availability of tracking data (blue arrow) of* M. leonina. Shaded cells indicates moulting period on land.

Regional Breeding Sites.



Population trends. Both Crozet and Kerguelen elephant seal populations exhibited a prolongated decrease in population size during the 1960's and 1970's. The decline was sharper and occurred over a longer period on Crozet Islands (80% decline in population size) compared to Kerguelen Islands, which declined by 40% from the late sixties to the mid-eighties. The reasons for such declines are still debated but there is a general consensus suggesting that the decline of elephant seal populations from the southern Indian Ocean was first driven by a global environmental shift (Weimerskirch et al., 2003) and accentuated locally at Crozet by the killer whale (*Orcinus orca*) predation pressure (Authier et al., 2010;Guinet et al., 1999).
The Kerguelen population is estimated to be about 130 000-150 000 individuals (all age and sex classes confounded) while the Crozet population is currently estimated to be within the range of 8 000-12 000 individuals.

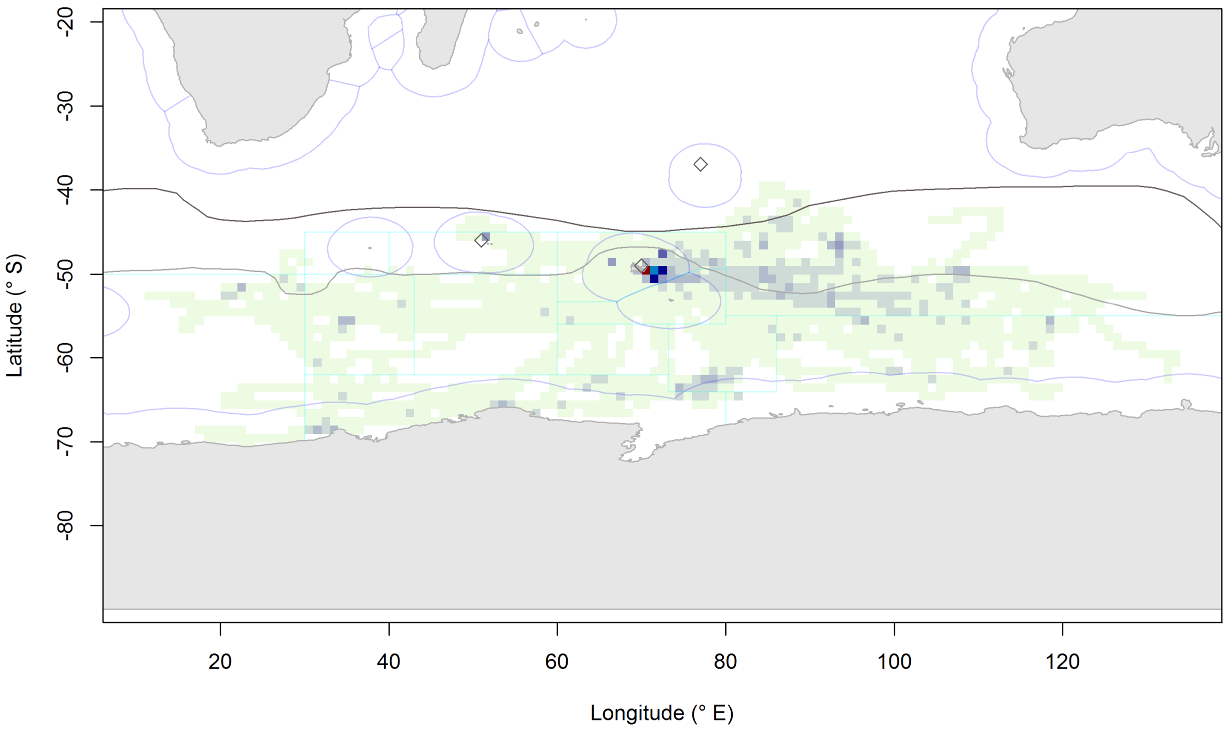
Diet and stable isotopes.
Stomach lavage on a few seals retrieved beaks from oceanic squids, with *Moroteuthis knipovitchi* and *Gonatus antarcticus* being the two commonest species (unpublished data). In the nearby Heard Island, squid remains were found in 100% of adult seals, with fish occurring in 74% of females (Slip, 1995). Since seals were fasting, no fresh remains were found thus inducing a bias towards items that better resist digestion and accumulate over the long term, e.g. cephalopod beaks.
At Kerguelen Islands, blood $\delta^{13}C$ and $\delta^{15}N$ values of lactating females and their pups show that adult females forage in subantarctic and Antarctic waters, where they most likely feed primarily on mesopelagic fish, with an estimated seal trophic position of 4.6 (Authier et al., 2012;Cherel et al., 2008;Ducatez et al., 2008). A preliminary isotopic investigation on adult males indicates a complete trophic segregation with adult females. Skin $\delta^{15}N$ values are higher in males and their $\delta^{13}C$ values show they forage over a wider range of habitats than females, both horizontally (from the subantarctic zone to high-Antarctica) and vertically (pelagic and benthic feeding) (unpublished data).

Marine distribution.

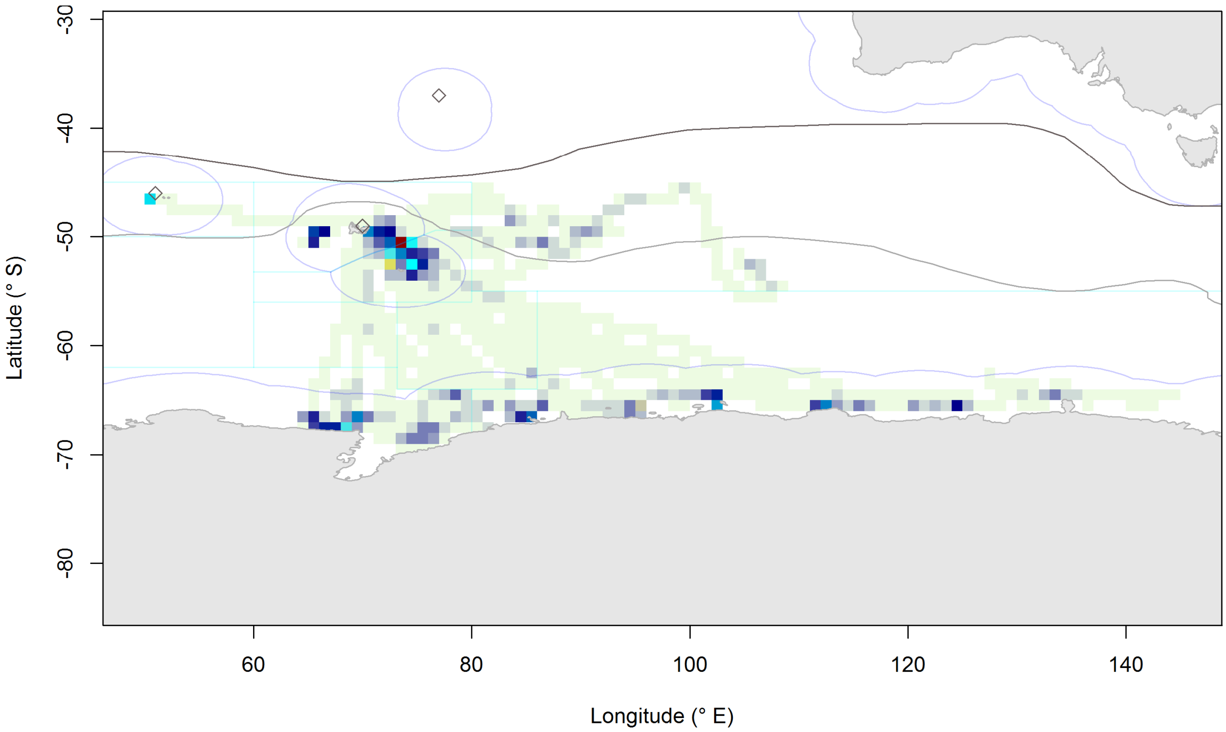
Important areas

Foraging locations information is only available for the Kerguelen population.

A spatial segregation is observed between females and males (Maps 84 & 85). The vast majority of males concentrate their foraging activity on shelf areas located on the Kerguelen and the Antarctic zones, however the respective proportion of males using both areas change according to age. By the age of 3-4, about 70% of the Kerguelen males forage on the Kerguelen plateau, mostly south of Kerguelen Island and 30% on the Antarctic shelf. For individuals older than 9 to 10 the opposite proportion was found leading to the question of the reason responsible for such changes. As individuals become faithful to their foraging habitat by the age of 4 this variation of proportion was interpreted as resulting from a differential survival of males according to their foraging locations, with Antarctic individuals exhibiting higher survival rates compare to subantarctic ones, either due to a better foraging success and/or a lower predation pressure. Elephant seal females forage predominantly over oceanic waters located between the subantarctic and the southern Antarctic Circumpolar Current fronts and east of Kerguelen Island. About 30% of the females were found to forage at least for one part of the year within the Antarctic zone, in close vicinity to sea-ice and a very small proportion of females (less than 5%) forage at least part of the year on the Kerguelen shelf. Seven to eight months post moulting foraging trips (February-October) extend further away from the breeding colony compare to the 2-3 months post breeding foraging trips (November-January).



Map 84. *Southern elephant seal, females, Kerguelen Island*. Observed distribution (satellite transmitters data; Time spent per square in each 1° cell) of adult during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 85. *Southern elephant seal, males, Kerguelen Island*. Observed distribution (satellite transmitters data; Time spent per square in each 1° cell) of adult during the inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Threats. No serious threats are currently identified. Bycatch of very few males in demersal longlines operated on the Kerguelen shelf have been reported by fish observers, but this remains anecdotal.

Gaps & Stakes. We are lacking information about the distribution of *M. leonina* from Crozet Island, although their stable isotope signature suggests a very similar ecology compared to Kerguelen Island. Furthermore no information is available on the at-sea distribution of first-year individuals. The cause of the differential survival of individuals according to their foraging habitat needs to be elucidated. Recent work suggests that females *M. leonina* are major mesopelagic myctophid predators, while subadult and adult males are benthic predators foraging on higher trophic level preys. There is a need to better identify male diet composition as they may be impacted by any fishery operating on the Kerguelen shelf seafloor. Southern elephant seal females could be more vulnerable if any significant large scale myctophid fishery were undertaken in the subantarctic zone. Myctophids represent the corner stone of the food web sustaining numerous penguins and pinnipeds species.

Pinnipeds/Antarctic fur seal

Arctocephalus gazella

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	NEAR THREATENED	LEAST CONCERN	NOT LISTED

@T. Jeanniard du Dot

TAXONOMY

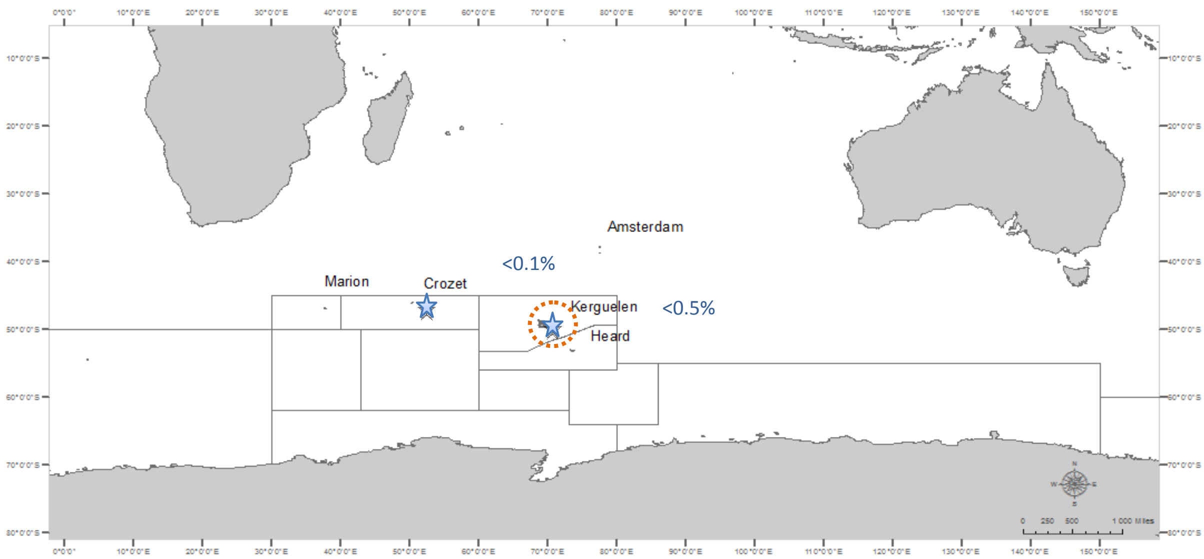
Order Carnivora / Family Otariidae / Genus *Arctocephalus* /Species *A. gazella*

Annual breeder

	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Breeding period																								
Inter-breeding period																								

Table 28. *Breeding cycle and availability of tracking data (blue arrow) of* A. gazella

Regional Breeding Sites.



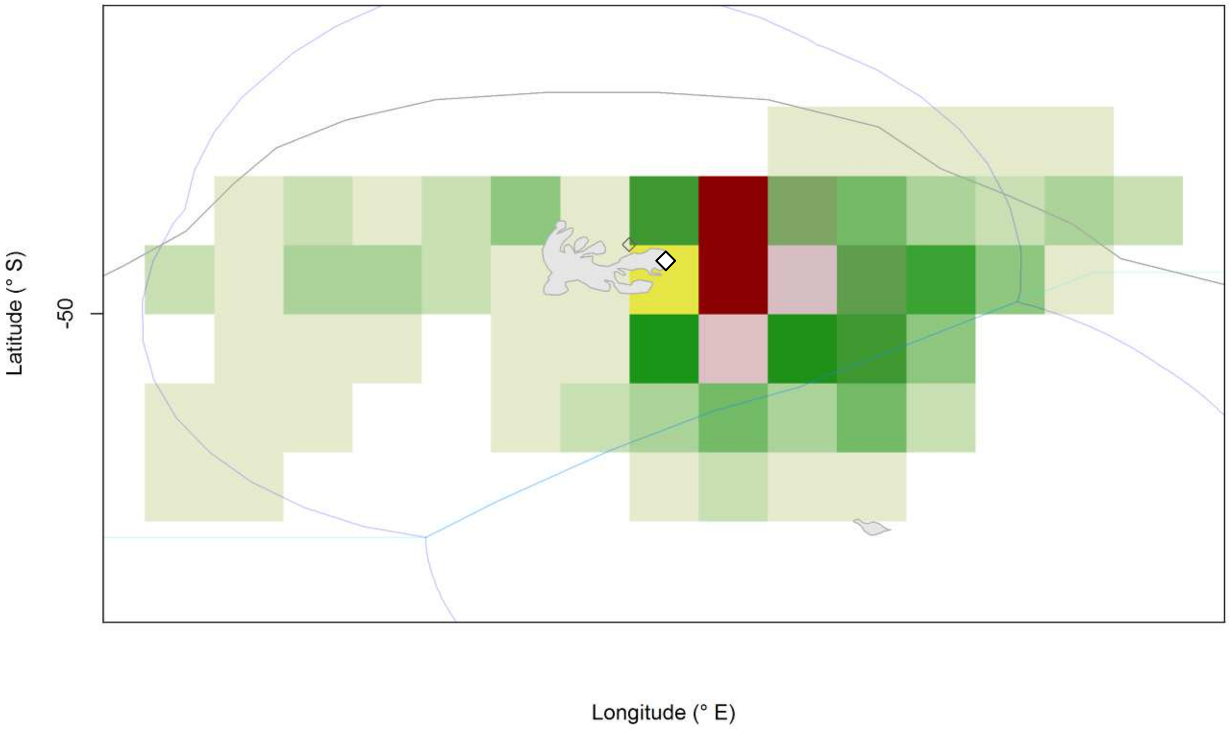
Population trends. Both the Crozet and Kerguelen populations are currently growing rapidly, and should continue to grow over the next decade as population size are thought to be well under pre-exploitation levels. We lack data on the exact size of the population for both locations as some colonies are occurring on islands which are rarely or never visited. Population size is in the order of tens of thousands on Kerguelen Island and in the range of a 1000-2000 on Crozet Island.

Diet and stable isotopes.
At the study colony of Cap Noir (Kerguelen), scat analysis shows that lactating females feed mainly on fish (91% by mass), with cephalopods accounting for the remainder (9%). Fish diet was dominated by oceanic myctophids, with *Gymnoscopelus piabilis* (26% by number), *Electrona subaspera* (18%) and *G. nicholsi* (11%) being the three main species. On warm years, the consumption of myctophids decreases, with a shift to the neritic icefish *Champsocephalus gunnari*. The main cephalopod prey is the ommastrephid squid *Martialia hyadesi* (Guinet et al., 2001;Lea et al., 2002;Lea et al., 2006). At Iles Nuageuses, female fur seals also prey primarily upon various species of myctophids (Cherel et al., 1997;Lea et al., 2008).
At Cap Noir, blood $\delta^{13}C$ and $\delta^{15}N$ values show that lactating females forage in oceanic waters, where they feed at a high trophic position (4.8) corresponding well with a myctophid-based diet (Cherel et al., 2008). Serially sampled whiskers show synchronous and regular oscillations in both their $\delta^{13}C$ and $\delta^{15}N$ values that are likely to represent the annual movement patterns of seals over several consecutive years. Whisker isotopic ratios indicate that adult females forage primarily in subantarctic waters all year long with limited dietary changes (unpublished data).

Marine distribution.

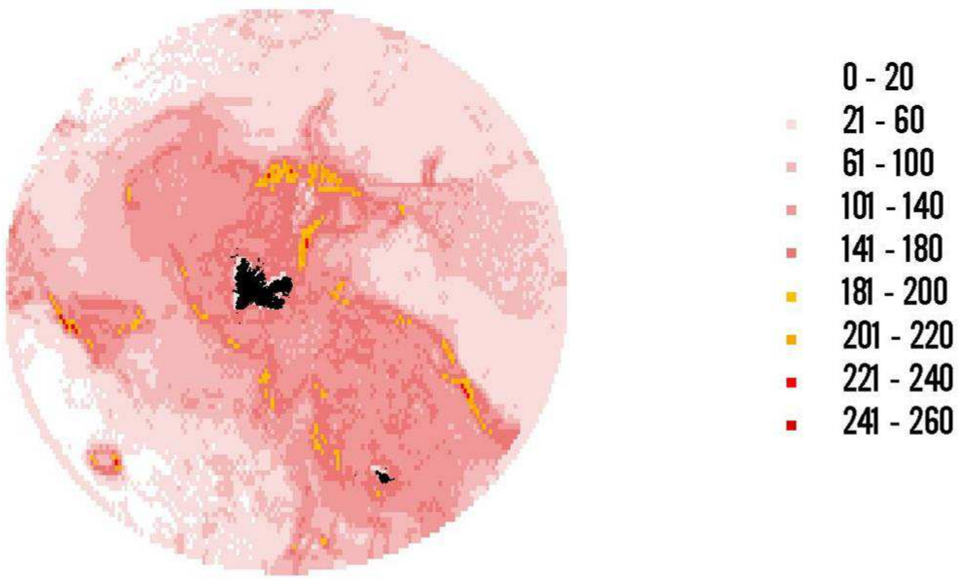
Important areas

Data are only available for breeding Antarctic females, and therefore we lack information about at-sea distribution for post breeding females, juveniles as well as adult males.



Map 86. *Antarctic fur seal, Kerguelen Island*. Observed distribution (satellite data; Time spent per square in each 1° cell) of adult during the breeding period. Oceanographic frontal structures is shown: the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Breeding females were found to concentrate their foraging activity on the outer edge of the Kerguelen shelf (Maps 86 & 87) where they forage almost exclusively on myctophids. Tracking data of breeding females were used to model their habitat according to bathymetric (depth and depth gradient) and oceanographic variables such as the sea surface temperature and surface chlorophyll-a concentration as well as their gradients. Bathymetric gradient was the largest contributing variable to the constructed model. Several key areas, all located along the Kerguelen-Heard shelf were identified and presented in Map 87.



Map 87. ***Antarctic fur seal, Kerguelen Island*. Habitat modeling of breeding females (satellite data) according to bathymetric (depth and depth gradient) and oceanographic variables (sea surface temperature and surface chlorophyll-a concentration as well as their gradients).**

Threats. No current threats are identified. The main issues remain the entanglement of individuals in packing bands and fishing gear and other marine debris. Indirect threats might be caused if any significant myctophid fishery was to be undertaken in the Indian sector of the Southern Ocean (which is not currently the case). Male fur seals are known to interact with the Patagonian toothfish fishery mostly at Kerguelen Island while very few interactions were observed at Crozet Islands. Fur seals were estimated to be responsible to fish loss varying from 0% to 1.6% depending on the season (Gasco et al. unpublished data)**.**

Gaps & Stakes. While data on the distribution of breeding females from 3 Kerguelen colonies are available, there is a considerable lack of knowledge about the distribution of non-breeding females, of males and juveniles. There is also a need to better assess overlap with fishing operations and document the level and distribution of interactions.

IMPORTANT MARINE AREAS AND THREATS TO BIODIVERSITY

Direct and indirect anthropogenic threats to seabirds and marine mammals are predominately sea-based. Hence, their conservation necessitates actions that extend beyond the protection of terrestrial breeding colonies and coastal breeding areas. Present-day conservation efforts are commonly restricted to coastal sites, such as breeding areas, but they are totally insufficient to cover the annual and life cycles of marine top predator species, especially for oceanic species such as albatrosses, petrels and penguins. There is an urgent need to protect the High Seas where top predators forage.

The ocean areas important for top predators identified in the *Atlas* are particularly critical for biodiversity conservation in those environments impacted by anthropogenic activities (i.e. fishing). The species richness approach used to select areas of importance for these top predatiors species has both its strengths and its weaknesses. However, It allows, through the patterns of distribution of four evaluation criteria (*species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness*; see Methods Section for details), identifying areas of importance.

Important Marine Areas for Biodiversity

Hotspots were identified by overlapping the top-scoring 10% and 5% of grid cells (Prendergast et al., 1993) for four evaluation criteria. We present here the results obtained for the top-scoring 5% for the four evaluation criteria employed (see complementary results for the top-scoring 10% of grid cells presented in the Appendix, Annex III - A). Patterns of seabirds and marine mammals according to these four evaluation criteria employed are plotted across the area of interest in the southern Indian Ocean.

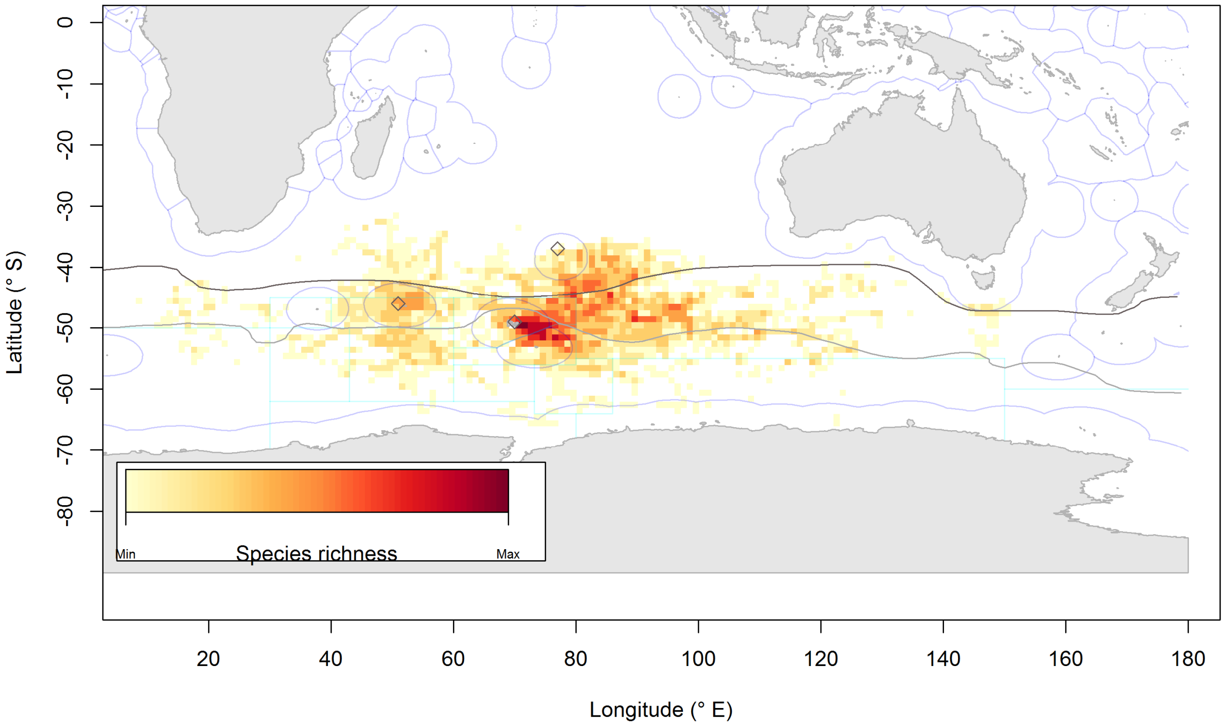
Table 29. Criterion used to identify important marine areas for seabirds and marine in the southern Indian Ocean (see p. 20-21)

Name of criterion	**Type of criterion**	**Measurement**
species richness	single	number of species
rarity-weighted richness	multiple	sum of rarity scores for all species present in a grid cell, where the rarity score for each species is the reciprocal of the number of cells in which it occurs; the cells with highest score value are therefore those which have a large number of restricted-range
threatened	multiple and	number of species for all the species present in a grid cell which

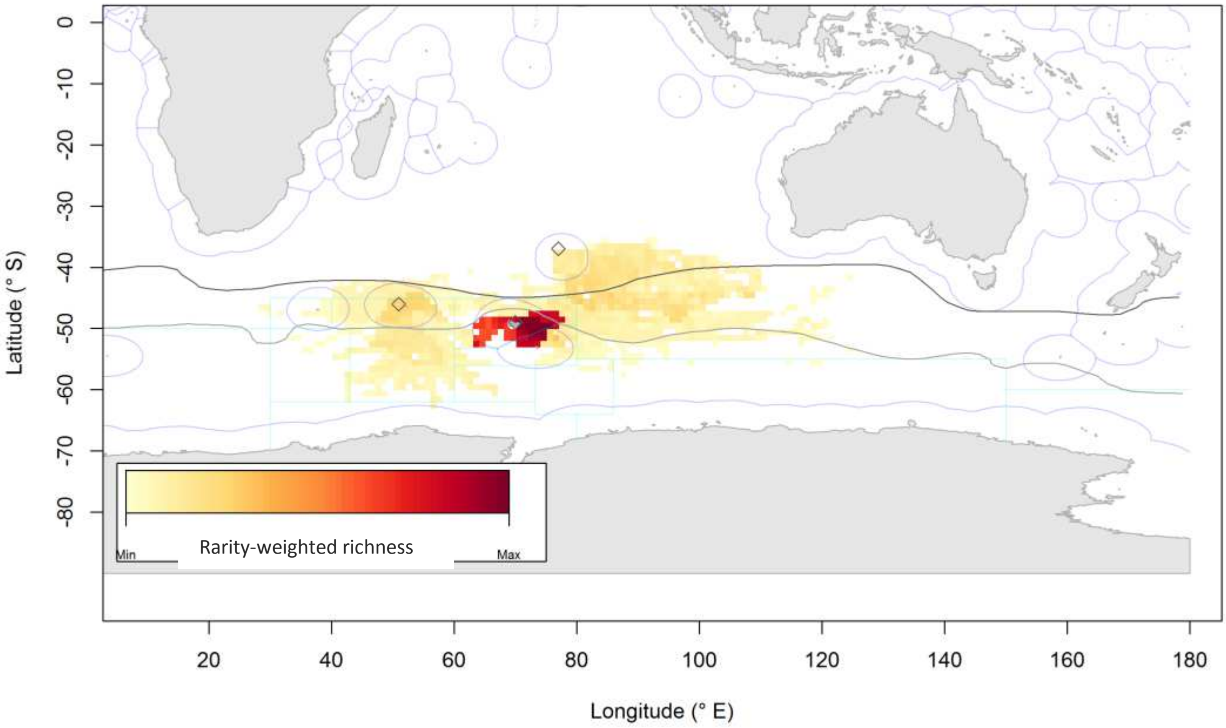
species richness	sequential	are classified as threatened
conservation-weighted rarity richness	multiple and sequential	*threatened species richness* weighted by a score for the IUCN status (i.e. Critically Endangered: 5, Endangered: 4 and so on)

1. Complete period: pooled breeding and inter-breeding periods

The first notable feature of patterns of spatial distribution (Maps 88 to 91) is a consistent attribution of high values to subtropical and subantarctic regions and to the area surrounding the breeding locations.

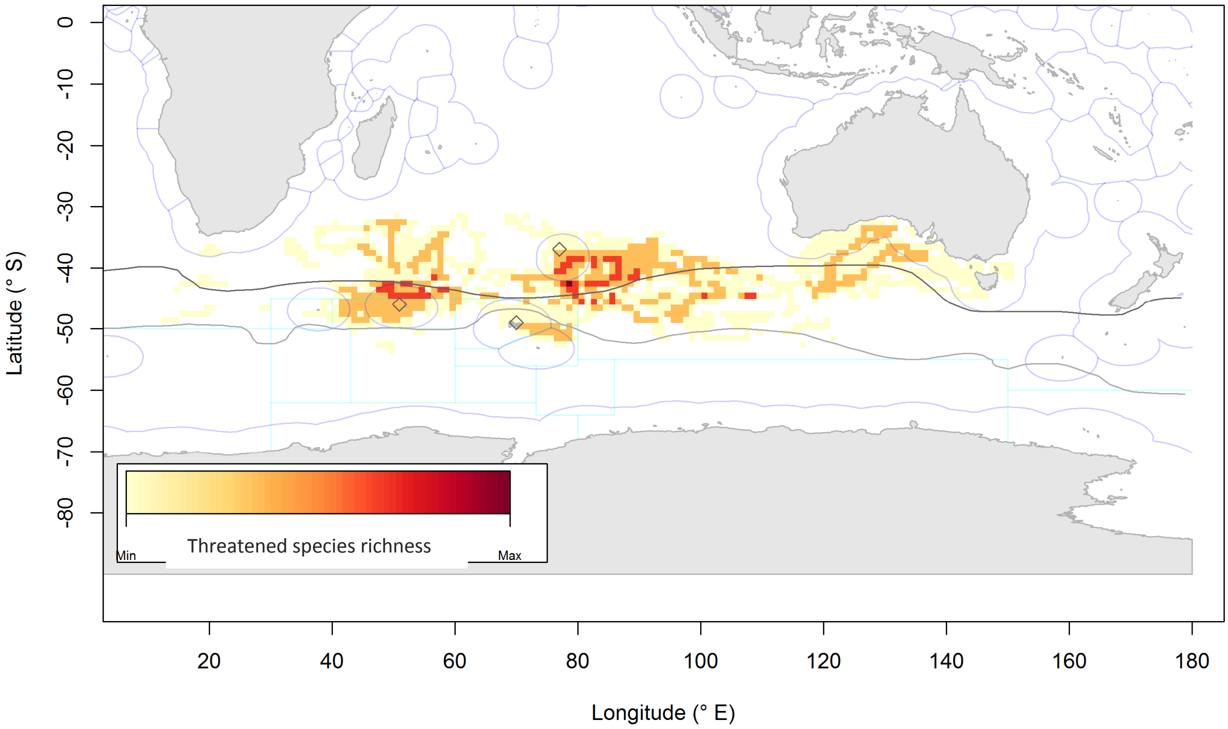


Map 88. *Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

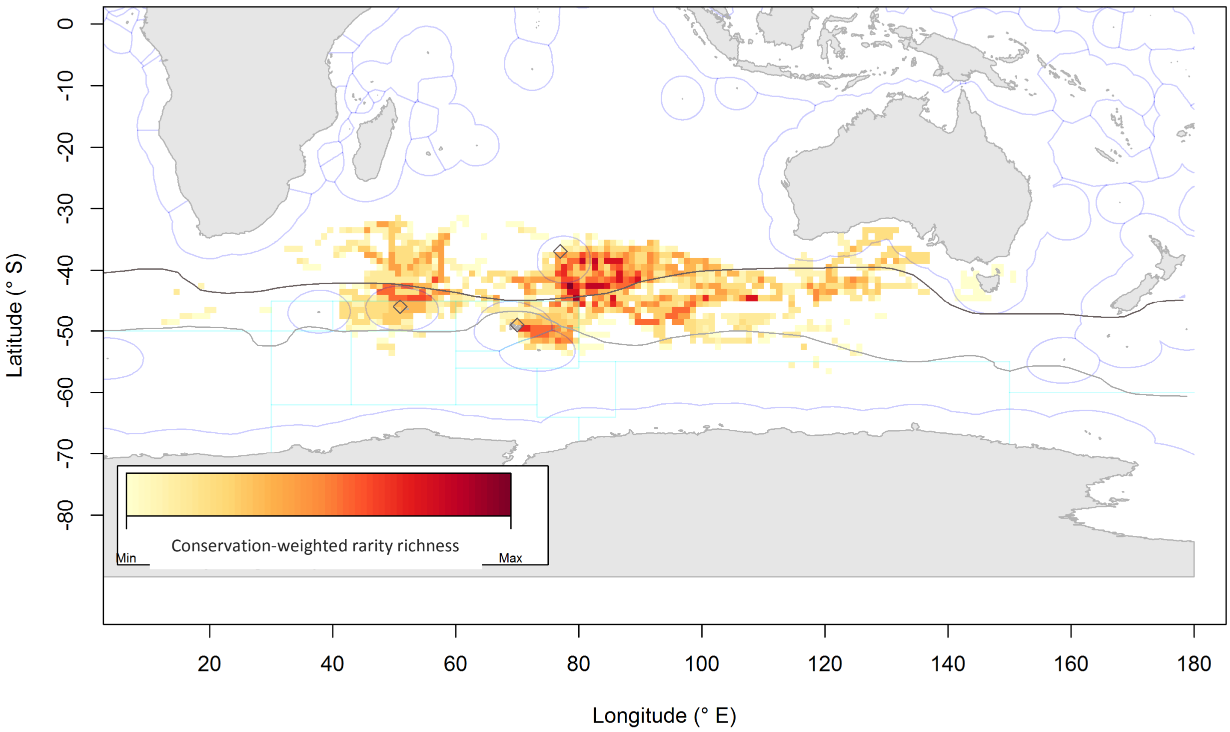


Map 89. ***Spatial pattern of diversity: rarity-weighted richness*****. Observed distribution of the evaluation criteria** ***rarity-weighted richness*** **(Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Values of species richness and rarity-weighted richness showed relatively little correspondence, suggesting that areas of high species richness are not always associated with a high rarity-weighted richness. This pattern is not unique to marine predators (see the following examples, mainly for terrestrial communities: Hacker et al., 1998;Prendergast et al., 1993;Williams and Humphries, 1996), indicating that rare species occur often outside hotspots of high species richness areas.



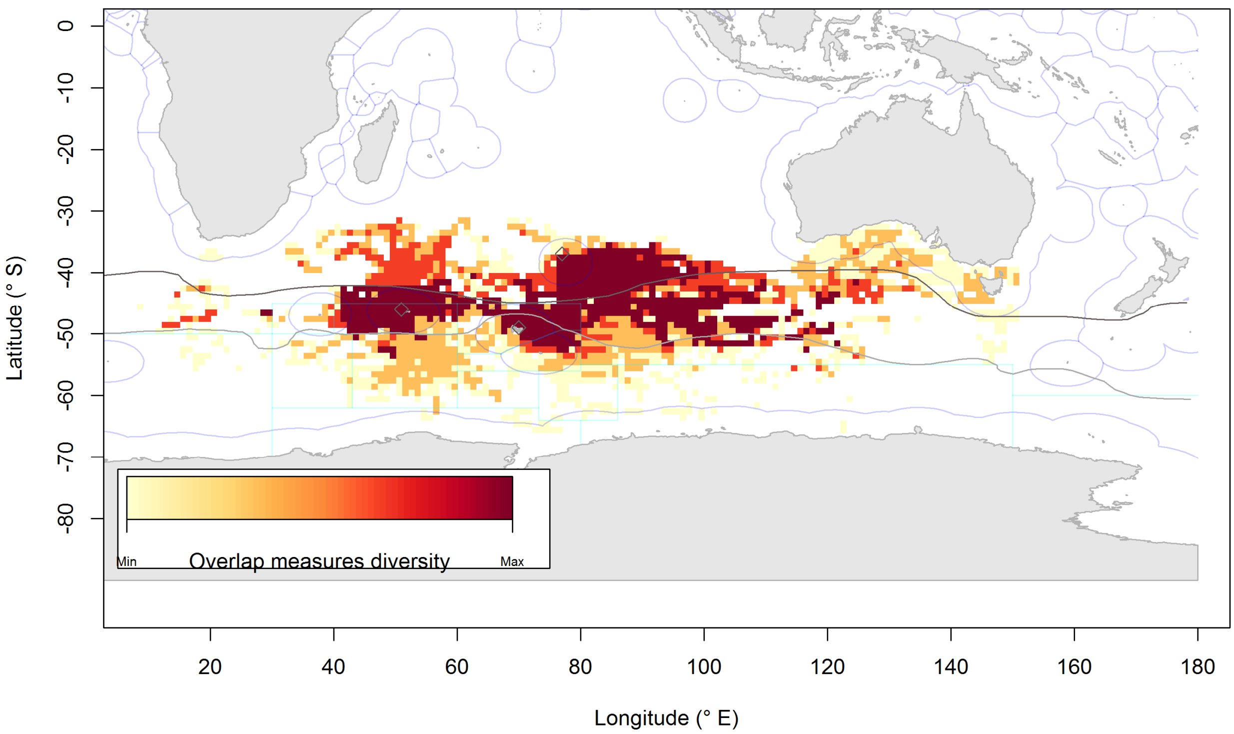
Map 90. ***Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 91. ***Spatial pattern of diversity: conservation-weighted rarity richness*****. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Similarly, little correspondence exists between hotspots for the threatened species richness and those for rarity-species richness. Several reasons can explain this discrepancy. Firstly, only one measure of rarity is used (range size) while other parameters can be more relevant (e.g. population size, population growth rate). Secondly, non-linearity could be incorporated (e.g. reciprocal of the square of range size) to reflect rarity more accurately. Thirdly, many threatened species are not rare but are at risk because of their declining trend. Finally, the measure is weighted by the species richness and may therefore represent a more complicated guide to the area concentrating the rarest species (Hacker et al., 1998).

The comparison of important areas for seabirds and marine mammals' diversity from the French Southern Territories in the southern Indian Ocean obtained by four evaluation criteria (*species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness*) was achieved by overlapping each spatial pattern (Map 92). Grid cells with maximum values are shown in dark red and indicate that all the four measures identify these cells as important areas. Grid cells with minimum values are shown in yellow indicating that only one measure identifies them as important areas.



Map 92. ***Spatial pattern of hotspots diversity*****. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 5% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin

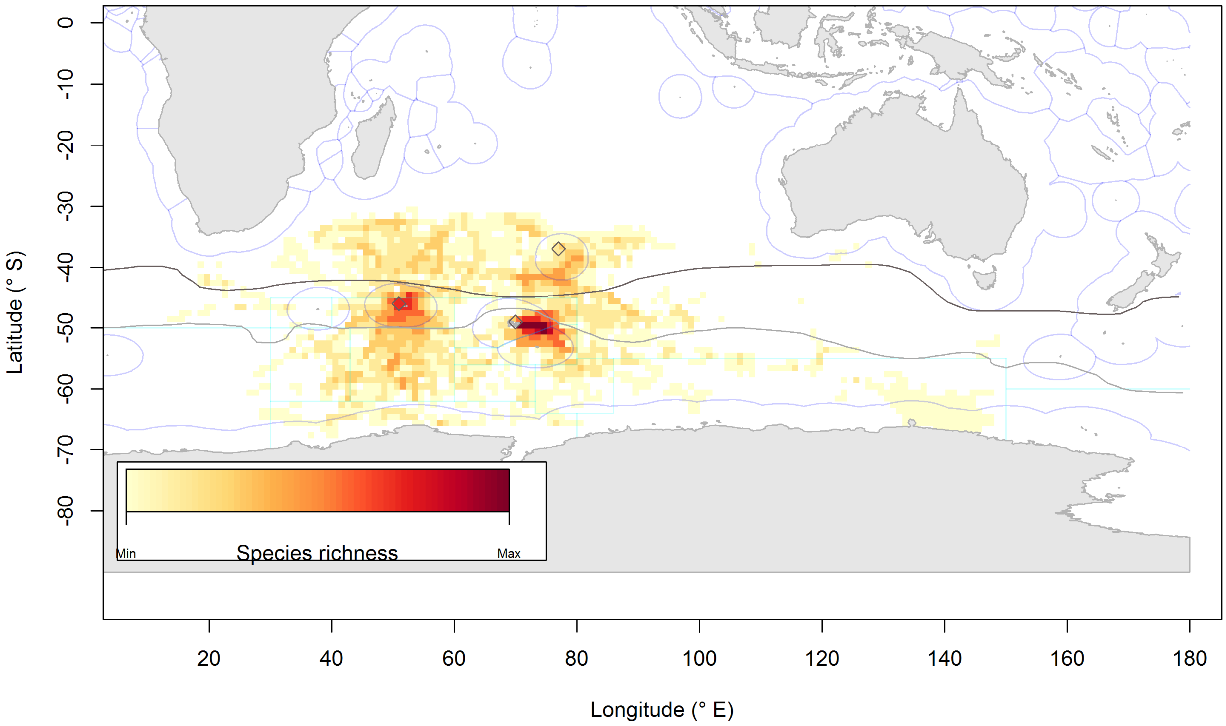
and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The areas identified by overlapping the top-scoring 5% of grid cells cover large areas in the southern Indian Ocean from subtropical to Antarctic regions. An important point is that hotspots for threatened species coincide with those for species richness. The zone that showed particularly important areas (with overlap of the four evaluation measures) corresponds to waters located between the South Subtropical Front, to the north and the Polar Front, to the south. It is noteworthy that subtropical waters located in the vicinity of the breeding colonies (north of Crozet Islands and south of Asmsterdam Islands) as well as subantarctic waters to the south of the colonies appeared of major importance.

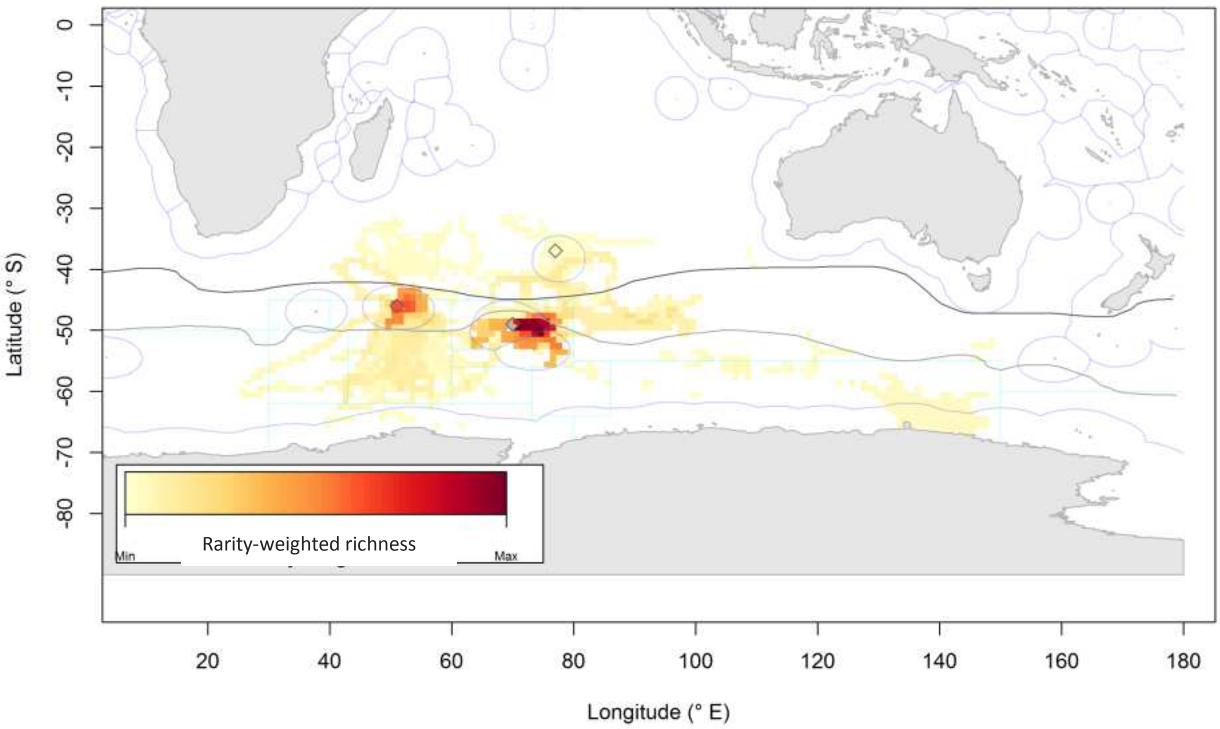
The zones surrounding the breeding locations obviously appear as particularly important (EEZs of Crozet, Kerguelen and Amsterdam Islands) at the exception of Adélie Land (Antarctica). More than 50% of the area of the French EEZs (Crozet, Kerguelen and Amsterdam Islands) exhibits the highest values of overlap of the four criteria. This is due to the central place foraging behavior of all species during the breeding season.The exception (Adélie Land) might be linked to the low number of tracked species compared to other breeding sites (see Map 2 p.15) and to the pattern of specific distribution (see pp. 108-121). Furthermore, the approach does not retain areas targeted by few species (especially when individuals exhibit a high variability in their patterns of distribution; (Péron et al., 2010b)), particularly in Antarctic waters. Consequently important areas for the Adélie Land seabird community are poorly retained here.

2. Breeding period

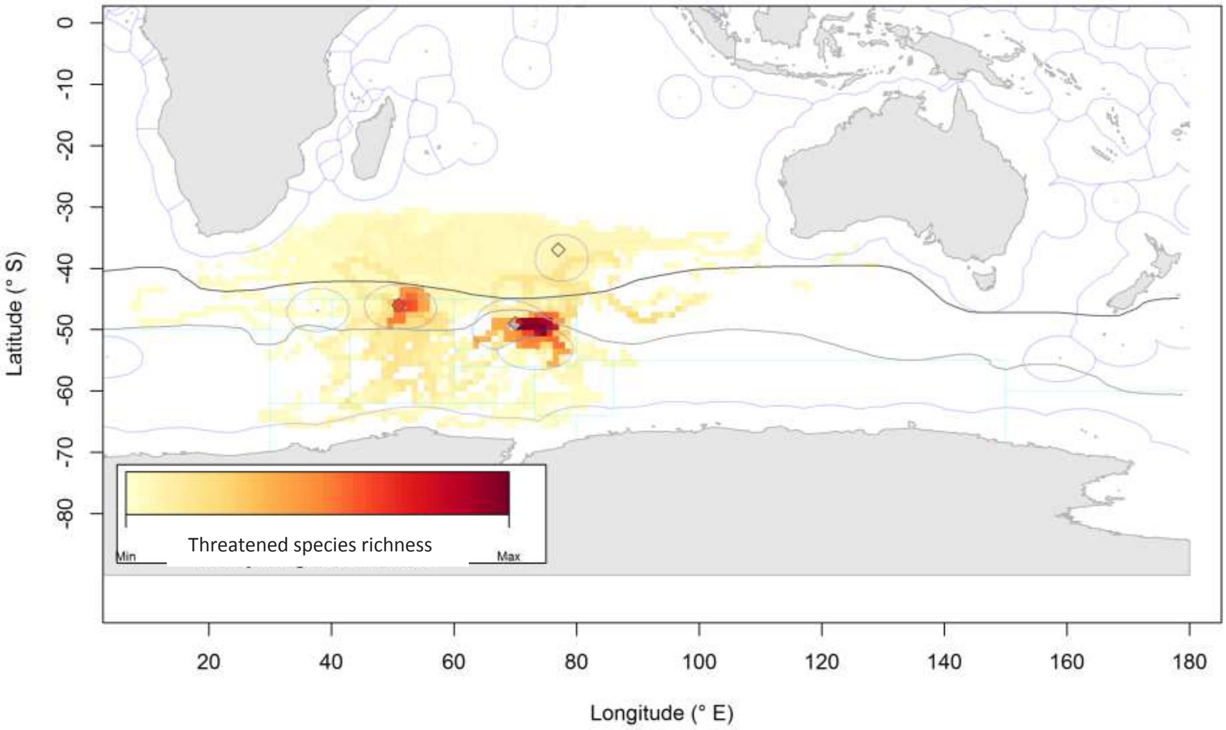
Focusing on the breeding period, it is noteworthy that the pattern of spatial distribution for the four criteria (Maps 93 to 96) highlights the consistent importance of subtropical and subantarctic regions, and particularly the area surrounding breeding locations. This is consistent with the fact that all the species included in the *Atlas* are central-place foragers when breeding, flying back and forth their breeding sites over several months.



Map 93. ***Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding periods.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

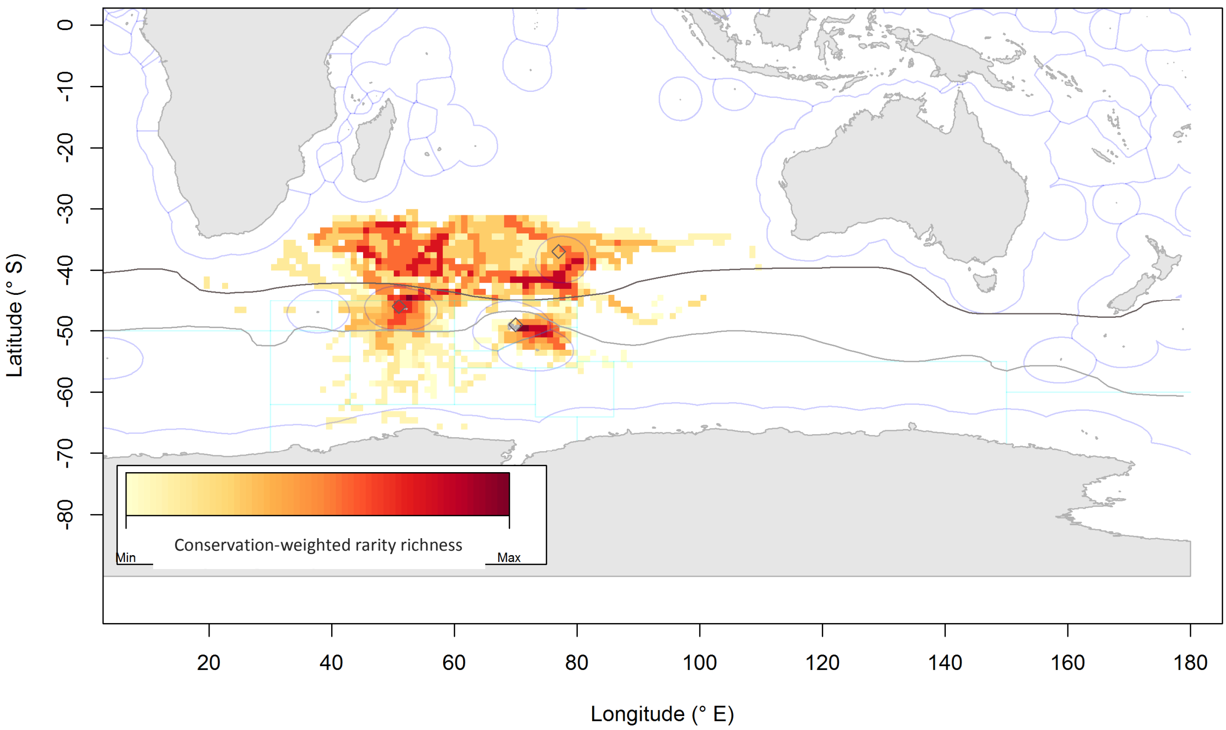


Map 94. *Spatial pattern of diversity: rarity-weighted richness*. Observed distribution of the evaluation criteria *rarity-weighted richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



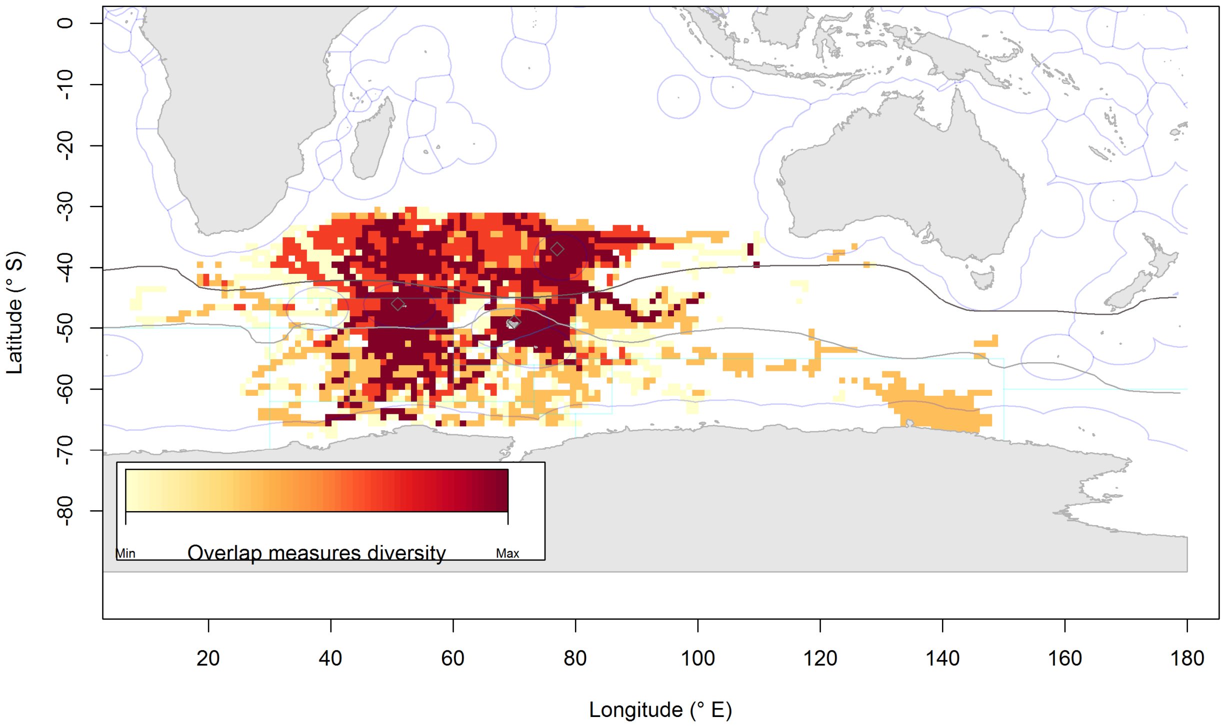
Map 95. *Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Similarly to the *Complete* period there is little correspondence between species richness and rarity-weighted richness criterion, and between hotspots for the threatened species richness with those for the rarity-species richness, for the *Breeding* period.



Map 96. ***Spatial pattern of diversity: conservation-weighted rarity richness*. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The zones identified by overlapping the top-scoring 5% of grid cells (Map 96) cover large areas in the southern Indian Ocean from subtropical to Antarctic regions. **The critical point is that important areas for threatened species are largely coincident with those for species richness**. **The zones that showed particularly important areas -overlap of the four evaluation measures- are centered on the breeding colonies and correspond to waters located between subtropical waters and Antarctic waters. The identified areas (extent and location) of importance correspond to the foraging ecology of top predator species included in the *Atlas*** (see Tables 1 & 2) many of them being long-distance oceanic foragers. **Not surprisingly the French EEZs (around Crozet, Kerguelen and Amsterdam Is.) and the waters neighboring Adélie Land are of particular importance.**



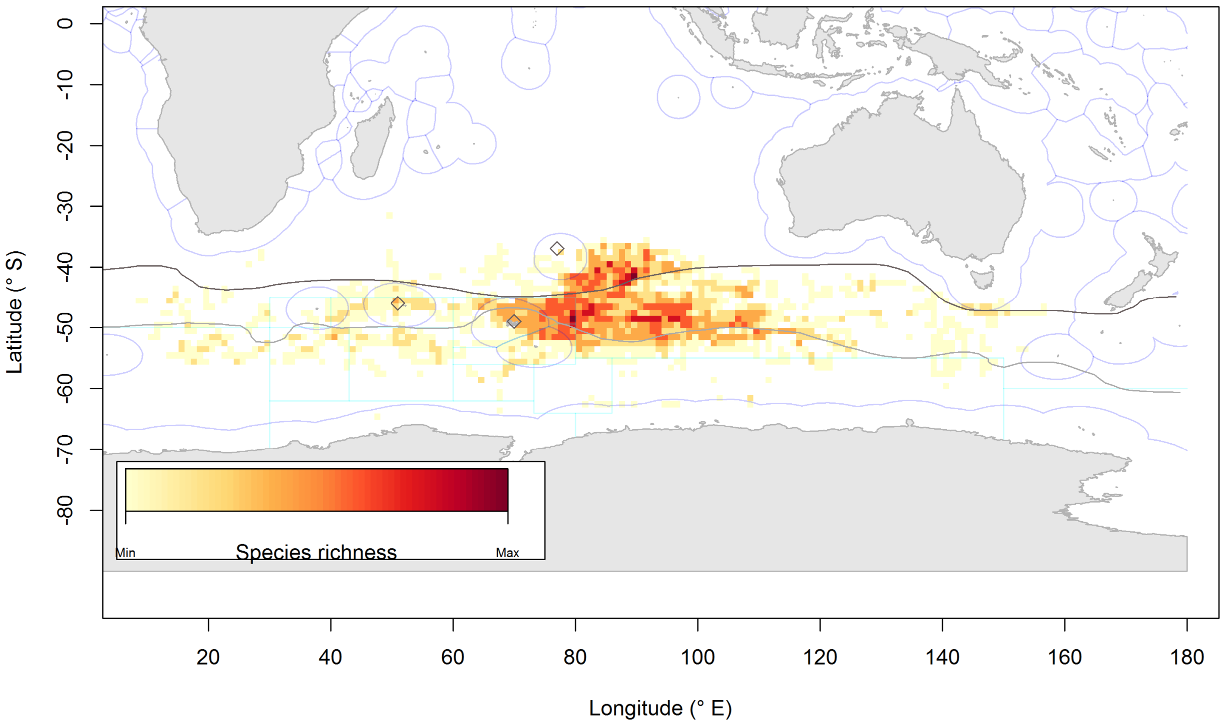
Map 97. ***Spatial pattern of hotspots diversity*****. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 5% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

More than 50% of the area of the French EEZs (Crozet, Kerguelen and Amsterdam Islands) exhibit the highest values of overlap of the four criteria (overlap of more than 2 measures). This indicates that all the criteria measures designated these areas as hotspots for conservation at the scale used (1°x1°). Similarly to the *Complete* period, Adélie Land showed less overlap values, possibly in relation to the low number of tracked species together with their conservation status (these four species have a Least Concern status) compared to others breeding sites (see Map 2 p.15 and pp. 108-121).

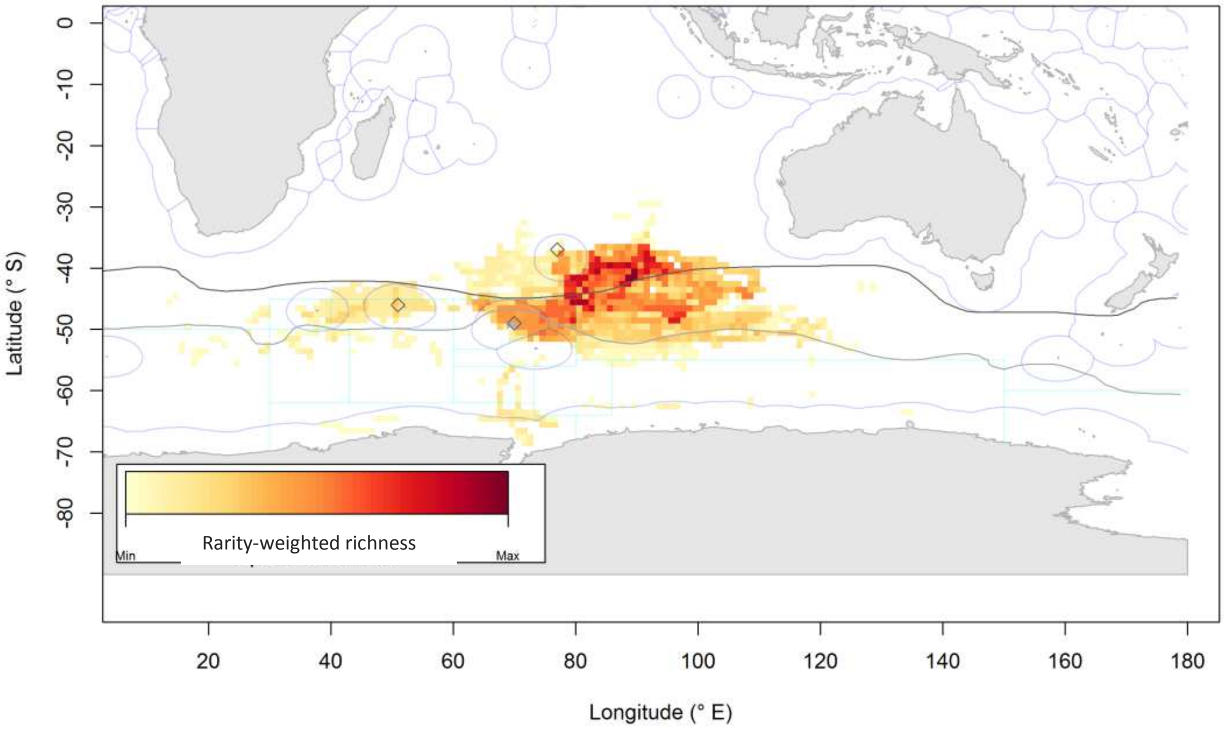
Compared to the *Complete* period, additional important areas were highlighted during the *Breeding* period. They include areas in subtropical waters, north of Crozet and Amsterdam Islands and areas in subantarctic waters, south of Crozet and Kerguelen Islands. Other areas lost some of their importance during the *Breeding* period compared to the *Complete* period. This is particularly the case for areas in the southwest Indian Ocean ridge, areas situated in the south of South Africa and areas south of Australia.

3. Inter-breeding period

During the inter-breeding period, the main pattern of spatial distribution for the four criteria (Maps 98 to 101) is a consistent attribution of high values to subtropical and subantarctic regions.

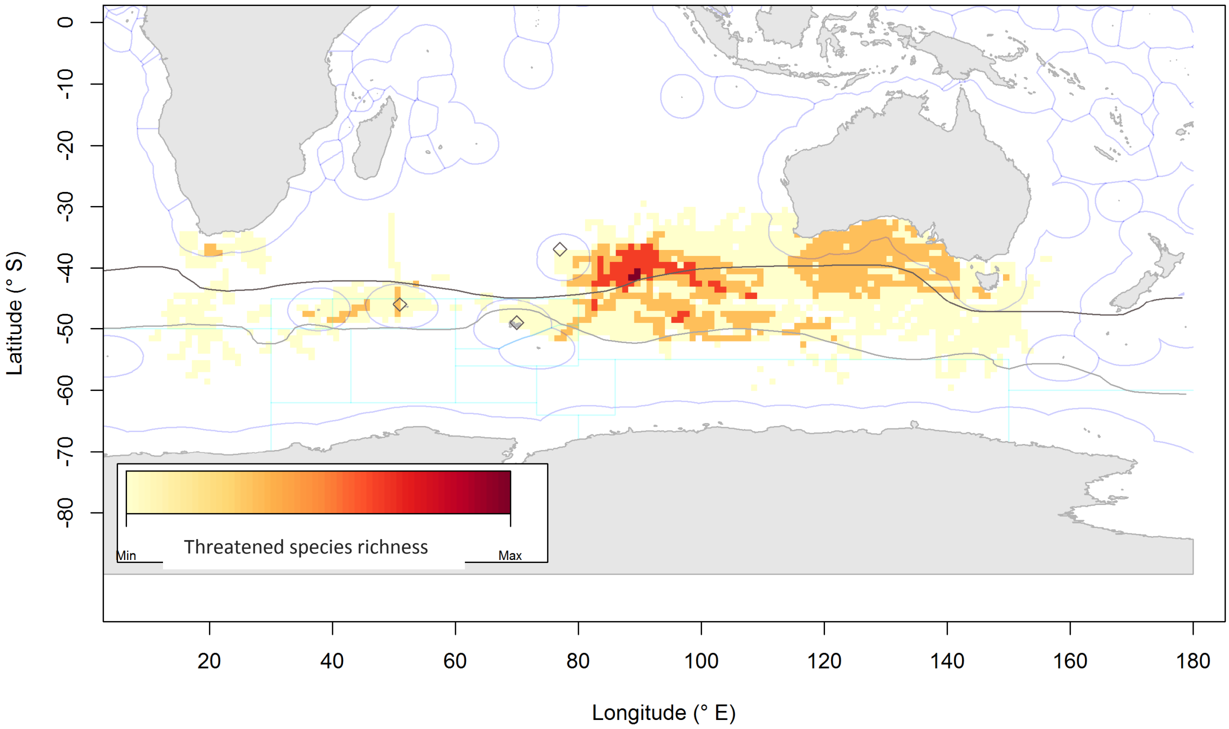


Map 98. *Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

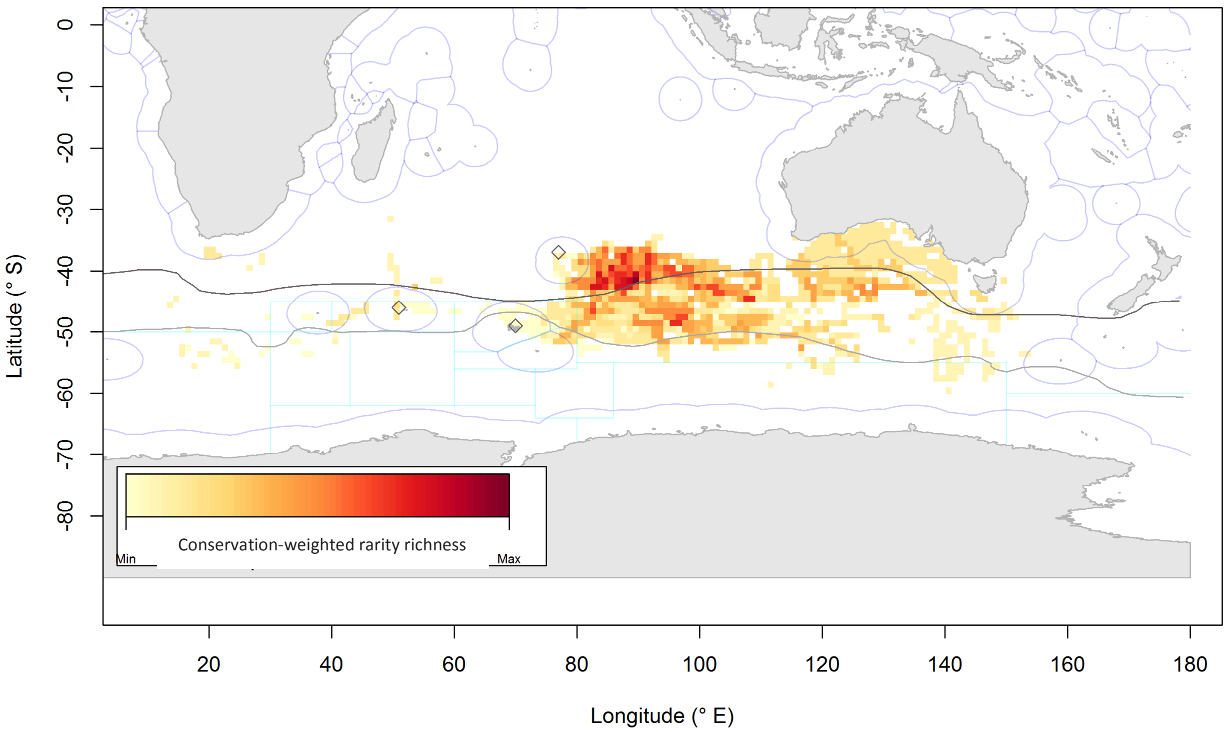


Map 99. ***Spatial pattern of diversity: rarity-weighted richness*****. Observed distribution of the evaluation criteria** ***rarity-weighted richness*** **(Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Contrary to the *Complete* (*Breeding* and *Inter-Breeding* periods pooled) and *Breeding* periods, there is a good correspondance between species richness and rarity-weighted richness, but not between hotspots for the threatened species richness with those for rarity-species richness in terms of principal values.

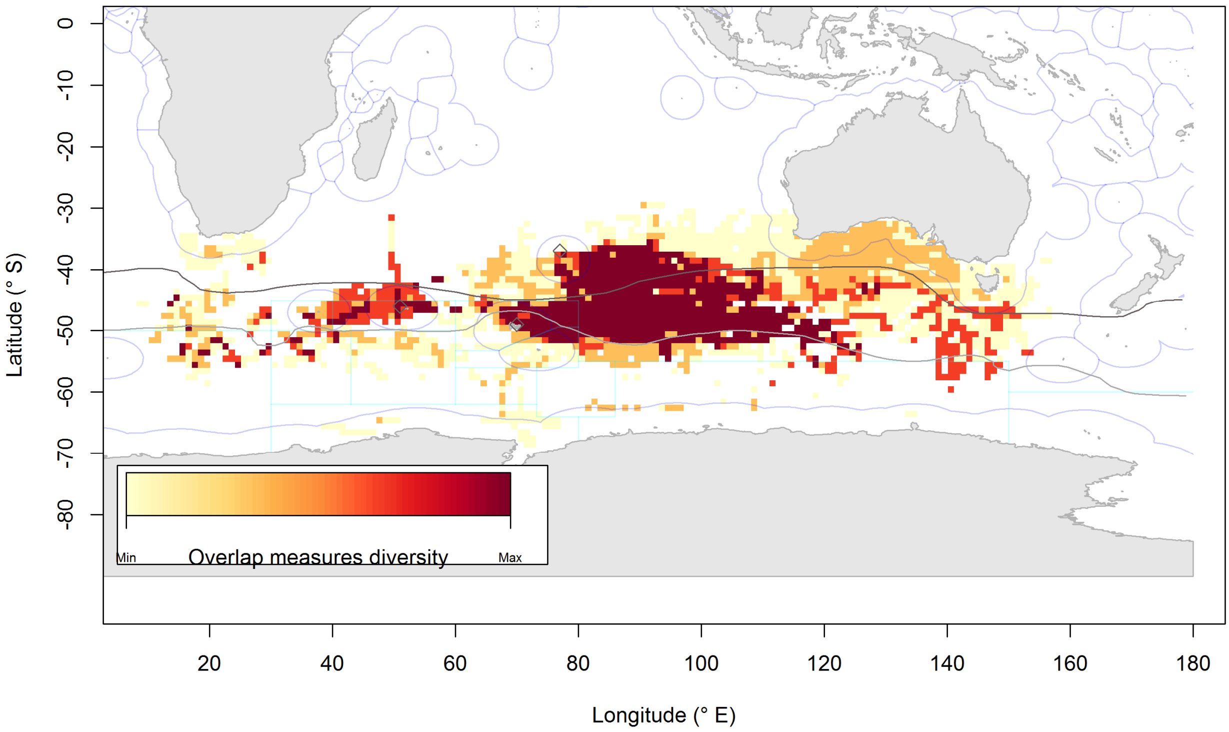


Map 100. ***Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996) updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 101. ***Spatial pattern of diversity: conservation-weighted rarity richness*. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The zones identified by overlapping the top-scoring 5% of grid cells (Map 101) cover large areas in the southern Indian Ocean from subtropical to subantarctic regions. Again, **the most important point is that important areas for threatened species are largely coincident with those for species richness**. The zone that showed particularly important areas is spread from subtropical to subantarctic waters. High values of overlap were observed mainly for areas more distant from the breeding colonies (southwest Indian Ocean ridge, Australian Great Bight or south of Tasmania). It is noteworthy that even during the *Inter-Breeding* period the waters situated in the vicinity of the breeding colonies (Crozet, Kerguelen and Amsterdam Islands) remained of importance. More than 50% of the area of the French EEZs (Crozet, Kerguelen and Amsterdam Islands) exhibit the highest values of overlap of the four criteria (overlap of more than 1 measure). This indicates that all the four criteria designated these areas as hotspots for conservation at the scale used (1°x1°). Similarly to the *Complete* or *Breeding* periods, Adélie Land showed less overlap values, possibly in relation to the low number of tracked species and to their conservation status (all four species are Least Concerned) compared to others breeding sites (see Map 2 p. 15).



Map 102. ***Spatial pattern of hotspots diversity*. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 10% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

Compared to the *Breeding* period, additional important areas were highlighted during the *Inter-Breeding* period, namely wintering grounds in subtropical and subantarctic waters, located mainly eastward from breeding colonies (southwest Indian Ocean ridge, Australian Great Bight or south Tasmania) and, although to a lesser extent, in the western part of the southern Indian Ocean (Del Cano Rise or south of South Africa).

Species diversity: comparison between guilds

Penguins are only found in the Southern Hemisphere, with a peak of diversity centred on the New Zealand region, between the East of the Indian Ocean and the Western part of the Pacific. The *Atlas* show that pelagic penguins of the French EEZ distribute during the inter-breeding period outside the center of the South Indian Ocean despite their low travelling speed. They distribute up to eastern sector of the South Indian Ocean (south of Australia) and also up to the western sector (South of Africa). Importantly populations from close localities exhibit contrasted migratory patterns and very different wintering areas.

For Albatrosses and Petrels the areas of importance identified in the *Atlas* are in accordance with the fact that Procellariiformes have been already identified to exhibit peaks in diversity confined to the Southern Ocean, namely in the southern Indian Ocean (Davies et al., 2010).

Pinniped species diversity is lowest in the tropics and highest at mid-latitudes in both hemispheres, in regions that correspond to marginal sea-ice zones and variable climate ((Kelly, 2001); (Higdon, 2011).

Adaptations to variable climate (and wide thermal tolerances) may thus be a significant factor explaining species range size and diversity. Mid-latitudes support both pagophilic and temperate species, leading to higher species diversity. At risk species occur in most regions, including the Indian Ocean.

The species richness approach that was used here suggests that important areas identified at a specific level might not coincide with the pluri-specific hotspots. Thus, adopting this unique approach may appear as a serious limitation. For instance, important areas for a *Critically Endangered* species such as the Amsterdam albatross during the inter-nesting period in the western part of is range were not represented in the hotspots identified here. Discrepancies between the pluri-specific approaches and the important areas identified at the specific levels are summarized in Table 29.

Table 30. Identification of gaps in the distribution data used in the Atlas and of mismatches between the distribution pattern of important areas at the species level and the hotspots identified using the pluri-specific approach

Species	Distribution data		Mismatch important area identification[2]		
	Gaps[1]	Nature of gaps	Gaps	Period	Areas
Penguins					
King penguin		Lack of data for period (I[3]) and colonies	No	–	–
Gentoo penguin		Lack of data for period (B,I) and colonies	No	–	–
Adélie penguin		Lack of data for period (B,I) and colonies	√	B	Antarctic sectors
Eastern rockhopper penguin		Lack of data for period (B) and colonies	No	–	–
Northern rockhopper penguin		Lack of data for period (B) and colonies	No	–	–
Macaroni penguin		Lack of data for period (B,I) and colonies	No	–	–
Albatrosses					
Amsterdam albatross			√	I	North of the southwest Indian Ocean ridge / subtropical
Wandering albatross		Lack of data for colonies	√	I	North of the southwest Indian Ocean ridge / subantarctic
Black-browed albatross		Lack of data for different colonies	√	I	Tasmania
Indian yellow-nosed albatross		Lack of data for different colonies	No	–	–
Light-mantled albatross		Lack of data for period (B)	√	I	Antarctic sectors (Prydz Bay), East of Bouvetøya Island
Sooty albatross		Lack of data for period (B, I)	√	I	Southwestern sector of Indian Ocean
Petrels					
Southern giant petrel		Lack of data for period (B)	No	–	–
Northern giant petrel		Lack of data for period (B)	No	–	–

Southern fulmar		Lack of accurate data (B, I)	√	B, I, T	Antarctic sectors
Cape petrel		Lack of accurate data (B, I)	√	B, I, T	Antarctic sectors
Snow petrel		Lack of accurate data (B, I)	√	B, I, T	Antarctic sectors
White-chinned petrel		Lack of data for period (I)	√	B, I, T	Benguela Current System, Antarctic sectors
Grey petrel		Lack of accurate data (B)	√	B, T	Southeastern Indian Ocean Ridge
Skuas					
Southern skua		Lack of accurate data (B, I) and different colonies	√	I	Benguela Current System, South Tasmania
Pinnipeds					
Southern elephant seal		Lack of data for period (B) and colonies	√	I	Antarctic sectors
Antarctic fur seal		Lack of data for period (I) and colonies	No	–	–

[1] Indicates the level of gaps in the distribution data. Red: several stages are missing, accurate data are missing and/or data for colonies are missing; orange: data for all stages but missing accurate data for several stages and/or colonies or small sample sizes; yellow: accurate data for all stages but missing data for several colonies; green: no gaps -accurate data for all stages and all colonies. The period concerned by the gaps is specified.
[2] Indicates if there is a mismatch between identification of important areas at the level species and the hotspots identified at the pluri-specific level. The period and area of mismatch are indicated.
[3] B : breeding, I : inter-breeding, T : total (breeding and inter-breeding combined).

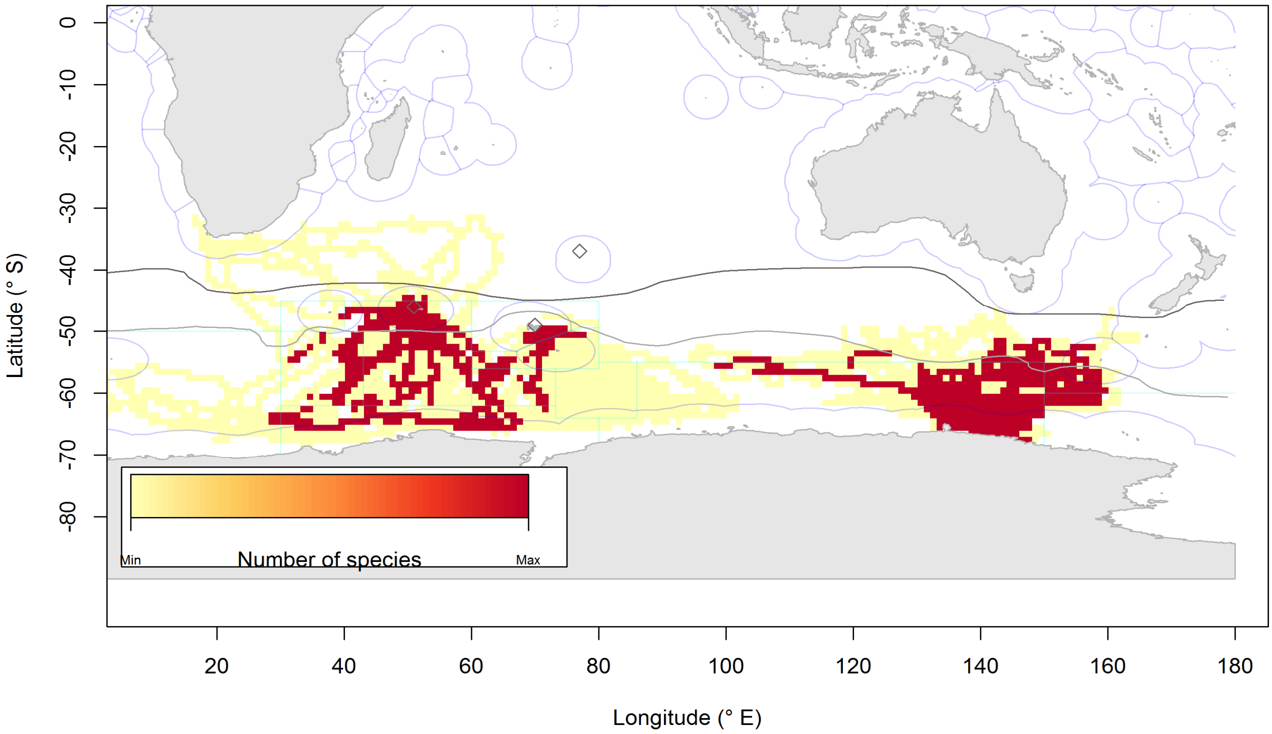
Foraging considerations for multispecies assemblages

Table 31. Dietary information on seabirds and marine mammals included in the analysis. The typology is based on the results of food composition presented in Table 7. The inclusion in the analysis of multispecies pattern of distribution depends on the availability of distribution data for each period (breeding/inter-breeding).

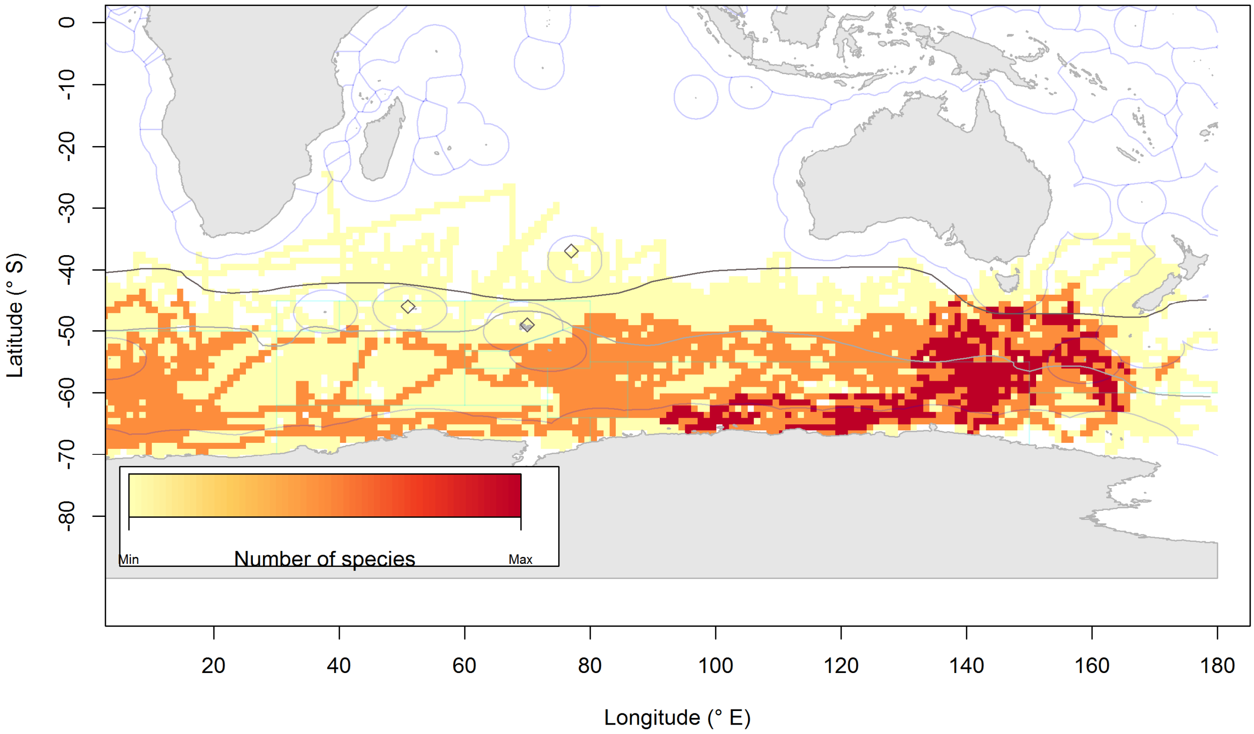
Species	Antarctic krill[3]	Other crustaceans*	Cephalopods	Myctophids	Breeding[1]	Inter-breeding[1]
King penguin				γ	γ	
Eastern rockhopper penguin		γ			NA	γ
Northern rockhopper penguin		γ			NA	γ
Macaroni penguin		γ		γ	γ	γ
Wandering albatross			γ		γ	γ
Black-browed albatross			γ		γ	**Exc[2]**
Light-mantled albatross	γ		γ		γ	γ
Sooty albatross			γ		γ	γ
Antarctic fulmar	γ				γ	γ
Cape petrel	γ				γ	γ
White-chinned petrel	γ		γ	γ	γ	**Exc**
Southern elephant seal				γ	NA	γ
Antarctic fur seal				γ	γ	NA

[1] Indicate which location data of species is included in the multispecies analysis regarding the period; [2]Species excluded from the analysis due to migration pattern and restricted wintering grounds: black-browed albatross in the Australian Great Bay, white-chinned petrel in the Benguela Current System; NA: no location data available; [3] *Euphausia superba*; *Other crustaceans species from krill species

Prey of seabirds and pinnipeds were clustered into four groups, namely Antarctic krill, other crustaceans, cephalopods and myctophid fishes. Noticeably, each group includes very different numbers of prey taxa, from one to > 30 species for Antarctic krill and cephalopods, respectively. Other crustaceans include amphipods and euphausiids other than Antarctic krill. The assignation of a given predator to a group of prey is based on dietary information during the breeding season presented in Table 7. It allows analyzing patterns of spatial distribution for predators feeding primarily on each of the four prey groups (Table 30). Comparing dietary data to the important areas identified by geospatial statistical analyses of species and multi-specific distribution help defining important feeding areas for the birds. Indeed, coupling foraging considerations for multispecies assemblages of breeding, resident and migratory species represents a realistic strategy for defining ecologically significant areas for seabirds (Sydeman et al., 2013).



Map 103. ***Spatial pattern of diversity: species eating Antarctic krill (light-mantled albatross, Antarctic fulmar, Cape petrel, white-chinned petrel).*** **Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 2) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

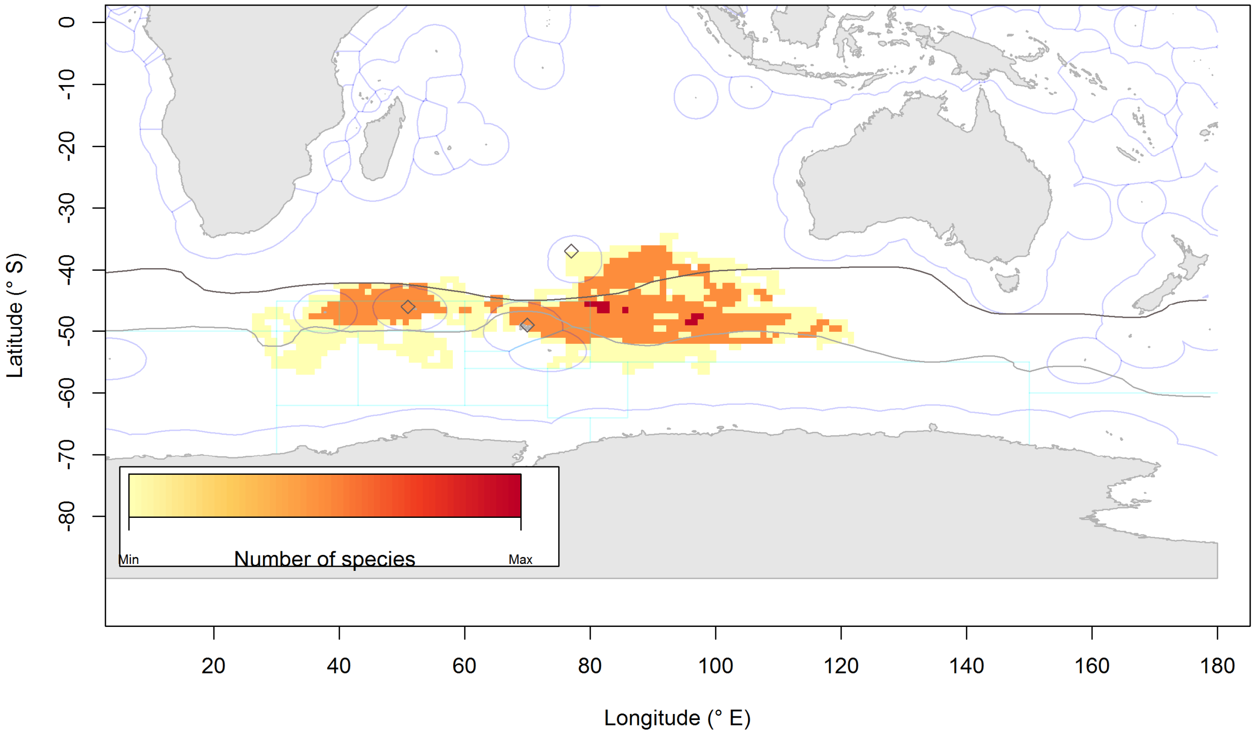


Map 104. ***Spatial pattern of diversity: species eating Antarctic krill (light-mantled albatross, Antarctic fulmar, Cape petrel). Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 3) of adult birds during the inter-breeding period.*** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The pattern of distribution highlights the importance of waters south the Polar Front during the breeding and inter-breeding periods for Antarctic krill-eating species. Indeed, in the southern Indian Ocean, Antarctic krill occurs almost exclusively in high-Antarctic waters, with some krill being also trapped in cold eddies, and thus occurring further north, but always south the Polar Front. Hence, the occurrence of Antarctic krill-eating species north the Polar Front is a methodological bias due to the inclusion in the data set of tracks during which predators feed on other prey than Antarctic krill (e.g. white-chinned petrels from Crozet during the incubation period and Cape petrels in New Zealand waters during the inter-breeding period).

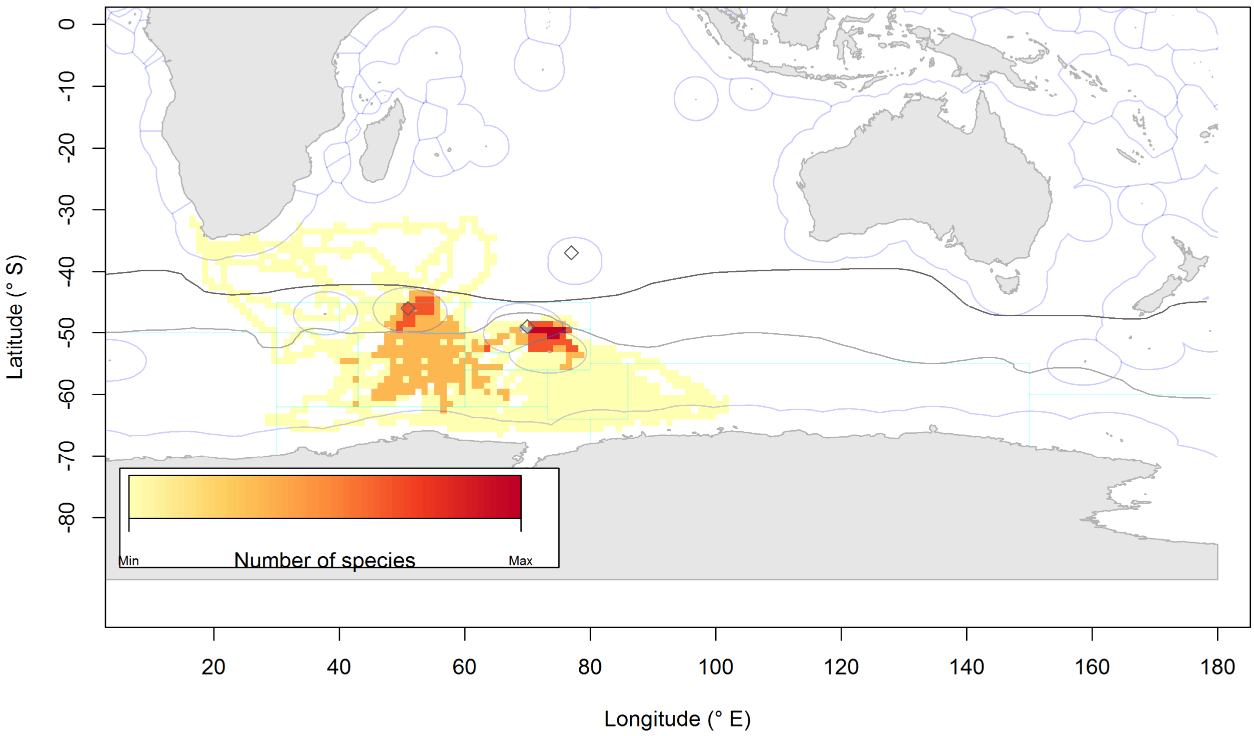
The first map emphasizes the importance of Antarctic krill for birds breeding in high-Antarctica (Adélie Land), but also for some species breeding in subantarctic islands (Crozet and Kerguelen). The latter species usually perform long trips during incubation and alternate between long and short trips during chick-rearing. During long trips, they reach high-Antarctic waters where they feed on Antarctic krill (e.g. white-chinned petrel and light-mantled albatross, but also grey-headed albatross, blue petrel and Antarctic and thin-billed prions).

The second map illustrates that Antarctic krill may also be a main prey during the inter-breeding period of some high-Antarctic and subantartic seabirds. Indeed, the feather isotopic signature of light-mantled sooty albatross, Cape petrel, snow petrel and Antarctic fumar indicate moulting at least in part in high-Antarctic waters where they feeds on low trophic level prey.

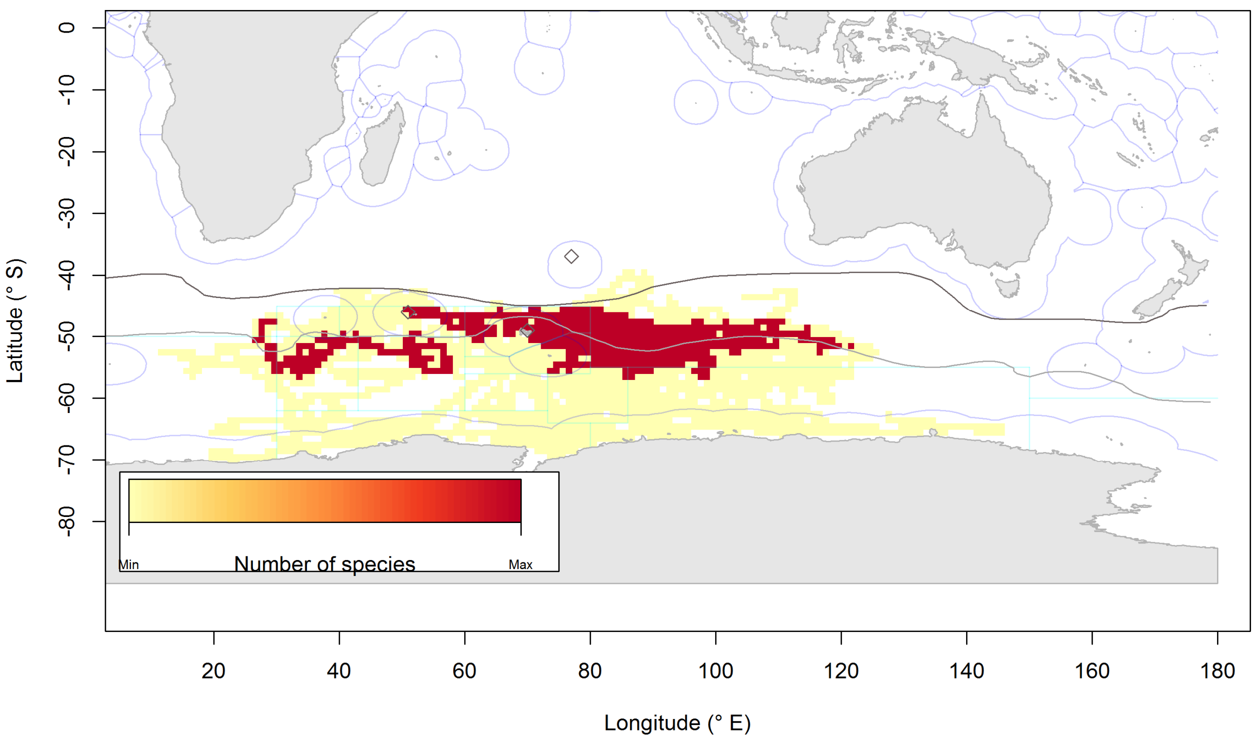


Map 105. ***Spatial pattern of diversity: species eating other crustaceans (macaroni penguin, eastern rockhopper penguin, northern rockhopper penguin).* Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 3) of adult birds during the inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The peaucity of tracking data during the breeding season precludes doing the analysis at that time. During the non-breeding period, the species of tracked birds that feed on other crustaceans (Map 105) include crested penguins (*Eudyptes* spp.) only. The spatial pattern is well-defined with the penguins being principally distributed in the subantarctic zone *lato sensu*, meaning between the Subtropical and Polar Fronts. The map also underlines the importance of the oceanic area of the southwestern Indian Ridge within that zone

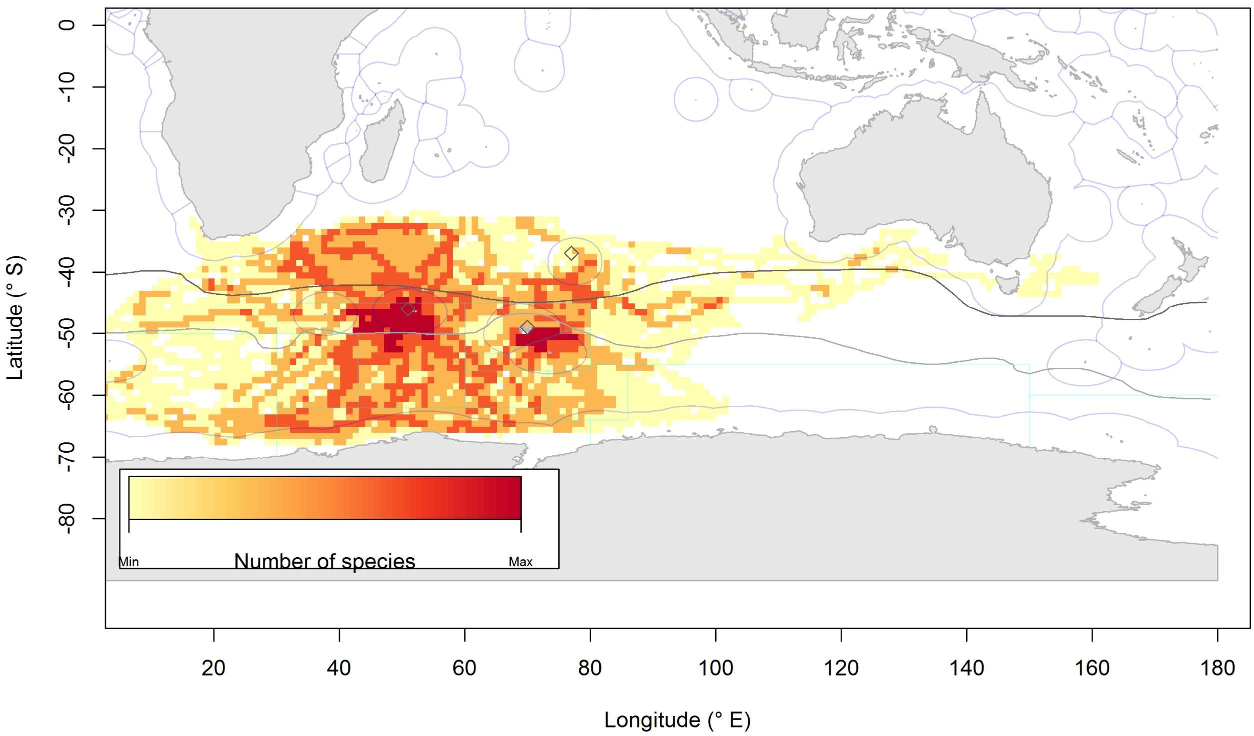


Map 106. ***Spatial pattern of diversity: species eating myctophids (king penguin, macaroni penguin, white-chinned petrel, southern elephant seal, Antarctic fur seal).*** **Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 2) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

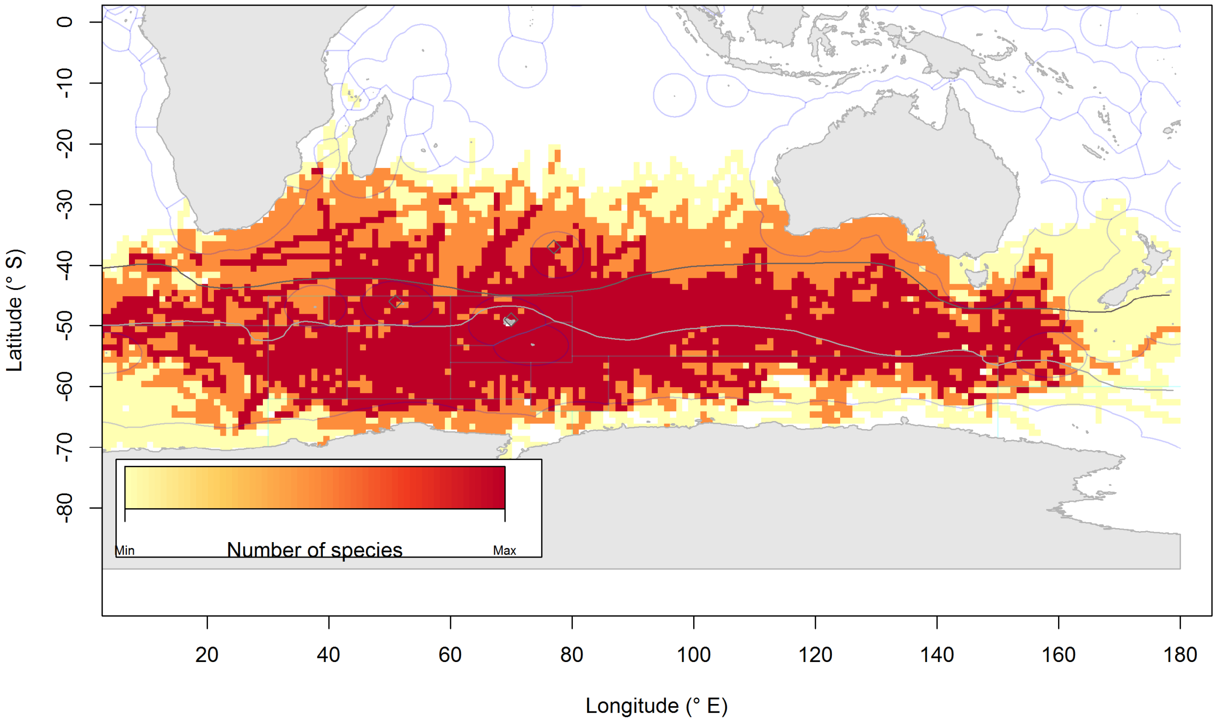


Map 107. ***Spatial pattern of diversity: species eating myctophids (macaroni penguin, southern elephant seal)*. Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 2) of adult birds during the inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During both the breeding and inter-breeding periods, myctophid-eaters forage mainly in southern subantarctic waters and in the vicinity of the Polar Front (Maps 106 & 107). Indeed, myctophids are known to be an abundant, but still poorly known, trophic ressource in these areas.



Map 108. ***Spatial pattern of diversity: species eating cephalopods (wandering albatross, light-mantled albatross, sooty albatross, black-browed albatross, white-chinned petrel)*. Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 4) of adult birds during the breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 109. ***Spatial pattern of diversity: species eating cephalopods (wandering albatross, light-mantled albatross, sooty albatross).* Observed distribution of the species richness (Occurrence data obtained from time spent per square in each 1° cell; min: 0 -max: 3) of adult birds during the inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

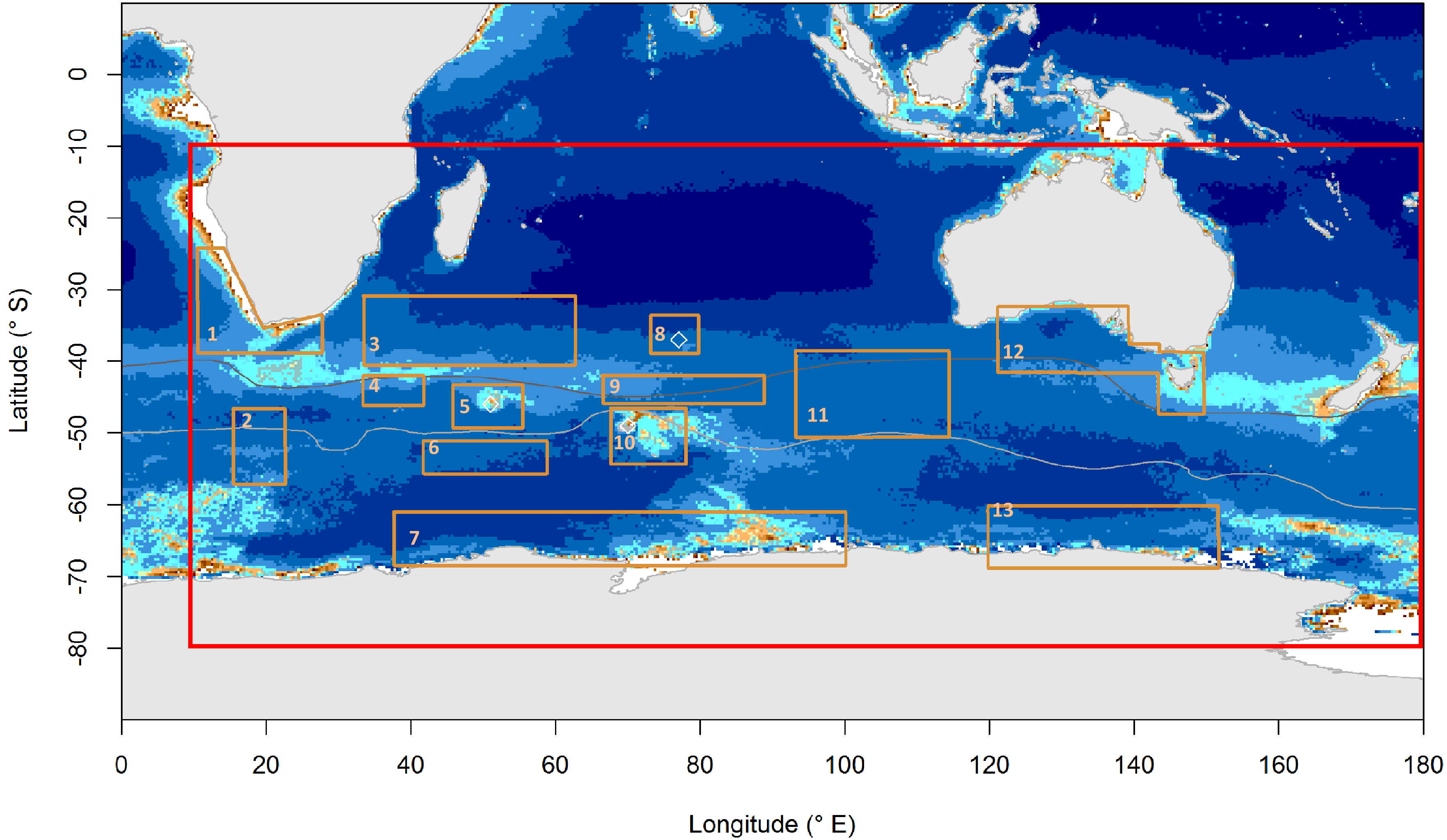
The distribution of species feeding on cephalopods is extremely large, encompassing the entire southern Indian Ocean (Maps 108 & 109). Two non-exclusive factors explain that pattern. Firstly, cephalopods are mainly eaten by large procellariiforms that are wide-ranging seabirds with amazing flying capabilities. Secondly, despite the peaucity of data on cephalopods, they are diverse and occur almost everywhere. Hence, albatrosses and petrels feed on a large number of oceanic squids representative of the Antarctic, subantarctic and subtropical zones. The breeding and inter-breeding patterns are quite different and reflect the behaviour of adult birds that are central-place foragers during the breeding period and disperse widely during the inter-breeding period.

CONCLUSION

This *Atlas* identify key areas using tracking data from both the breeding and non-breeding periods for 22 marine predators species of the French Southern Territories with different ecological niches and ranging in status from Least Concern to Critically Endangered (cf Table 3). The analysis of combined data sets on top-predators tracked from Crozet, Kerguelen, Amsterdam and Adélie Land clearly indicates the importance of several areas in the Southern Indian Ocean (Map 110). These areas are extensively used by these species at some key periods of their annual life cycles, such as wintering and/or breeding (incubation, chick rearing) periods.

Our study suggests that important areas for seabirds and marine mammals can be highlighted revealed by combining a variety of approaches, including geospatial statistical analyses of seabird distribution, pluri-specific assemblage approaches and foraging considerations for multispecies assemblages.

The species of seabirds and marine mammals found within each identified key areas are summarized in Table 31.



Map 110. ***Identified key areas (orange boxes) in the Southern Indian Ocean for 22 species of seabirds and marine mammals from French Southern Territories (Amsterdam, Crozet, Kerguelen and Adelie Land).*** Areas of importance are as follow: 1 Benguela and Agulhas Currents; 2 East Bouvetøya; 3 North Subtropical Front - Southwest Indian Ridge; 4 Marion and Prince Edward Islands and the Del Cano Rise; 5 Crozet islands; 6 Ob and Lena Banks; 7 East Antarctica: Prydz Bay - Queen Maud Land sectors; 8 Amsterdam and Saint Paul islands; 9 Mid-Indian Ridge: North of Kerguelen;10 Kerguelen Plateau; 11 Eastern Indian Ocean - Southeast Indian Ridge; 12 Great Australian Bight and Tasmania; 13 East Antarctica: Adelie Land sector. Area of interest (red box) and breeding colonies are indicated (white diamonds). Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown. Mean chlorophyll a concentrations (NOAA CoastWatch, Data courtesy of NASA/GSFC/DAAC, GeoEye; downloaded at http://coastwatch.pfel.noaa.gov/coastwatch/CWBrowserWW180.jsp; http://spatial-analyst.net/wiki/index.php?title=Global_datasets).

1. **Breeding colonies and surrounding zones**

Marion and Prince Edward islands and the Del Cano Rise (4) The South African islands support large colonies of seabirds and seals, with several species of global importance. For example, the Prince Edward Islands together with the adjacent Crozet Islands (included in the CCAMLR Planning Domain 5) host the entire population of the Crozet shag, about 70% of the world population of wandering albatrosses, 54% of king penguins, 33% of Indian yellow-nosed albatrosses, 33% of subantarctic fur seals, 27% of sooty albatrosses and 21% of eastern rockhopper penguins, some populations are decreasing (Crawford et al., 2006).The high biological productivity in the vicinity of the islands allows large populations of seabirds and seals to breed and feed on the surrounding marine resources. The Del Cano Rise is a highly productive seamount. The areas are targeted by industrial fisheries.

Crozet Islands (5) The Crozet Islands area is of importance for top-predators from several guilds (i.e. macro-zooplanktonic feeders, benthic feeders, squid feeders and scavengers). Analysis of tracking data indicates that some oceanic, vulnerable or endangered seabirds distribute over the Del Cano Rise during winter or have a much wider foraging range over the year. Some Vulnerable species such as the wandering albatross disperse over the whole CCAMLR convention area, depending on their breeding status. Most importantly, several species also move northward beyond the CCAMLR convention area and overlap extensively with the southern IOTC convention area, especially FAO area 55.1. This highlights the urgent need to strengthen collaborations between CCAMLR and other RFMOs. The Crozet area is targeted by a Patagonian toothfish demersal fishery.

Kerguelen Plateau (10) The Kerguelen Plateau (CCAMLR Planning Domain 6) is the major area in the Indian sector of the Southern Ocean and is the largest Plateau of the Southern Ocean. It strongly affects the circulation and the position of the frontal systems within the region. Biological productivity is very high over the Plateau. The area is targeted by a Patagonian toothfish demersal fishery.

Amsterdam and Saint Paul Islands (8) The Amsterdam and Saint Paul Islands area is of importance for several species of top-predators, including one rare endemic and highly endangered species, the Amsterdam albatross.

East Antarctica: Adélie Land sector (13) This area host the largest Antarctic seabird communities of the world in terms of biomass and is highly productive.Fishing activity is limited.

2. Upwelling zones

Benguela and Agulhas Currents (1) The areas are already identified as importance foraging grounds for a large community of seabird species breeding at distant colonies in the South Atlantic (South Georgia), the Southern Indian Ocean (Marion and Prince Edward Islands), but also in the North Atlantic (Phillips et al., 2006;Phillips et al., 2005). These current systems are amongst the highest productive areas in the Worlds' Ocean, and, hence, they are exploited by numerous pelagic and demersal industrial fisheries. Bycatch issues concerning seabirds were identified in these sectors (Watkins et al., 2008).

3. Oceanic zones

East Bouvetøya (2) Oceanic waters exhibiting high biological productivity of Antarctic krill.

North Subtropical Front - Southwest Indian Ridge (3) The North Subtropical front is a highly productive area due to the Return Agulhas Current that produces pulses of eddies. Numerous pelagic fisheries targeting tunas operate in the sector (IOTC area). Recent data indicated that bycatch issues concerning seabirds exist in these sectors (Huang and Liu, 2010b).

Ob and Lena Banks (6) Seamounts with highly productive waters targeted by toothfish fisheries, including an illegal, unreported and unregulated fishery in recent years.

East Antarctica: Prydz Bay - Queen Maud Land sectors (7) Highly productive areas (Antarctic krill) that host numerous seabirds and marine mammals (Woehler et al., 2010;Woehler et al., 2003;Woehler, 1997b). These areas are targeted by Antarctic toothfish fisheries.

Mid-Indian Ridge: North of Kerguelen (9) Area of the Subtropical front exhibiting high productivity.

Eastern Indian Ocean - Southeast Indian Ridge (11) Located between the South Subtropical Front and Polar Front, the area is of particular importance for a large community of seabirds and marine mammals originated from different colonies spread within the Indian Ocean.

Great Australian Bight and Tasmania (12) The area is a combination of a plateau area and shelf slope with highly productive waters. This sector is of crucial importance, mainly during the inter-breeding period, for numerous species breeding in the French Southern Territories that overwinter there.

East Antarctica: Adélie Land sector (13) This area is highly productive (Antarctic krill, silver fish).The Antarctic toothfish fishery activity is very limited.

Table 32. Important key areas identified for seabirds and marine mammals from the French Southern Territories and the Adelie Land-Antarctica

Number of the area	Identified key area	Species concerned	Number of species	Life stage[1]
1	Benguela and Agulhas Currents	Amsterdam albatross, black-browed albatross, sooty albatross, white-chinned petrel, brown skua	5	I
2	East Bouvetøya	Light-mantled albatross, sooty albatross, southern giant petrel	3	I
3	North Subtropical Front - Southwest Indian Ridge	Amsterdam albatross, wandering albatross, Indian yellow-nosed albatross, sooty albatross, white-chinned petrel	5	B, I
4	Marion and Prince Edward Islands and Del Cano Rise	Eastern rockhopper penguin, macaroni penguin, wandering albatross, sooty albatross, southern giant petrel, northern giant petrel, white-chinned petrel	8	B, I
5	Crozet Islands	King penguin, gentoo penguin, eastern rockhopper penguin, macaroni penguin, wandering albatross, sooty albatross, northern giant petrel, white-chinned petrel, southern elephant seal	8	B, I
6	Ob and Lena Banks	King penguin, wandering albatross, southern elephant seal	4	B, I
7	East Antarctica: Prydz Bay - Queen Maud Land sectors	Light-mantled albatross, southern giant petrel, southern fulmar, snow petrel, white-chinned petrel	5	B, I
8	Amsterdam and Saint Paul Islands	Northern rockhopper penguin, sooty albatross, Indian yellow-nosed albatross, brown skua	4	B, I
9	Mid-Indian Ridge: North of Kerguelen	Northern rockhopper penguin, wandering albatross, sooty albatross, grey petrel, brown skua	5	I
10	Kerguelen Plateau	King penguin, gentoo penguin, eastern rockhopper penguin, macaroni penguin, wandering albatross, light-mantled albatross, northern giant petrel, southern fulmar, white-chinned petrel, grey petrel, brown skua, southern elephant seal, Antarctic fur seal	13	B, I
11	Eastern Indian Ocean - Southeast Indian Ridge	Eastern rockhopper penguin , northern rockhopper penguin, macaroni penguin, wandering albatross, black-browed albatross, Indian yellow-nosed albatross, light-mantled	11	B, I

		albatross, sooty albatross, grey petrel, brown skua, southern elephant seal		
12	Great Australian Bight and Tasmania	Amsterdam albatross, wandering albatross, black-browed albatross, Indian yellow-nosed albatross, light-mantled albatross, sooty albatross, Cape petrel, brown skua	8	I
13	East Antarctica: Adélie Land sector	Southern fulmar, Cape petrel, snow petrel	3	B, I

[1] B : breeding, I : inter-nesting

This inventory of areas of key importance is necessarily incomplete, mainly because of the lack of data on several keystone species such burrow petrels which could not be studied in this work.

Surveys and substantial coverage (individual tracking data, see Annex II Tables A1 & A2 for details) were available for much of the French Southern Territories making important areas delineations both practical and feasible, with some missing data (poor or no data for some breeding colonies or life stages; cf Annex II). Models of top predators habitat associations and various spatial relationships, among seabirds and marine mammals with their physical and biological environments, may be useful to identify potential or even probable key areas where survey coverage is sparse (Arcos et al., 2012;Montevecchi et al., 2012;Nur et al., 2011;Wakefield et al., 2011).

In conclusion, the results presented here show an unprecedented improvment in the identification of priority areas within the Southern Indian Ocean, which should be the primary targets of site-based conservation efforts in the near future.

ANNEXES: Methodological Notes – Tables – Additional Results

Annex I: Methodological Notes

A. Distribution data

1. Devices Used for Tracking Data

Three types of devices were used to obtain the tracking data used in the Atlas:

i. Global Positioning System loggers, or GPS loggers, work in the same way as a hand-held GPS. They obtain their location fixes from orbiting satellites and store them in an on-board flash memory card. They have the advantages over other devices of being very accurate (typically less than 5 m) and able to record positional fixes as frequently as every second. However power consumption is high and some foraging trips may be incomplete (especially in diving birds). Furthermore the devices are still too large to be deployed on smaller animals. Diving seabirds are difficult to track during their eThey are also relatively expensive and need to be retrieved in order to download their data, although GPS loggers which upload data via satellite have been recently developed.

ii. Platform terminal transmitters, or PTT instruments, also obtain their fixes via satellite (Argos system). Since the late 1980's these devices have been deployed on a wide variety of marine mammals, sea turtles and seabirds. Although not as accurate as GPS loggers (accuracy varies from a few kilometres to tens of kilometres), they have a longer battery life that can be extended by switching the device off for periods of time (duty-cycling). Solar-powered devices have been recently developed, removing the limitation of battery life although the problem of attaching the device for longer periods remains. A major advantage is that location fixes –several locations per day, depending on the speed and position of the animal– are sent to a receiving station and can be downloaded, allowing real-time tracking of the animal. However these devices are also relatively expensive.

iii. An alternative to GPS and PTT devices is geolocation, or the use of a Global Location Sensing (GLS; manufactured by the British Antarctic Survey) tag. The device records daylight levels at pre-determined intervals; once the device is retrieved this record can be downloaded and, together with the device's internal clock, be used to calculate the animal's track. Longitude is determined from the local times of sunrise and sunset and latitude from the day length. There are several problems associated with this method –accuracy is within the hundreds of kilometres according to the species (180 km in penguins, 200 km for albatrosses) and can be affected by poor light levels due to cloud or shading by the animal. For several weeks during the equinox period it is almost impossible to determine latitude accurately as the variation in day length is small. The use of seawater temperature data recorded by the same logegrs during the same period considerably increases the reliability of thegeolocation data. These devices are pretty small, easily attached (often on a bird ring) and can be deployed for several years, allowing researchers to investigate the distribution of marine animals during the poorly known non-breeding periods. Although they have to be retrieved to download the data, they are inexpensive compared to the other types of devices.

2. Processing of Tracking Data

Three types of tracking data were used, depending on the type of device deployed and pre-processing analyses. These consisted of:

i. GPS (Global Positioning System) tracks, with sampling rates varying from seconds to hours. No pre-processing had been performed.
ii. PTT (satellite transmitter) tracks, either duty-cycled or continuous, where no pre-processing was performed beyond the selection of the most likely location between the alternate locations for each uplink (often performed by Argos itself).
iii. GLS (geolocator) tracks which had been processed to provide 2 locations per day.

3. Validation of Tracking Data

All tracks were validated using a velocity filter based on McConnell et al. (1992), which has successfully been used to validate the wide range of datasets included in marine top predators (BirdLife International, 2004). This filter calculates the averaged velocity between the current point and the four adjacent points. Unrealistic positions were then filtered using the maximum mean velocity known for each species (from empiric data when available or found in the literature). However when processing PTT tracks for which the Argos location quality code had been provided, points with high accuracy –location classes 1, 2 and 3 with accuracies of up to 1 km (Argos)– were not rejected even if their average velocity was above the maximum mean velocity.

4. Deriving Residence Time

Tracks were assigned to the breeding or inter-breeding periods according to the phenology of the breeding cycle for each species and breeding site and then grouped into datasets including unique combinations of period/ species/colony (see Annex II, Table A1 & A2).

The point locations in each dataset were then converted into residence time distributions using Time Spent per Square (TPS). TPS-based methods have been used comprehensively to convert tracking data to gridded distribution (Louzao et al., 2011;Pedersen et al., 2011;Péron et al., 2010a;Péron et al., 2012).The TPS was calculated by period/ species/colony.

Residence time was calculated using the *tripGrid* function (trip package, Sumner 2012) in R (R Core Team 2012 that creates a grid of time spent from each individual track by exact cell crossing methods, weighted by the time between locations for separate trip events and finally calculates the time spent in each spatial unit. Then, we assigned the corresponding percentage of time spent in relation to the total trip duration. We kept the estimated percentage of TPS calculated from linear interpolation of the tracks during the OFF-period of the solar PTTs. The 1° cell size (29 610 cells) was chosen according to the lowest accuracy among the tracking devices used. The area of interest is the southern Indian Ocean (10° to 180°E; 20° to 90°S). The TPS values for each combination of period/ species/colony were then normalized (0-1) to be comparable and combined such as to have residence time distributions for each species/period.
The TPS distribution permits to obtain occurrence distribution (presence/pseudo-absence data) for each species/period.

5. Building Composite Distributions

Annual grids (also named '*Complete*' grid) were created as the combination of available period grids (breeding/inter-breeding) even when data were not available (see Annex II, Table A1 & A2). These grids were built by combining the dataset grids produced previously.

Composite distributions for all tracked species were created by combining TPS grids. Diversity grids were obtained by combination of occurrence grids.

6. Mapping

Residence time distributions are represented on the maps, with the TPS values (0 to 1) indicating a percentage of residence time of the at-sea time (0 means 0% of time residency, 1 means 100% of time residency).
It is important to note that areas of low residence time on these maps do not imply an absence of the tracked species. Areas in close proximity to deployment locations could show a higher utilisation bias as the tracks are not independent samples of the species' distribution. In addition data points were not separated into "commuting" or "foraging" points –it is thus recognised that not all areas used by the tracked species will be areas of foraging.

B. Habitat modeling: methods

1. White-chinned petrel

Breeding period ; From (Péron et al., 2010b).
*"We focused on the breeding season and used a hierarchical modeling approach to relate oceanographic variables to residence times estimated via Argos data (see (Péron et al., 2010b) for detailed methodology). We assigned the corresponding percentage of time spent in relation to the total trip duration. Ultimately, environmental data were temporally and spatially matched to this index of spatial usage at the same spatial scale. Environmental variables were selected depending on their biological relevance and availability in the study area (52 to 102° E, 45 to 66° S). Habitats were investigated by determining the oceanographic parameters (bathymetry: BAT; sea surface temperature: SST; chlorophyll a concentration: CHLA; and their gradients: BATG, SSTG, CHLAG). We selected both fixed (BAT) and dynamic variables (SST, SSTG, CHLA, CHLAG and distance to daily sea-ice limit, DIST-ICE), because they are likely to influence foraging behaviour. These explanatory variables were standardised (centered and scaled) to improve algorithm convergence and scale the range of the predictors. We checked for colinearity by calculating all pairwise Spearman rank correlation coefficients (rS). When pairs of predictor variables were strongly correlated (|rS| > 0.6), we ran 2 univariate models with each of these predictors and selected the predictor that led to the lowest Akaike Information Criteria (AIC) (Burnham & Anderson 2002). We used linear mixed models with the log-transformed percentage of time spent as response variable, and non-correlated oceanographic parameters as explanatory variables. Models were fitted with a Gaussian error distribution and an identity link function. We included individual identity as a random intercept term (during incubation) and trip nested within individual (during chick rearing) to account for the hierarchical structure of the data (Bolker et al. 2009). Non-independence of the error due to spatial autocorrelation was accounted for by adding an autoregressive term (Dormann et al. 2007). We tested multiple autocorrelation structures and selected the one that provided the lowest AIC and best fitted the experimental variogram (Zuur et al. 2009). An exponential correlation structure was thereby selected. We performed all possible linear combinations of explanatory variables and ranked the models based on their AIC values. We then calculated the Akaike weight (wi) for each model, which represents the relative likelihood of candidate models (Burnham & Anderson 2002). Predictive performances of the best models were assessed by cross-validation. In each simulation (n = 1000), models were fitted to a training dataset (70% of each trip, selected randomly) and the predictive performance was assessed by comparing observed and predicted time spent of the test dataset (remaining 30%). We used Pearson correlation coefficients to assess model predictive performance for each simulation. Ultimately, we mapped the predicted spatial distribution of foraging habitat during both incubation (December 2007) and chick rearing (January 2006) within a spatial extent in accordance with the observed range of long trips performed by white-chinned petrels.
The standard deviation of the random intercept terms in the models indicated the level of inter- and/or intra-individual variability. Predictions were made for each trip and then averaged to take into account inter- and/or intra-individual variability and so draw inferences at the population level.*

Cross-correlation analysis indicated that SST and DIST-ICE were highly correlated, as were CHLA and GCHLA (see (Péron et al., 2010b) Table S4 in the supplement at www.intres.com/articles/suppl/m416p267_supp.pdf). Univariate ranking led to the removal of CHLA from both models, whereas SST was discarded from the incubation model and DIST-ICE from the chick-rearing model. The models with lowest AIC had relatively high support (Akaike weight, wi ~90%) and the ΔAIC between these models and the second best models were greater than 5 (see (Péron et al., 2010b) Table S5 in the supplement; www. intres.com/articles/suppl/m416p267_supp.pdf). Consequently, we did not apply an averaging procedure but retained the most parsimonious model ((Péron et al., 2010b); Table 3). The most important predictors explaining residence time of incubating birds were DIST-ICE and CHLAG ((Péron et al., 2010b); Table 3), indicating that birds foraged preferentially in areas close to the pack ice and characterized by high CHLA variability. During chick rearing, residence time was negatively related to SST and positively associated with CHLAG. SST appeared to be a better predictor of residence time than distance to pack ice later in the breeding season. SSTG was retained by the model selection procedure but its influence on residence time was minor during both stages ((Péron et al., 2010b); Table 3). Model ranking indicated that BAT and BATG had weak influences on spatial allocation of time spent at sea. The standard deviations of the random effects included in the 2 models were relatively small, which suggests low between and within individual variability in response to oceanographic variables ((Péron et al., 2010b); Table 3). Despite the high Akaike weights of the models with the lowest AIC, indicating low parameter uncertainties, the cross-validation procedure revealed poor predictive performance (r^2 test = 0.28 and 0.30 for incubation and chick rearing, respectively, (Péron et al., 2010b); Table 3). However, the averaged spatial predictions of the percentage of time spent matched well with the observed patterns ((Péron et al., 2010b); Fig. 7). During incubation, white-chinned petrel foraging zones were restricted to a narrow latitudinal strip along the pack ice, and zones of maximal CHLAG ((Péron et al., 2010b); Fig. 7a), whereas during chick rearing, sea ice retreated and SST was the most important predictor leading to much larger potential habitat ((Péron et al., 2010b); Fig. 7b). The habitat model for chick-rearing birds identified a key foraging area—the Kerguelen plateau—which was visited during short trips but not included in the modeling process."

2. King penguin

a. Breeding period; From (Louzao et al., 2011;Péron et al., 2010b)

"We used a hierarchical modelling approach to identify those environmental variables (see details in Table 1) that most accurately reflected the seascape and both foraging and feeding habitats of wandering albatross within the information theoretic approach (Fig. S1, Supporting information; (Louzao et al., 2009).

Selecting predictors

Prior to modelling, all environmental variables were standardized (Zuur et al., 2007). Strongly 'correlated' (|rs| > 0.5) predictors were identified by estimating all pair-wise Spearman rank correlation coefficients (Table S2, Supporting information). Then, we removed those explaining less deviance by comparing Akaike Information Criteria values (AICs) of generalized linear mixed models (GLMMs) with only one predictor to avoid colinearity and related problems with parameter estimations (Zuur et al., 2007). This approach led to the removal of different predictors depending on the habitat index and breeding stage considered.

Habitat models

Once 'non-correlated' environmental variables were identified, GLMMs were fitted for all possible linear combinations of predictors based on the lmer function (lme4 package; (Pinheiro and Bates, 2000)). For each breeding stage, the (log-transformed) percentage of time spent per unit area was fitted with a Gaussian error distribution (identity link), whereas the two binomial dependent variables ('foraging/not foraging' and 'feeding/not feeding') were fitted with a binomial error distribution (logit link).We only included the 'individual identity' as a random term in order to account for individual effects, although 'year' and/or 'sex' effects were also tested (to account for inter-annual variability in sampling effort and sex-related foraging ground location) but AIC values did not improve (decrease).

Model selection and inference

Within the Information Theoretic Approach, we evaluated competing models by assessing their relative support (based on AIC and Akaike weight) in relation to observed data, rather than using the best single model approach (Burnham and Anderson, 2002). When the model with lowest AIC value has an Akaike weight value lower than 0.9, a model averaging procedure might be more appropriate to account for parameter uncertainty (Burnham and Anderson, 2002). Therefore, we constructed a 95% confidence set of models where the sum of Akaike weights was >0.95 (Louzao et al., 2009). Accordingly, averaged coefficients were estimated from the 95% confidence set of models containing that variable, as well as variance estimator in order to assess the precision of the estimates (Burnham and Anderson, 2002).

Model checking
In parallel, we checked the distribution and spatial autocorrelation of the residuals, but no significant evidence was found (results not presented) and we did not consider any spatial autocorrelation structure in GLMMs.

Model evaluation
To assess the predictive performance of habitat models, we estimated the concordance index (C-index) of the averaged models estimated with the Hmisc package (Harrell, 2001). This index is equivalent to the area under the Receiver Operating Characteristics curve (AVC) and probably the most useful measurement for distribution modeling (Vaughan and Ormerod, 2005), since it allowed the comparison of the predictive performance of all three models (time spent: continuous, foraging and feeding: binomial; (Harrell, 2001). The C-index varies from 0.5 to 1 with the following model predictive performance classification: > 0.9 excellent, 0.9–0.8 good, 0.8–0.7 reasonable, 0.7–0.6 poor and 0.6–0.5 unsuccessful (Swets, 1988).
We applied a cross-validation procedure using two different approaches: (1) an independent dataset for time spent and foraging patterns in order to assess the predictive performance of averaged models (built with data from Crozet) in predicting distribution patterns of birds from Kerguelen and (2) bootstrapping the original data for feeding patterns (no independent dataset) which provides an alternative approach for evaluating the model with the original data (Guisan and Zimmermann, 2000;McAlpine et al., 2008).
Working on two spatially distinct groups (Crozet and Kerguelen) allowed us to assess the model performance to predict in different conditions/areas. Although both populations differed slightly in their habitat availability, a previous study showed no evidence of difference in habitat selection (Pinaud and Weimerskirch, 2007).
During 1000 simulations, models within the 95% confidence set were fitted to 70% of the test dataset and the modelling output was then used to predict distribution patterns of the remaining 30%.
Then, the C-index was estimated for each simulation (up to 1000) and the mean, upper and lower 95% confidence interval (CI) of the C-index were used as a cross-validation measure of the predictive performance of the models (McAlpine et al., 2008). If the lower 95% CI limit did not include the 0.5 value, there was evidence that averaged habitat models were able to accurately predict beyond training dataset."

b. Inter-nesting period; Source B. Raymond et al. unpublished
The observed track distributions (e.g. Map 33) show the geographic space directly utilized by the tracked birds. This information can be generalized by modeling the spatial distribution as a function of environmental conditions. The model output gives an estimate of habitat suitability across the region, where "habitat suitability" is an indication of the expected habitat usage in relation to the range of habitat that is accessible to the birds.

This modeling approach is very similar to conventional species distribution modeling, which uses presence and absence information to estimate the probability of the species being present given the environmental conditions at a location. For tracking data, there are no absences *per se* (the tracks only indicate where the birds were present, not where they were absent) and so the modeling approach used here is analogous to presence-only species distribution modeling methods such as Maxent (Elith et al., 2011). Similarly to Maxent, the approach used here gives an indication of habitat suitability, but these suitability values cannot be strictly interpreted as probabilities of presence.

In order to fit the model, a set of "surrogate tracks" are first constructed, in a similar manner to (Zydelis et al., 2011). These are simulated random tracks that are statistically similar to the observed tracks. They can be viewed as simulations of where the birds might have travelled, if they had no environmental preferences, and thus indicate the spatial areas available to the birds. By building a statistical model that discriminates the environmental characteristics of the actual tracks from those of the surrogate tracks, we can obtain an indication of environmental conditions that are preferred by the birds. A boosted regression tree (De'ath, 2007) was used for this step, with five environmental predictor variables: sea surface temperature (SST), bathymetry, the proportion of time the ocean is covered by sea ice, distance to the nearest subantarctic island, and the wind cost residual (which is the relative energetic cost of travel by gliding flight from Kerguelen Island to the point of interest).

The resulting map of estimated habitat utilization is shown in Map 36. The corresponding partial effects (environmental dependencies) fitted by the model are shown in Figure 1. The most important predictors are SST and wind residual. The SST response (dropping off below about 5 °C and above about 20 °C) provides a broad latitudinal delineation of habitat. The wind residual has a strong response for negative wind residual values, indicating the birds' preference for areas that are most easily accessible when wind patterns are taken into account (i.e. downwind, or to the east of Kerguelen Island). The remaining predictors indicate preferences for areas relatively close to subantarctic islands, and for areas covered by sea ice for not more than about half the season, but no obvious dependence on water depth (bathymetry).

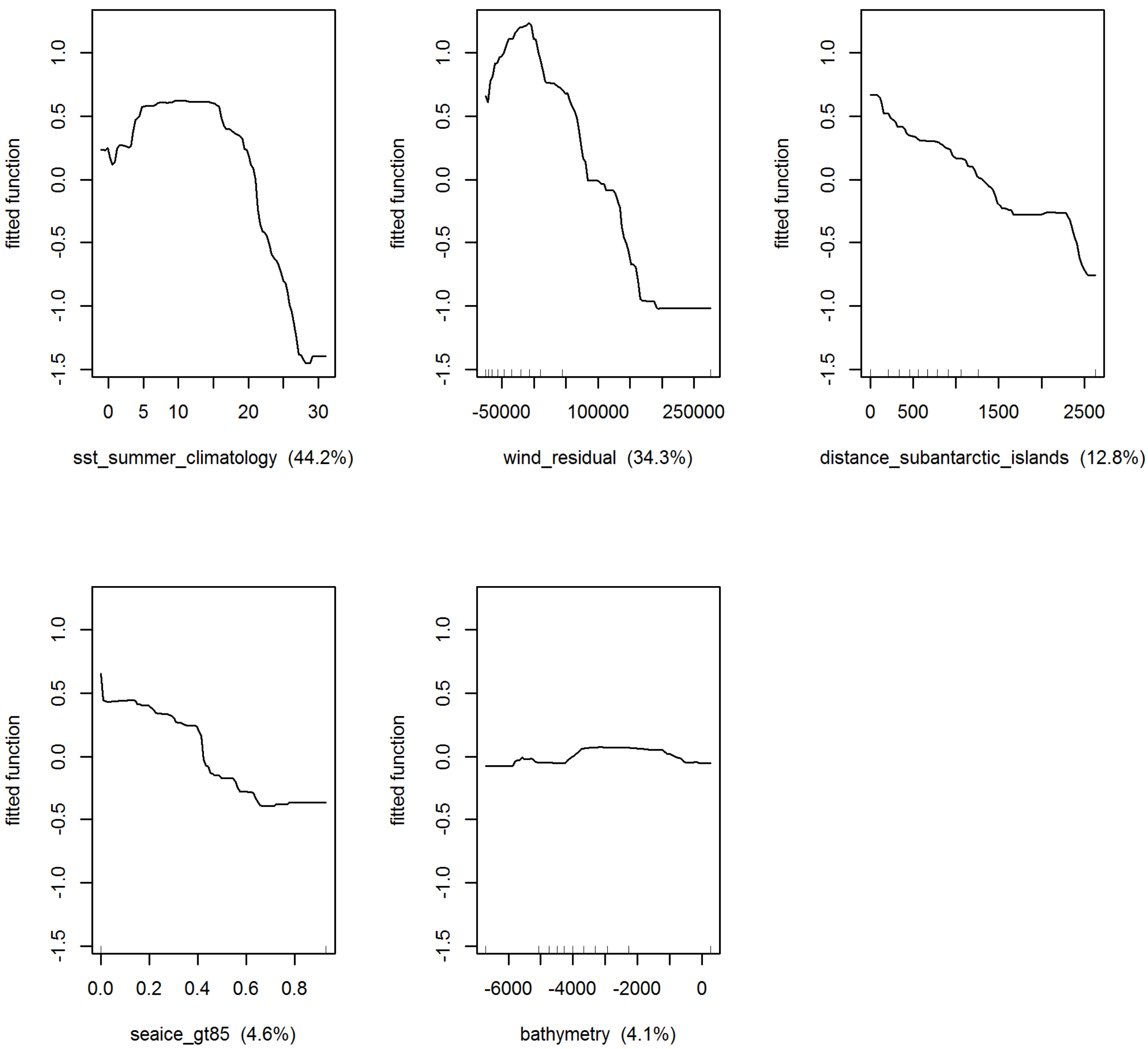


Figure 1. The fitted partial effects from the habitat preference model shown in Map 36. Values in parentheses are the variable importances estimated by the model.

The accuracy of the habitat importance model was assessed using a cross-validation procedure. Each individual animal in the training data was assigned to one of ten data "folds". The model was fitted using nine of the ten folds, and tested on the individuals in the remaining one. This was repeated ten times in total, withholding each of the ten folds in turn. The predictive accuracy was evaluated using the area under the receiver operating curve (AUC). An AUC value of 1 indicates perfect predictive performance; a value of 0.5 indicates performance that is no better than random guessing.

The mean (SD) predictive accuracy of the model was 0.68 (0.10). This is significantly better than random (P<0.001), but it does not indicate particularly strong predictive performance. It suggests that while the general spatial pattern of the predictions is broadly correct, the model is unable to resolve fine-scale spatial structure in the birds' habitat preferences. This might be a true reflection of the behaviour of the animals: their foraging behaviour is not constrained by breeding demands (i.e. they do not need to return to the nest to feed their chicks) and so they might be foraging in a relatively opportunistic manner, without specifically targeting particular habitat features. Alternatively, the results might simply indicate that the habitat features being utilized by the birds are not well described by the available predictor variables, and so the model is unable to isolate those features. The relative inaccuracy of the GLS locations (with position uncertainties of up to several hundred kilometres) may also contribute.

3. King penguin

Breeding period; Crozet, Source (Péron et al. 2012)

Habitat models concern the spatial distribution of the king penguins during the summer period (see Péron et al. 2012 for details). Time spent per 0.1 °cell was converted into percentage of time spent in relation to the total trip duration and log-transformed to meet normality. This proxy was matched temporally and spatially to 8 environmental variables that were likely to influence penguin foraging behaviour. We included bathymetry, SST, Chlorophyll a concentrations, Sea Surface Height deviation and Eddy-Kinetic Energy. Additionally, spatial gradients of bathymetry, sea surface temperature and chlorophyll a concentration. All these environmental variables were normalized and re-interpolated on a grid of 0.1×0.1° to match with the habitat-use proxy. Linear mixed-effects models were used with the log-transformed percentage of time spent in a cell as response variable and non-correlated oceanographic variables ($|r^2|<0.7$) as explanatory variables. By including spatial autocorrelation structure and random effects (‘Year’ as a random intercept term and the ‘Individual’ identity nested within ‘Year’), we accounted for the hierarchical structure of the tracking data.. Each breeding stage (incubation, brooding) was modelled separately.

Model selection was performed using a maximum likelihood approach to select the best model by minimizing the Akaike Information Criterion (AIC). Models with all combinations of variables were ranked according to their respective Akaike weight (w_i), which represents the relative likelihood of each candidate model. As there was no obvious evidence of a single best model (w_i>0.90), we applied a model averaging procedure to account for uncertainties in model selection. For each breeding stage, a set of models totalling 95% of the Akaike weights was kept and used to calculate models parameters.Model validation was performed by checking model residuals and calculating model goodness-of-fit by cross-validation (n=100). Models were fitted using a 70% subset of the tracking data and then evaluated with the remaining 30% using Spearman rank correlation coefficients. Finally, validated models were generalized to predict habitat-use probability within the spatial extent accessible to king penguins from 1998 to 2008, in January and February for incubation and brooding, respectively.

4 Eastern rockhopper penguin

Inter-breeding period; Source (Thiebot et al. 2013)

Habitat suitability for the penguins during the wintering period was modelled using Mahalanobis Distances Factor Analysis (MADIFA) in R package 'adehabitat'. This method is appropriate for building habitat suitability maps from presence-only data, such as tracking data In the MADIFA, two principal components analyses (PCAs) successively summarize available information comprising: (i) the environment described by spatial variables; and (ii) the relationship between the locations of animals and the environment. Environmental variables used were bathymetry and its gradient, sea-surface temperature and its gradient, SST anomalies, sea-surface chlorophyll a concentration, mixed-layer depth and eddy kinetic energy. MLD was a mean of annual data obtained since 1941.. The temporal resolution selected for dynamic variables was one month, and the spatial grid 1° in accordance with the geolocation technique accuracy. The spatial data were obtained from the NOAA's ETOPO, the LOCEAN and the AVISOwebsites. The habitat model was based on the at-sea distribution of the birds from Crozet, and the model predictions were projected on the whole study area in order to compare predictions with the actual locations of the birds from all sites. The time window for modelling wintering habitat was one month, according to seasonality in this oceanic region, and taking into account the minimum mobility of the birds (that suggests intensive use of a wintering area, which occurred in September for *E. filholi*.

C. Biological diversity characterization

Biological diversity can be evaluated on the basis of single or multiple criterion indices. Four indices (two of each type) are used in the analysis of area evaluation, following (Hacker et al., 1998).

The first single-criterion index is "*species richness*" deduced from the occurrence data of the species. The *species richness* is the sum of the species present in each grid cell of the area of interest (min. 0 – max. 12).

Two alternative approaches can be used in multiple-criterion evaluation (e.g. (Williams, 1997)).

The first approach is to produce a single index that combines two or more such index, where species richness is weighted by spatial range size of the species present to determine the "*rarity-weighted richness*" of an area. Range size is a common measure of rarity (Gaston, 1994). The *rarity-weighted richness* is calculated as the sum of rarity score for all species present in a grid cell, where the rarity score for each species is the reciprocal of the number of cells in which it occurs (e.g. (Williams and Humphries, 1996); the cells with highest score value are therefore those which have a large number of restricted-range species.

The second approach to multiple-criterion indices is that of sequential filtering. This is used in an index in which species richness is combined with endangerment by discarding all the species which are not classified as threatened (following Stevenson et al. 1992; CR: Critically Endangered, EN: Endangered, VU: Vulnerable; Table 4) and then evaluating species richness for the remaining database of threatened species. This measure is called "*threatened species richness*".
Finally, we consider the *threatened species richness*, by integrating a weight for IUCN status (i.e. Critically Endangered: 5, Endangered: 4 and so on) and combining it in a final index "*conservation-weighted rarity richness*".

Hotspots were identified by overlapping the top-scoring 10% and 5% of grid cells (Prendergast et al., 1993) for *species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness* .

Annex II: Tables

Table A1. Species included in the *Atlas* and availability of tracking data by colony and for each period

Species	**Scientific name**	**Availability of tracking data**[1]			
		Amsterdam	**Crozet**	**Kerguelen**	**Adélie Land**
Penguins					
King Penguin	*Aptenodytes patagonicus*		**B**	**B**	
Gentoo Penguin	*Pygoscelis papua papua*			**B**	
Adélie Penguin	*Pygoscelis adeliae*				**B**
Eastern Rockhopper Penguin	*Eudyptes chrysocome filholi*		**I**	**I**	
Northern Rockhopper Penguin	*Eudyptes moseleyi*	**I**			
Macaroni Penguin	*Eudyptes chrysolophus*		**B, I, T**	**B, I, T**	
Albatrosses					
Amsterdam Albatross	*Diomedea amsterdamensis*	**B, I, T**			
Wandering Albatross	*Diomedea exulans*		**B, I, T**	**B, I, T**	
Black-browed Albatross	*Thalassarche melanophrys*		[2]	**B, I, T**	
Indian yellow-nosed Albatross	*Thalassarche carteri*	**B, I, T**			
Light-mantled Albatross	*Phoebetria palpebrata*		**B, I, T**	**B, I, T**	
Sooty Albatross	*Phoebetria fusca*	**B, I, T**	**B, I, T**		
Petrels					
Southern Giant Petrel	*Macronectes giganteus*		**B, I, T**		
Northern Giant Petrel	*Macronectes halli*		**B, I, T**	**B, I, T**	
Southern Fulmar	*Fulmarus glacialoides*				**B, I, T**
Cape Petrel	*Daption capense*				**B, I, T**
Snow Petrel	*Pagodroma nivea*				**B, I, T**
White-chinned Petrel	*Procellaria aequinoctialis*		**B, I, T**	**B, I, T**	
Grey Petrel	*Procellaria cinerea*			**B, I, T**	
Skuas					
Brown Skua	*Catharacta antarctica lonnbergi*			**B, I, T**	
Pinnipeds					
Southern Elephant Seal	*Mirounga leonina*			**I**	
Antarctic Fur Seal	*Arctocephalus gazella*			**B**	

[1] B : breeding, I : inter-nesting, T : total (breeding and inter-nesting combined);

[2] Grey cells indicated gaps in the distribution data for adults by breeding site

Table A2. Characteristics of the datasets used in the *Atlas*

Species	Colony	Individual trips	Data	Year
Penguins				
King Penguin	Crozet Is., Possession Is.	133	PTT	1998-2009
	Kerguelen Is., Courbet	60	PTT	1992-2004
Gentoo Penguin	Kerguelen Is., Courbet	6	PTT	2002
Adélie Penguin	Adélie Land	33	PTT	2004-2006
Eastern Rockhopper Penguin	Crozet Is., Possession Is.	11	GLS	2007
	Kerguelen Is., Courbet	14	GLS	2007
Northern Rockhopper Penguin	Amsterdam Is.	11	GLS	2007
Macaroni Penguin	Crozet Is., Possession Is.	20	PTT	2009-2010
	Crozet Is., Possession Is.	11	GLS	2007
	Crozet Is., Possession Is.	15	GPS	2013
	Kerguelen Is., Courbet	5	PTT	2000-2001
	Kerguelen Is., Courbet	19	GLS	2007
Albatrosses				
Amsterdam Albatross	Amsterdam Is.	41	PTT	1996; 2000; 2011-2012
	Amsterdam Is.	20	GPS	2011
	Amsterdam Is.	14	GLS	2006-2012
Wandering Albatross	Crozet Is., Possession Is.	278	PTT	1989-1992 ; 1994 ; 1998-2005 ; 2008 ; 2010
	Crozet Is., Possession Is.	36	GLS	2006-2011
	Kerguelen Is., Courbet	31	PTT	1998;2002
	Kerguelen Is., Courbet	16	GLS	2007-2010
Black-browed Albatross	Kerguelen Is., Ronarch	94	PTT	1994-1995 ; 1999; 2004-2007; 2009
	Kerguelen Is., Ronarch	52	GLS	2009-2012
Indian yellow-nosed Albatross	Amsterdam Is.	101	PTT	1996 ; 2001 ; 2002 ; 2006
	Amsterdam Is.	17	GLS	2007-2008
Light-mantled Albatross	Crozet Is., Possession Is.	4	PTT	2008-2009
	Crozet Is.,	9	GLS	2009-2010

	Possession Is.			
Species	**Colony**	**Individual trips**	**Data**	**Year**
	Kerguelen Is., Ronarch	5	PTT	1994; 2008-2009
	Kerguelen Is., Ronarch	11	GLS	2008-2009
Sooty Albatross	Amsterdam Is.	7	PTT	2008
	Amsterdam Is.	16	GLS	2008-2010
	Crozet Is.	28	PTT	1992-1994, 2007-2009
	Crozet Is.	31	GLS	2007-2010
Petrels				
Southern Giant Petrel	Crozet Is., Possession Is.	9	PTT	2008
	Crozet Is., Possession Is.	14	GLS	2009-2010
Northern Giant Petrel	Crozet Is., Possession Is.	6	PTT	2008
	Crozet Is., Possession Is.	17	GLS	2009-2010
	Kerguelen Is., Courbet	6	PTT	2008
	Kerguelen Is., Courbet	11	GLS	2009-2010
Southern Fulmar	Adélie Land, Pétrels Is.	10	GLS	2008 ; 2011
Cape Petrel	Adélie Land, Pétrels Is.	6	GLS	2011
Snow Petrel	Adélie Land, Pétrels Is.	8	GLS	2011
White-chinned Petrel	Crozet Is., Possession Is.	16	PTT	1996-1997
	Kerguelen Is., Ronarch	30	PTT	2006-2007
	Kerguelen Is., Ronarch	25	GLS	2006-2008
Grey Petrel	Kerguelen Is., Morbihan Gulf	7	PTT	2008
	Kerguelen Is., Morbihan Gulf	10	GLS	2007-2008
Skuas				
Brown Skua	Kerguelen Is., Morbihan Gulf	6	GLS	2008
Pinnipeds				
Southern Elephant Seal	Kerguelen Is., Courbet	87	PTT	2003-2010
Antarctic Fur Seal	Kerguelen Is., Courbet	111	PTT	1998-1999; 2007-2009

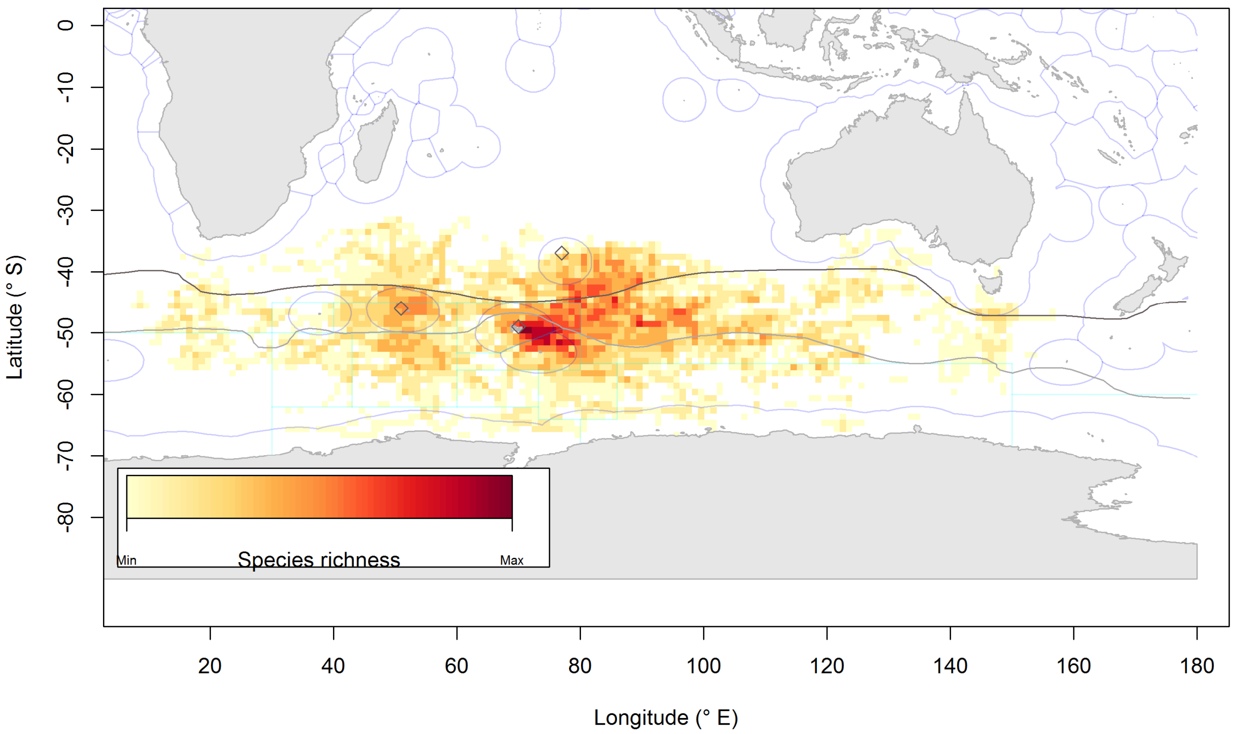
Annex III: Additional results

A. Hotspots identification

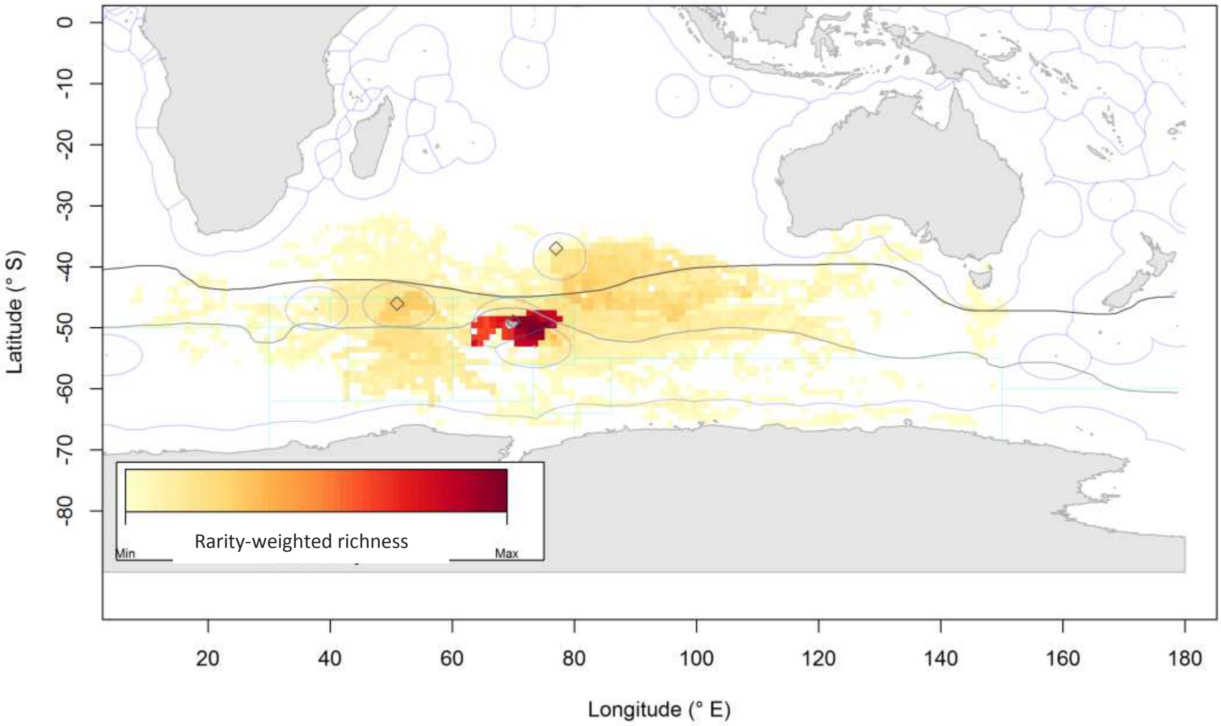
Hotspots were identified by overlapping the top-scoring 10% and 5% of grid cells (Prendergast et al., 1993) for *species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness*. Here we present here the results obtained for the top-scoring 10% for the four evaluation criteria employed (results for top-scoring 5% are presented in the main text of the *Atlas*). Patterns of seabirds and marine mammals according to these four evaluation criteria are plotted across the area of interest in the southern Indian Ocean.

4. Complete period: pooled breeding and inter-breeding periods

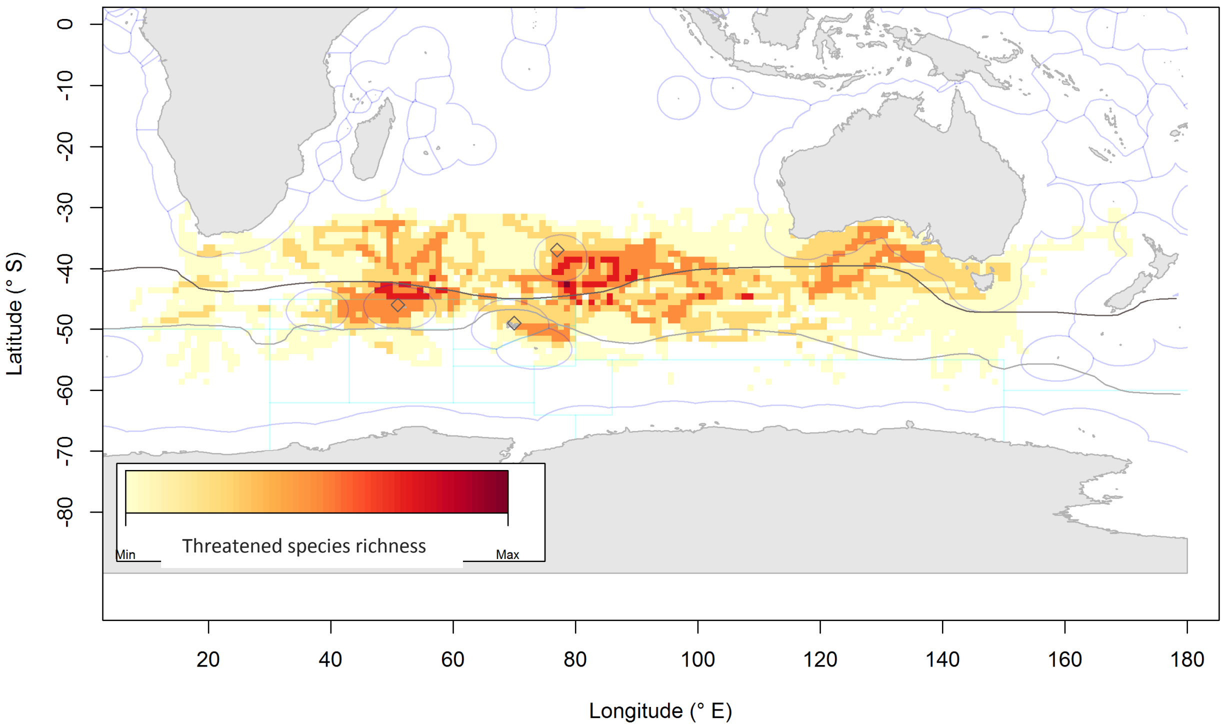
The first notable feature of patterns of spatial distribution for the four criteria (Maps 111 to 1114) is a consistent attribution of high value to subtropical and subantarctic regions and the area surrounding the breeding locations.



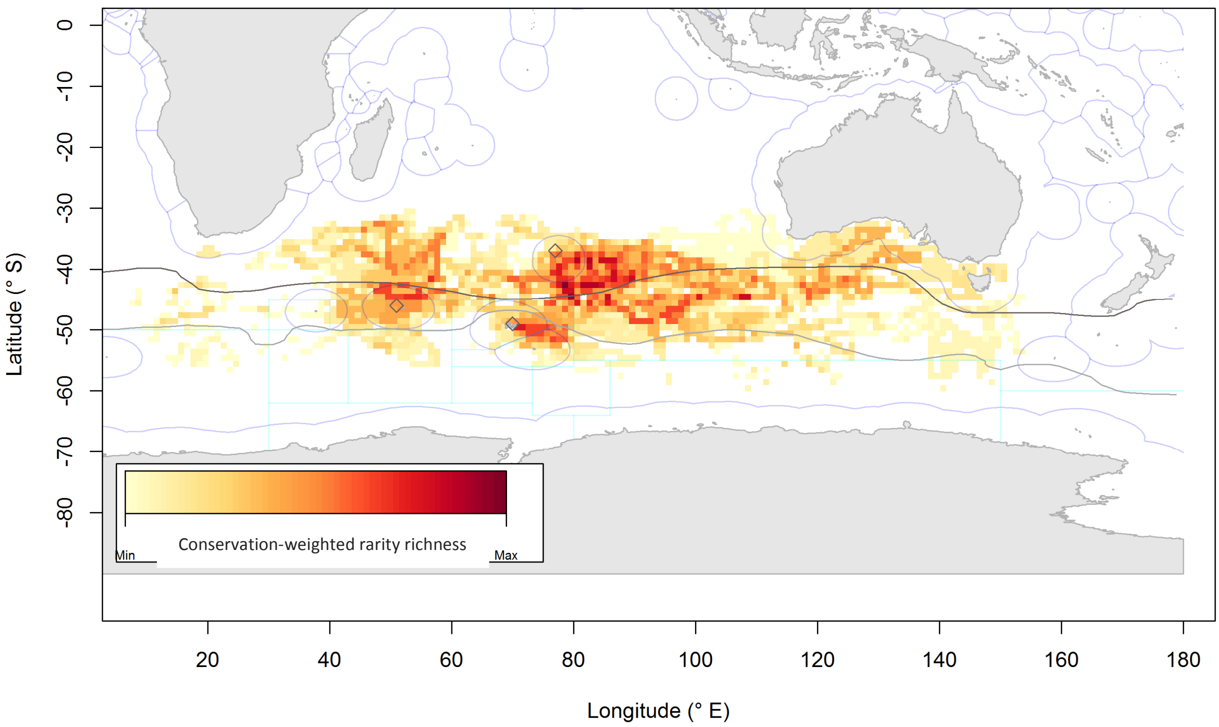
Map 111. ***Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 112. ***Spatial pattern of diversity: rarity-weighted richness*. Observed distribution of the evaluation criteria *rarity-weighted richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

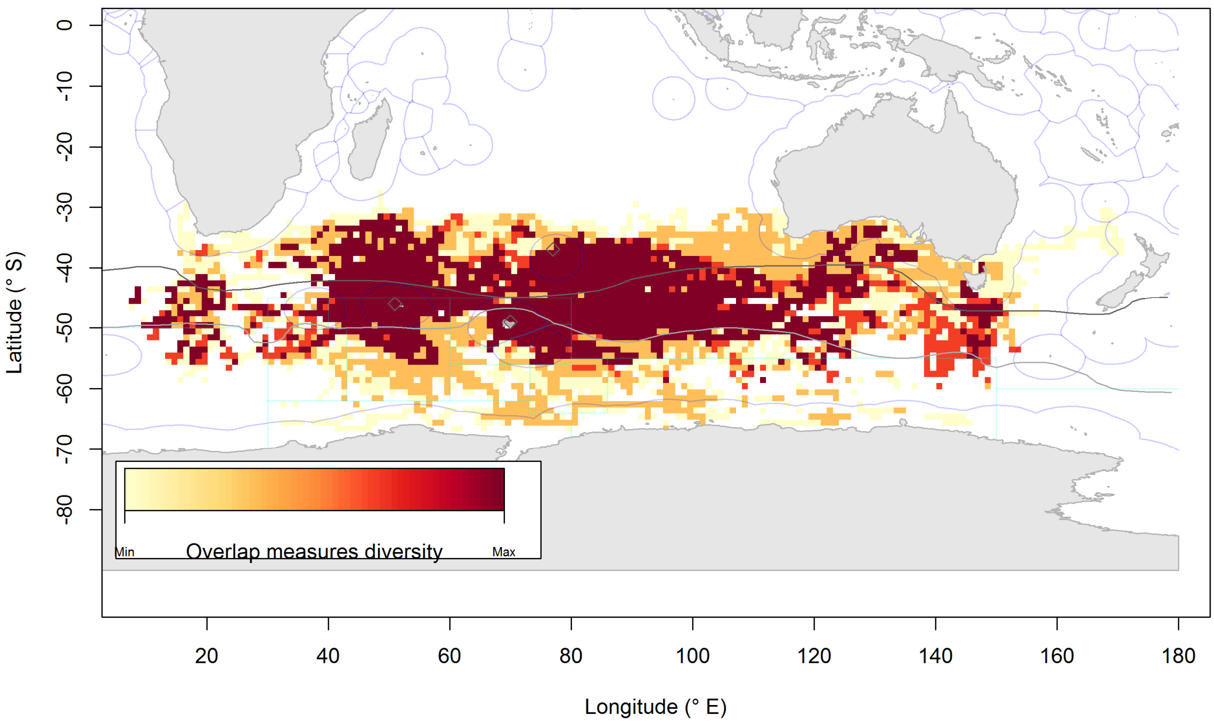


Map 113. ***Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 114. ***Spatial pattern of diversity: conservation-weighted rarity richness*. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-breeding periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

The comparison of important areas for seabird and marine mammal diversity from the French Southern Territories in the southern Indian Ocean obtained by four evaluation measures (*species richness*, *rarity-weighted richness*, *threatened species richness* and *conservation-weighted rarity richness*) was achieved by overlapping each different spatial pattern (Map 115). Grid cells with maximum values are shown in dark red indicating that all the four measures identify them as important area, whereas grid cells with minimum values are shown in yellow indicating that one measure identify them as important area.

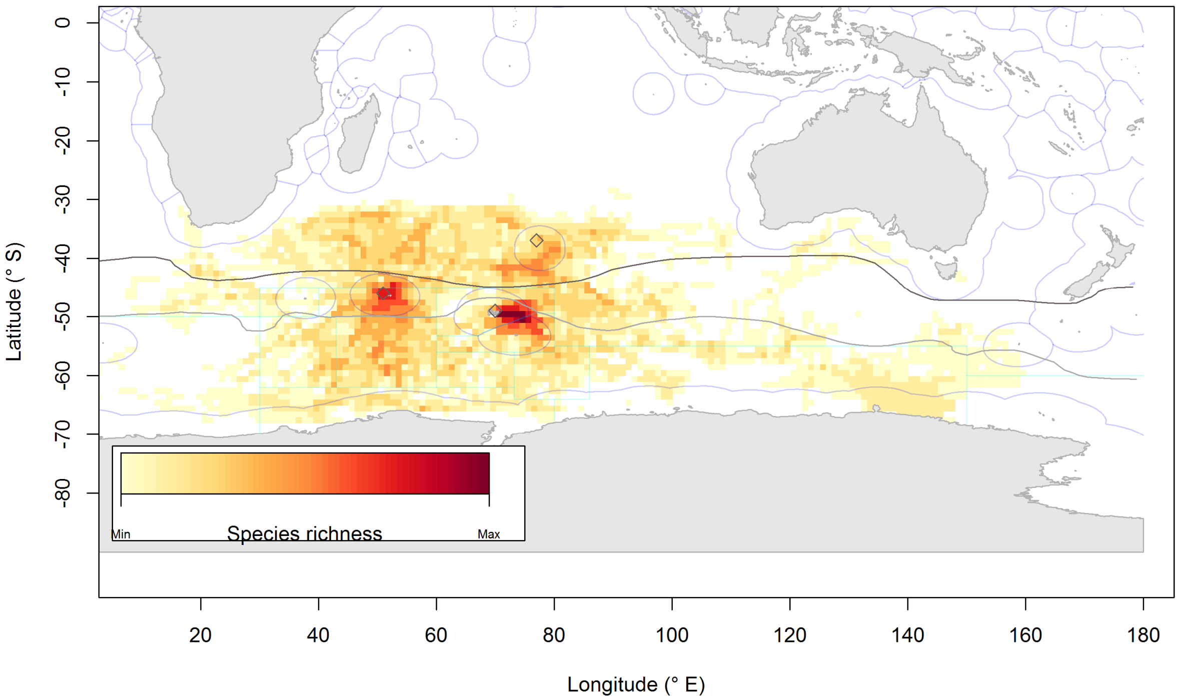


Map 115. ***Spatial pattern of hotspots diversity*****. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 10% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds (pooled breeding and inter-nesting periods).** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) ((Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

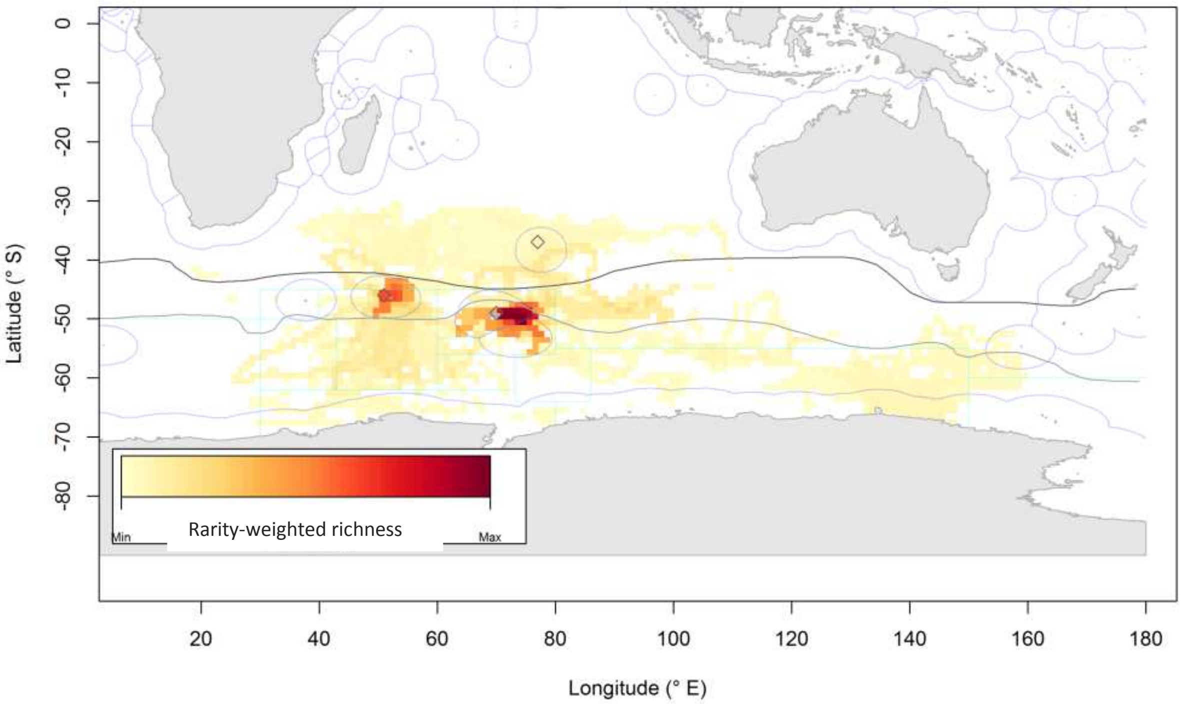
The areas identified by overlapping the top-scoring 10% of grid cells cover very large areas in the southern Indian Ocean from subtropical to Antarctic regions, especially the zones surrounding the breeding locations (Crozet, Kerguelen and Amsterdam Islands and Adélie Land - Antarctica).

5. Breeding period

Focusing on the breeding period, it is noteworthy to highlight that the patterns of spatial distribution for the four criteria (Maps 116 to 119) is a consistent attribution of high value to subtropical and subantarctic regions and particularly in the area surrounding the breeding locations. This is consistent with the fact that all the species included in the *Atlas* are central-place foragers, and realize foraging trips during breeding period returning regularly to the breeding colony.

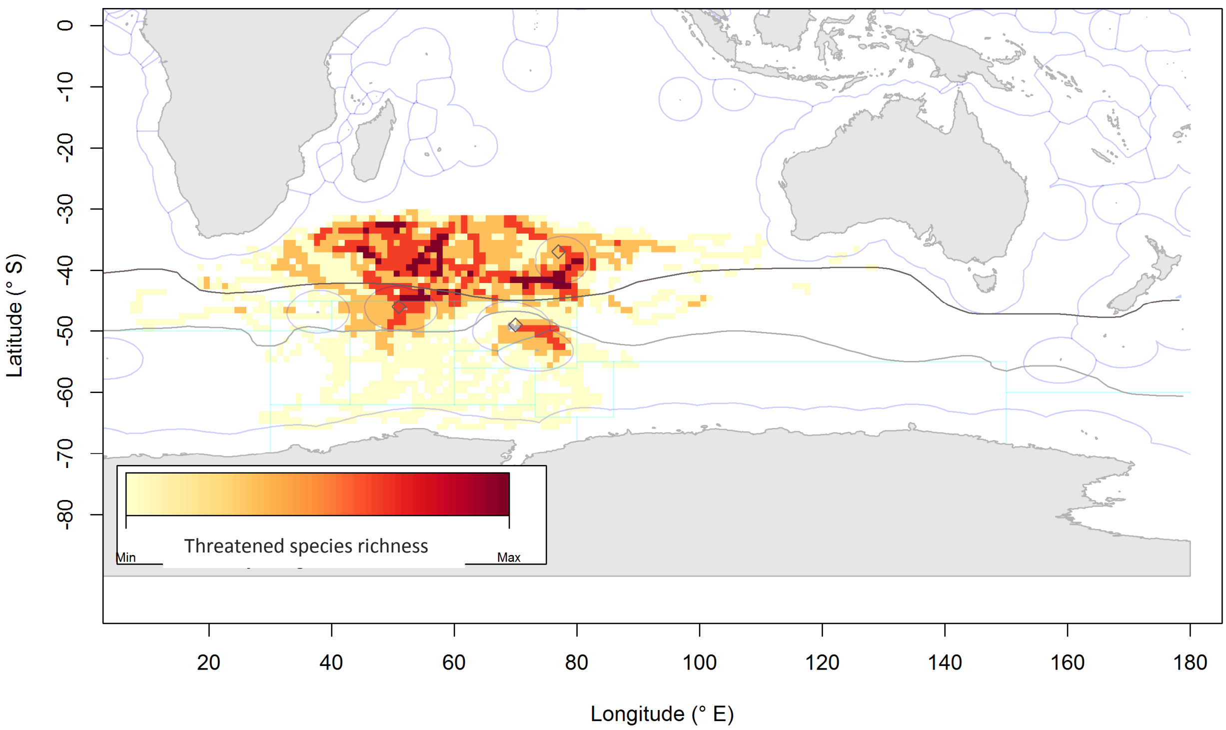


Map 116. ***Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

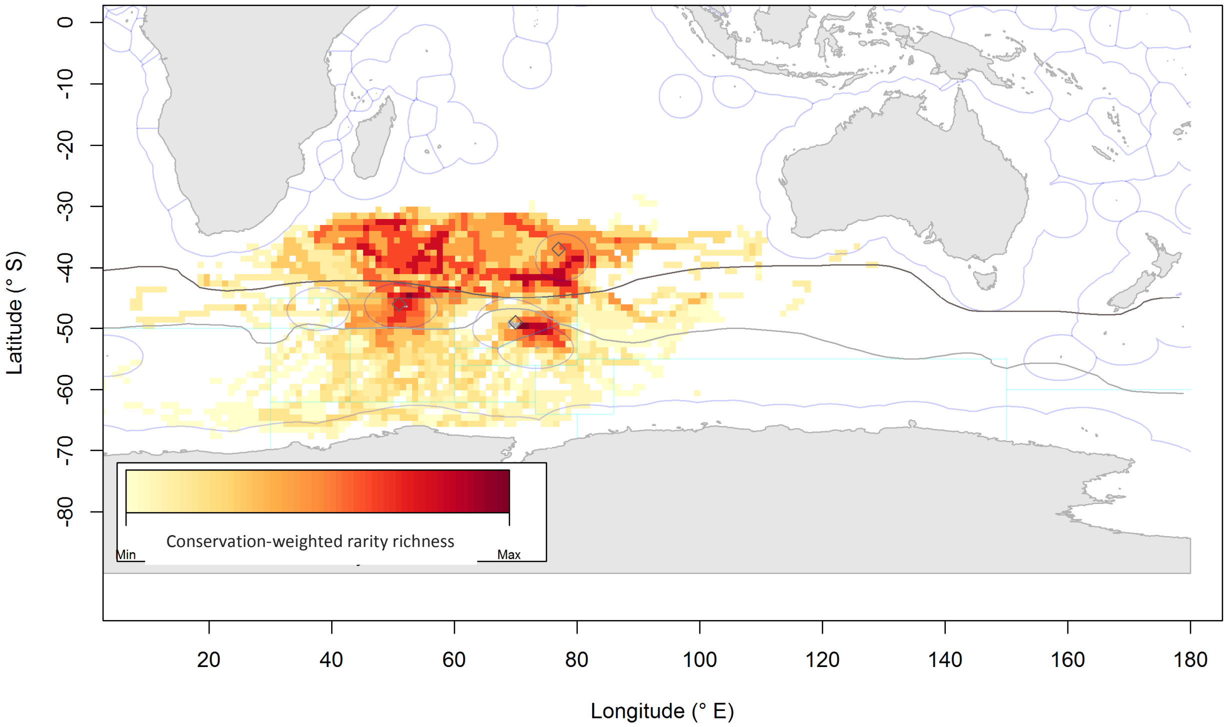


Map 117. ***Spatial pattern of diversity: rarity-weighted richness*. Observed distribution of the evaluation criteria *rarity-weighted richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003).

Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

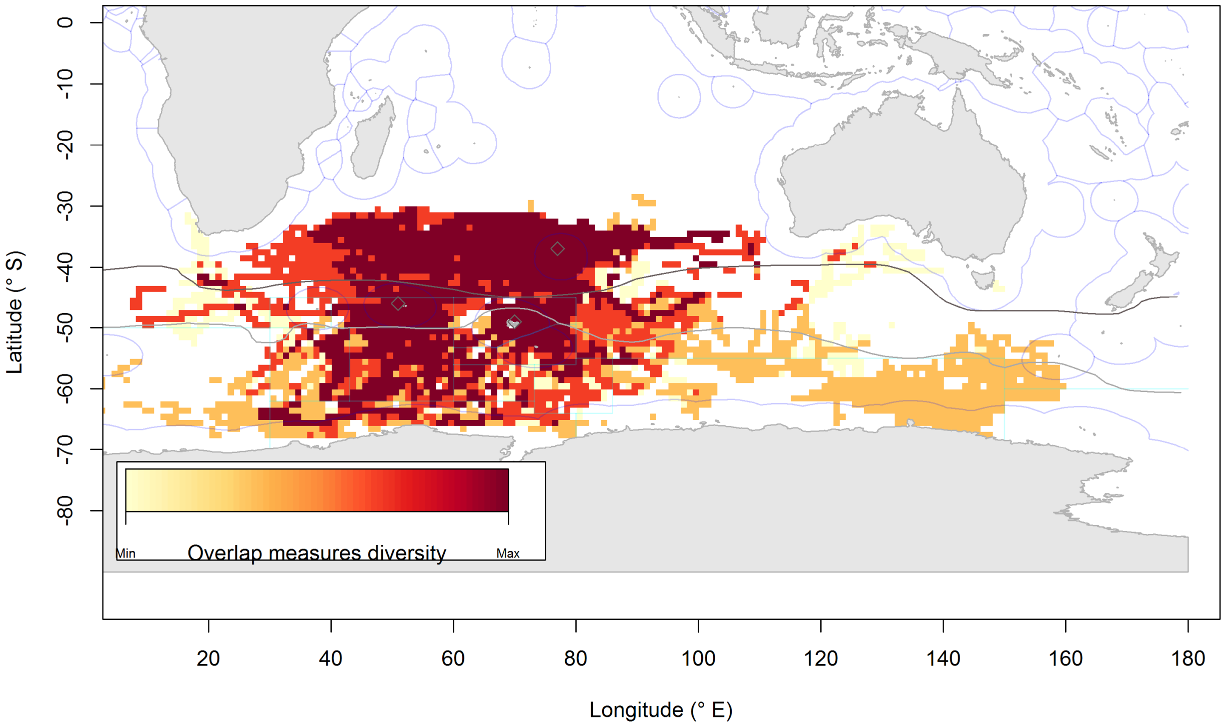


Map 118. *Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 119. ***Spatial pattern of diversity: conservation-weighted rarity richness*. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

There is a correspondence between the highest values of species richness and of rarity-weighted richness. This suggests that at this scale rare species are often inside hotspots of high species richness. Nonetheless, some important areas identified by the levels of species richness do not correspond to high value of rarity-weighted richness. This may be explained by the fact that some species tended to reduce their foraging range more than others during the breeding period.

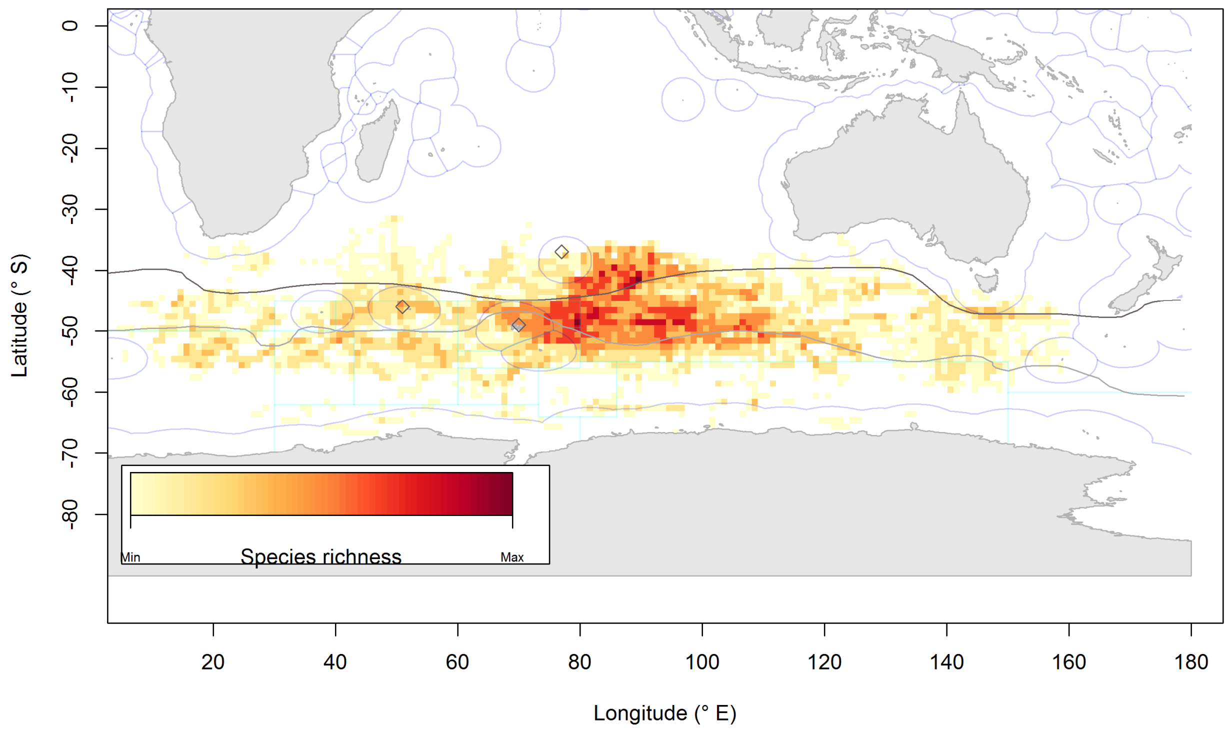


Map 120. ***Spatial pattern of hotspots diversity*****. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 10% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds during breeding periods.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

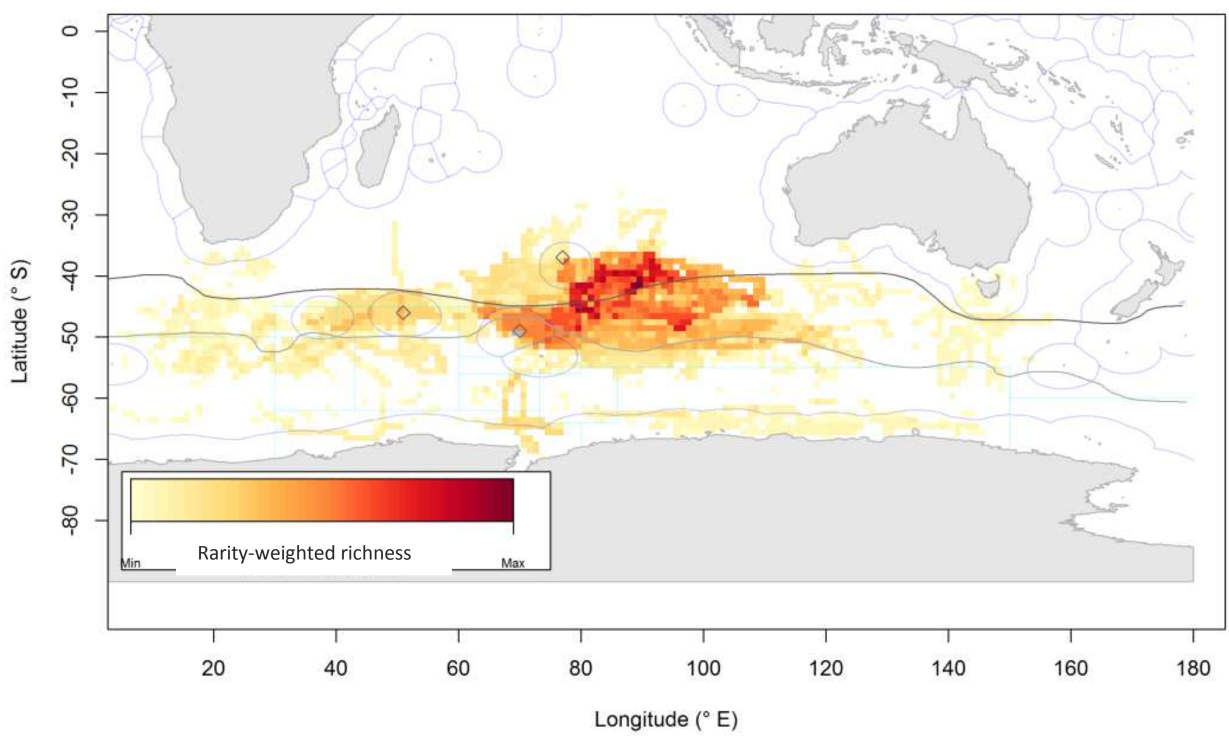
The areas identified by overlapping the top-scoring 10% of grid cells cover large areas in the southern Indian Ocean, from subtropical to Antarctic regions, mainly in the zones surrounding the breeding locations (Crozet, Kerguelen and Amsterdam Islands and Adélie Land - Antarctica).

6. Inter-breeding period

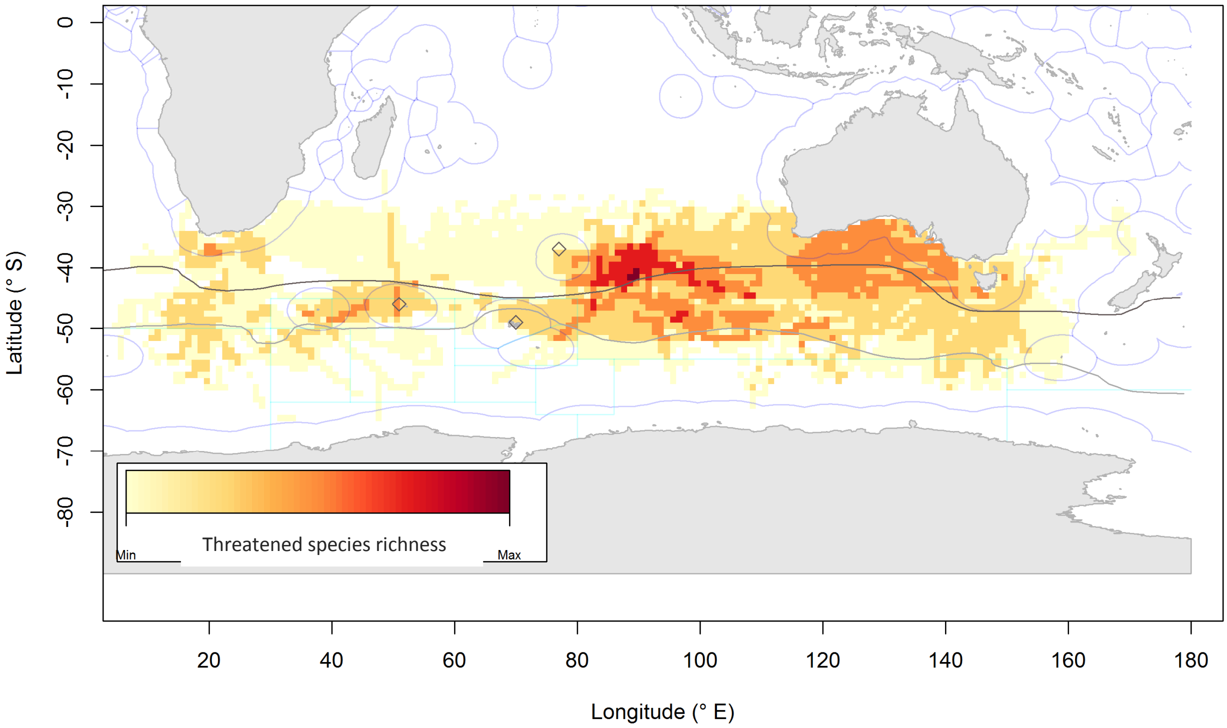
Focusing on the inter-breeding period, the patterns of spatial distribution for the four criteria (Maps 121 to 124) are a consistent attribution of high value to subtropical and subantarctic regions. In contrast to the breeding period, animals are no longer central-place foragers at that time, being not constrained by the breeding sites.



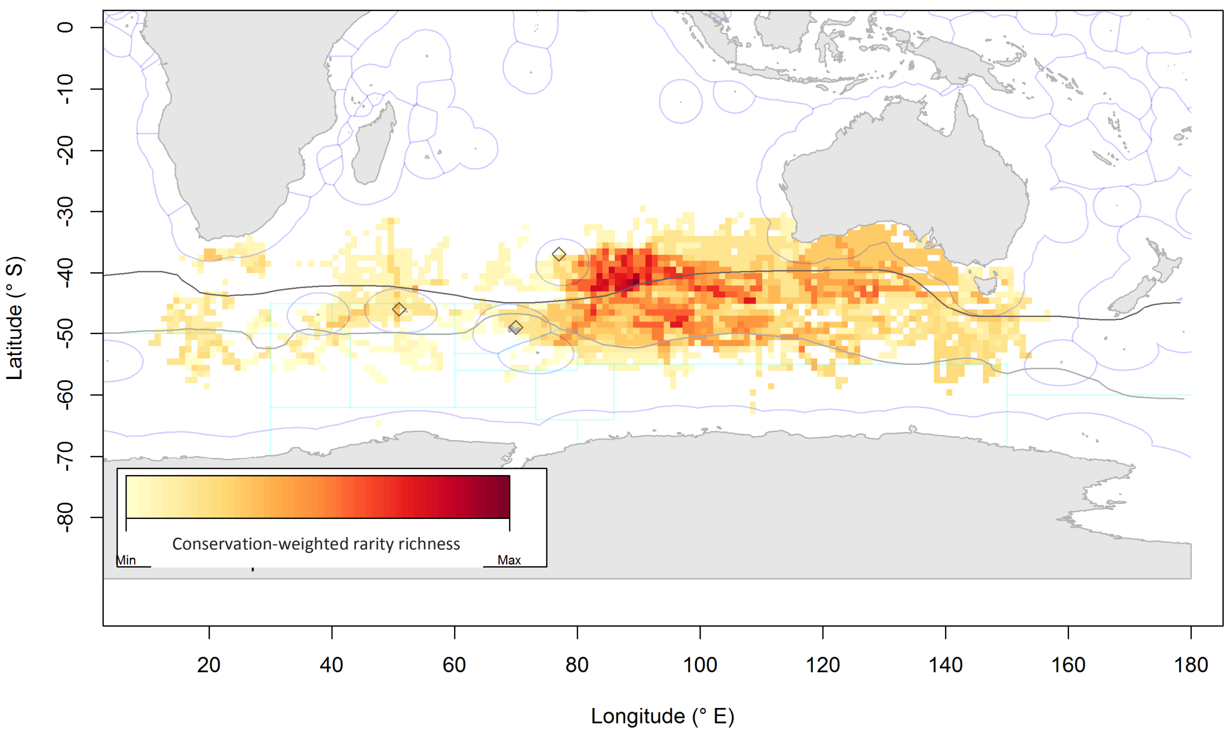
Map 121. ***Spatial pattern of diversity: species richness*. Observed distribution of the evaluation criteria *species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 122. ***Spatial pattern of diversity: rarity-weighted richness*. Observed distribution of the evaluation criteria *rarity-weighted richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

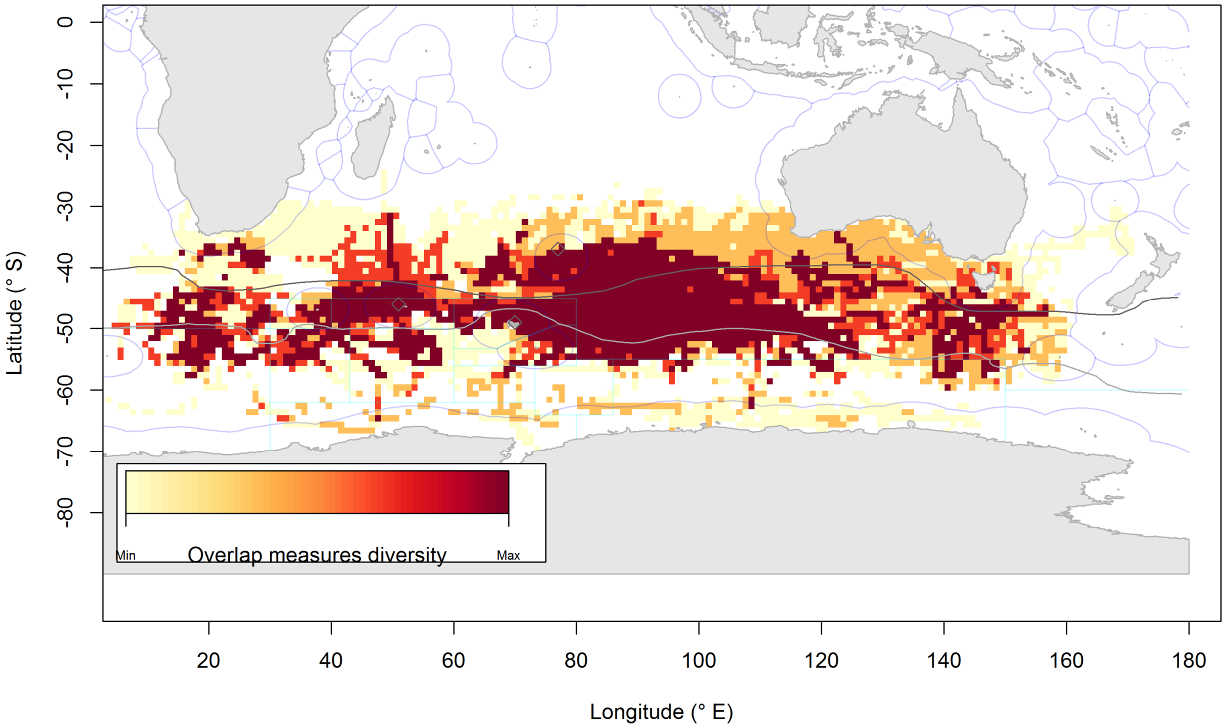


Map 123. ***Spatial pattern of diversity: threatened species richness*. Observed distribution of the evaluation criteria *threatened species richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.



Map 124. *Spatial pattern of diversity: conservation-weighted rarity richness*. Observed distribution of the evaluation criteria *conservation-weighted rarity richness* (Occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding period. Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

A fairly good correspondence between species richness and rarity-weighted richness was observed, suggesting that rare species often occurred within hotspots of high species richness.



Map 125. ***Spatial pattern of hotspots diversity*****. Overlap of hotspot diversity distribution selected using four evaluation measures (Top 10% of all the grid cells, occurrence data obtained from time spent per square in each 1° cell) of adult birds during inter-breeding periods.** Oceanographic frontal structures are shown: the subtropical waters north of the South Subtropical Front (dark grey line; SSTF), and the Polar Front (light grey line; PF) (Belkin, 1988;Belkin, 1993;Belkin and Gordon, 1996; updated 2003). Boundaries of CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources (light blue lines) and of Exclusive Economic Zones (dark blue lines; EEZs) are also shown.

During the inter-breeding period, the areas identified by overlapping the top-scoring 10% of grid cells cover large areas in the southern Indian Ocean from subtropical to subantarctic regions.
These important areas identified differ from the breeding period and can be grouped in 6 major regions: the Benguela Current System, West of Bouvetøya, Del Cano Rise/Southwest Indian ridge, Southeast Indian ridge, Great Australian Bight/Tasmania, East Macquarie Island. A few scattered small areas are also identified in Antarctic waters.

SOURCES

This *Atlas* refers to Species assessments published by ACAP - Agreement on the Conservation of Albatrosses and Petrels. http://www.acap.aq/index.php/resources/acap-species2:

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The conservation status of the species presented in the *Atlas* refers to BirdLife International 2012 – IUCN Red List of Threatened Species, http://www.iucnredlist.org/:

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