Census of Antarctic Marine Life
SCAR-Marine Biodiversity Information Network

BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

CHAPTER 8. BIOGEOGRAPHIC PATTERNS OF BIRDS AND MAMMALS.

Ropert-Coudert Y., Hindell M.A., Phillips R., Charrassin J.B., Trudelle L., Raymond B., 2014.

In: De Broyer C., Koubbi P., Griffiths H.J., Raymond B., Udekem d'Acoz C. d', et al. (eds.). Biogeographic Atlas of the Southern Ocean. Scientific Committee on Antarctic Research, Cambridge, pp. 364-387.

EDITED BY:
Claude DE BROYER & Philippe KOUBBI (chief editors)

with Huw GRIFFITHS, Ben RAYMOND, Cédric d'UDEKEM d'ACOZ, Anton VAN DE PUTTE, Bruno DANIS, Bruno DAVID, Susie GRANT, Julian GUTT, Christoph HELD, Graham HOSIE, Falk HUETTMANN, Alexandra POST & Yan ROPERT-COUDERT

SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

The “Biogeographic Atlas of the Southern Ocean” is a legacy of the International Polar Year 2007-2009 (www.ipy.org) and of the Census of Marine Life 2000-2010 (www.coml.org), contributed by the Census of Antarctic Marine Life (www.caml.aq) and the SCAR Marine Biodiversity Information Network (www.scarmarbin.be; www.biodiversity.aq).

The “Biogeographic Atlas” is a contribution to the SCAR programmes Ant-ECO (State of the Antarctic Ecosystem) and AnT-ERA (Antarctic Thresholds- Ecosystem Resilience and Adaptation) (www.scar.org/science-themes/ecosystems).

Edited by:

Claude De Broyer (Royal Belgian Institute of Natural Sciences, Brussels)
Philippe Koubbi (Université Pierre et Marie Curie, Paris)
Huw Griffiths (British Antarctic Survey, Cambridge)
Ben Raymond (Australian Antarctic Division, Hobart)
Cédric d’Udekem d’Acoz (Royal Belgian Institute of Natural Sciences, Brussels)
Anton Van de Putte (Royal Belgian Institute of Natural Sciences, Brussels)
Bruno Danis (Université Libre de Bruxelles, Brussels)
Bruno David (Université de Bourgogne, Dijon)
Susie Grant (British Antarctic Survey, Cambridge)
Julian Gutt (Alfred Wegener Institute, Helmoltz Centre for Polar and Marine Research, Bremerhaven)
Christoph Held (Alfred Wegener Institute, Helmoltz Centre for Polar and Marine Research, Bremerhaven)
Graham Hosie (Australian Antarctic Division, Hobart)
Falk Huettmann (University of Alaska, Fairbanks)
Alix Post (Geoscience Australia, Canberra)
Yan Ropert-Coudert (Institut Pluridisciplinaire Hubert Currien, Strasbourg)

Published by:

The Scientific Committee on Antarctic Research, Scott Polar Research Institute, Lensfield Road, Cambridge, CB2 1ER, United Kingdom (www.scar.org).

Publication funded by:

- The Census of Marine Life (Albert P. Sloan Foundation, New York)
- The TOTAL Foundation, Paris.

The “Biogeographic Atlas of the Southern Ocean” shared the *Cosmos Prize* awarded to the Census of Marine Life by the International Osaka Expo’90 Commemorative Foundation, Tokyo, Japan.

Publication supported by:

- The Belgian Science Policy (Belspo), through the Belgian Scientific Research Programme on the Antarctic and the “biodiversity.aq” network (SCAR-MarBIN/ANTABIF)
- The Royal Belgian Institute of Natural Sciences (RBINS), Brussels, Belgium
- The British Antarctic Survey (BAS), Cambridge, United Kingdom
- The Université Pierre et Marie Curie (UPMC), Paris, France
- The Australian Antarctic Division, Hobart, Australia
- The Scientific Steering Committee of CAML, Michael Stoddart (CAML Administrator) and Victoria Wadley (CAML Project Manager)

Mapping coordination and design: Huw Griffiths (BAS, Cambridge) & Anton Van de Putte (RBINS, Brussels)

Editorial assistance: Henri Robert, Xavier Loréa, Charlotte Havermans, Nicole Moortgat (RBINS, Brussels)

Printed by: Altitude Design, Rue Saint Josse, 15, B-1210 Brussels, Belgium (www.altitude-design.be)

Lay out: Sigrid Camus & Amélie Blaton (Altitude Design, Brussels).

Cover design: Amélie Blaton (Altitude Design, Brussels) and the Editorial Team.

Cover pictures: amphipod crustacean (*Epimeria rubrieques* De Broyer & Klages, 1991), image © T. Riehl, University of Hamburg; krill (*Euphausia superba* Dana, 1850), image © V. Siegel, Institute of Sea Fisheries, Hamburg; fish (*Chaenocephalus* sp.), image © C. d’Udekem d’Acoz, RBINS; emperor penguin (*Aptenodytes forsteri* G.R. Gray, 1844), image © C. d’Udekem d’Acoz, RBINS; Humpback whale (*Megaptera novaeangliae* (Borowski, 1781)), image © L. Kindermann, AWI.

Online dynamic version :

A dynamic online version of the Biogeographic Atlas will be available on the SCAR-MarBIN / AntaBIF portal : atlas.biodiversity.aq.

Recommended citation:

For the volume:

De Broyer C., Koubbi P., Griffiths H.J., Raymond B., Udekem d’Acoz C. d’, Van de Putte A.P., Danis B., David B., Grant S., Gutt J., Held C., Hosie G., Huettmann F., Post A., Ropert-Coudert Y. (eds.), 2014. Biogeographic Atlas of the Southern Ocean. Scientific Committee on Antarctic Research, Cambridge, XII + 498 pp.

For individual chapter:

(e.g.) Crame A., 2014. Chapter 3.1. Evolutionary Setting. In: De Broyer C., Koubbi P., Griffiths H.J., Raymond B., Udekem d’Acoz C. d’, *et al.* (eds.). Biogeographic Atlas of the Southern Ocean. Scientific Committee on Antarctic Research, Cambridge, pp. xx-yy.

ISBN: 978-0-948277-28-3.

PART 8. BIOGEOGRAPHIC PATTERNS OF BIRDS AND MAMMALS

8. Biogeographic Patterns of Birds and Mammals

Yan Ropert-Coudert[1, 2], Mark A. Hindell[3], Richard A. Phillips[4], Jean-Benoit Charrassin[5], Laurène Trudelle[5] & Ben Raymond[3, 6, 7]

Additional data contributors:

Jorge Acevedo[8], Anelio Aguayo-Lobo[9], David G. Ainley[10], Horst Bornemann[11], Peter G. Ryan[12], Eric J. Woehler[13] & IWC[14]

[1] *Université de Strasbourg, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France.*
[2] *CNRS, UMR7178, Strasbourg, France*
[3] *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia*
[4] *British Antarctic Survey, Natural Environment Research Council, High Cross, Cambridge, UK*
[5] *LOCEAN, Muséum National d'Histoire Naturelle/Université Pierre et Marie Curie/CNRS/IRD, Université Pierre et Marie Curie, Paris, France*
[6] *Australian Antarctic Division, Department of the Environment, Kingston, Tasmania, Australia*
[7] *Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Tasmania, Australia*
[8] *Centro de Estudios del Cuaternario de Fuego-Patagonia y Antártica (CEQUA), Punta Arenas,Chile*
[9] *Instituto Antártico Chileno, Punta Arenas, Chile.*
[10] *H.T. Harvey & Associates Ecological Consultants, Los Gatos, California, USA*
[11] *Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany*
[12] *Percy FitzPatrick Institute of African Ornithology, DST/NRF Centre of Excellence, University of Cape Town, Rondebosch, South Africa*
[13] *School of Zoology, University of Tasmania, Hobart, Australia*
[14] *International Whaling Commission, Cambridge, UK.*

1. Introduction

The Atlas would not be complete if the representatives — and sometimes most emblematic species — of the top of the food chains were left aside, and so this section is concerned with sightings of top predators: seabirds, seals and cetaceans. Top predators are classically divided into two broad categories: seabirds and marine mammals. For the purpose of the Atlas, top predators have been split into four main "grand" taxa: flying seabirds (primarily Procellariiformes) are distinguished from penguins (Spheniscidae), while pinnipeds (otarids and phocids) and cetaceans (toothed and baleen whales) are considered separately in the marine mammal category. The distribution maps presented here are based on at-sea sightings data. These observations differ from the other taxa of the Atlas in at least two major aspects:

1. Being air-breathing species, penguins, seals, and cetaceans return frequently to the surface and — with the exception of cetaceans — spend part of their life cycle on land. Although seabird colonies and marine mammal haul-out sites are essential to the understanding of the distribution and ecology of top predators, we have focused here on the at-sea distribution to be comparable with other taxa in the Atlas.

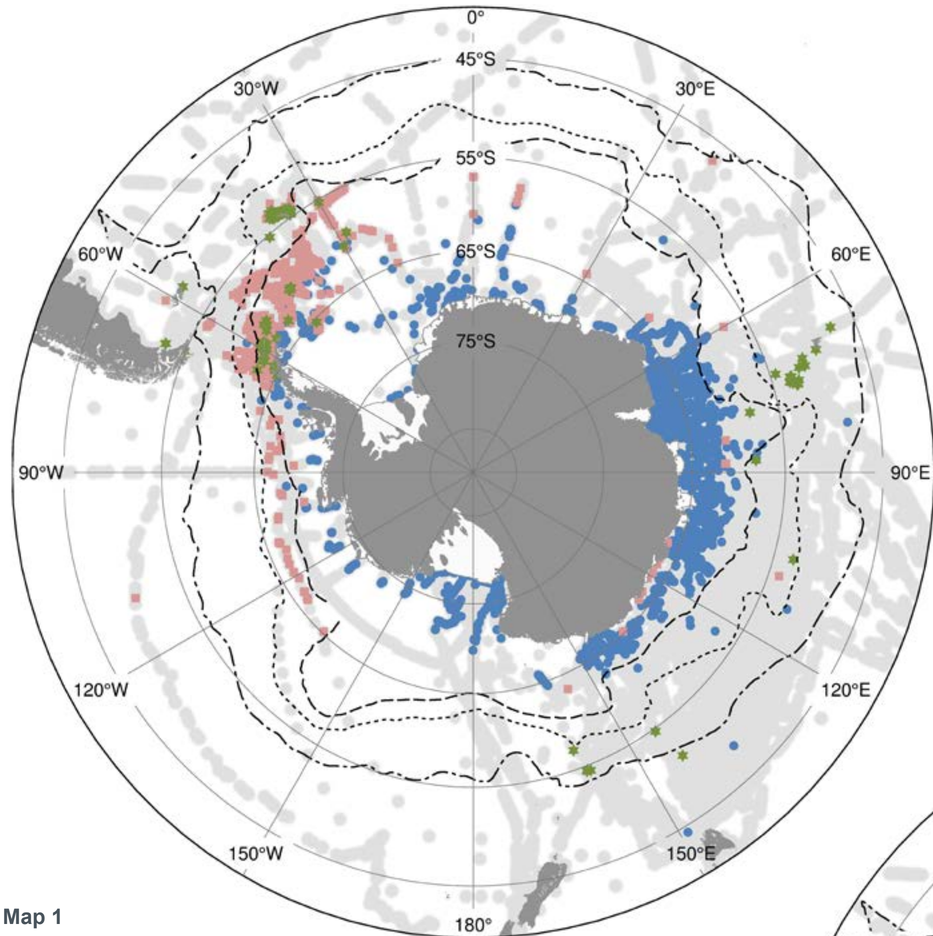
2. Like fish, top predators are highly mobile species. At-sea observations of top predators should thus be taken as snapshots of their real, dynamic distribution in both space and time. Some aspects of the at-sea distributions of top predators are arguably better captured by tracking studies (e.g. Argos or GPS tracking) than by at-sea sightings. However, tracking deployments are labour- and cost-intensive (typically, such a study will track only a few individuals from a small number of colonies). Ship-based observations provide a means for broad sampling of large regions of the Southern Ocean and — although not utilized here —information that is less easily obtained from tracking studies, such as the presence of other animals and observations of behaviour.

Photo 1 Adélie Penguin, *Pygoscelis adeliae*. Image © Alain De Broyer, Brussels.

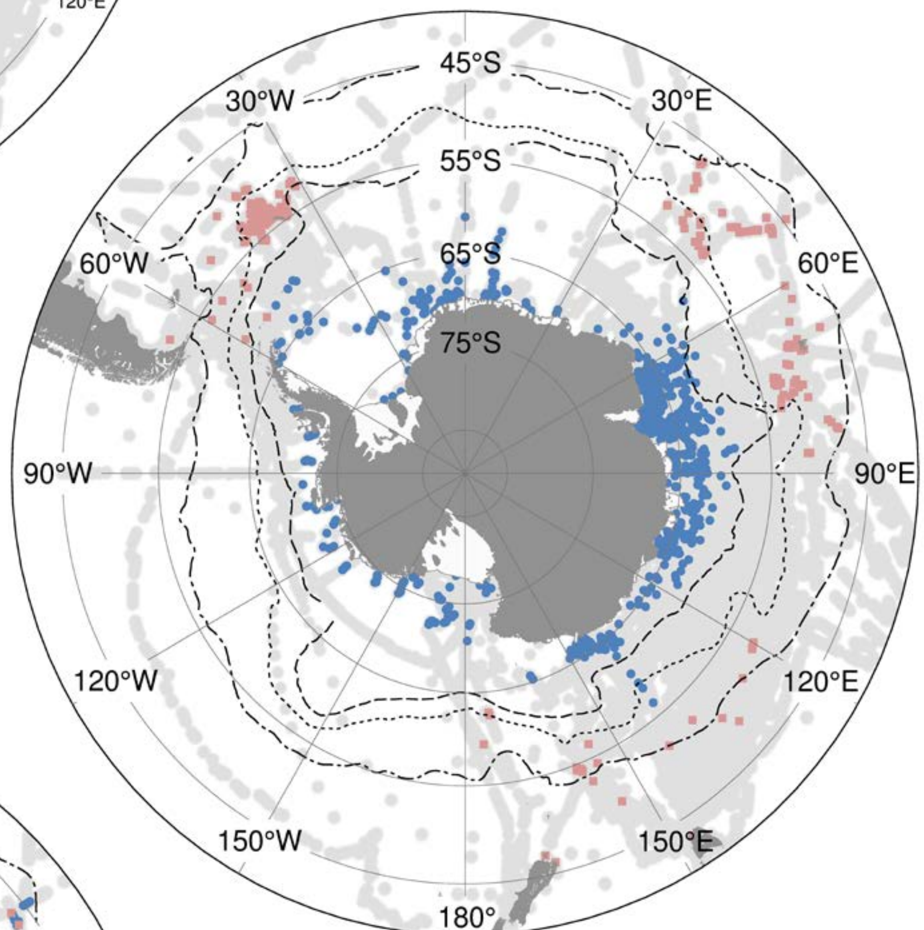
A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission. At-sea sightings data were collected by different observers, either during the regular cruises between southern hemisphere countries (mainly Australia, New Zealand, South Africa, Argentina and Chile) and the research bases located on sub-Antarctic islands or the Antarctic continent, or on transects conducted by these ships during dedicated marine science surveys. Because of the scheduling of resupply voyages to research bases, and the logistic difficulties of sampling the Southern Ocean during the winter time, most of the data presented here were collected during the austral summer, i.e. roughly from October to April. Sighting data span from 1955 to 2011, although the majority of the data were collected from the 1980s onward. The IWC historical commercial catch database started in 1900. The observations are irregular in space and time as they depend on the ships' schedules and the weather. Different protocols of observation were used throughout the years by the research teams involved. Further variability in the data arises from the varying degrees of taxonomic expertise of the observers, the resemblance of certain species (especially some of the petrels), the difficulty in identifying each individual spotted, particularly among seabirds, thus leading to a risk of counting the same individual more than once and the difficulty in counting groups of animals that continuously alternate between diving and surfacing (especially seals and cetaceans). Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys). To provide an indication of the breadth of survey effort, and so to assist the reader in distinguishing areas of likely species absence from areas that have not been surveyed, the survey effort is shown in light grey on each map. The survey effort is simply the complete set of locations where any presence data were recorded, indicating that a survey was made at that location. Survey effort was estimated separately for seals and cetaceans (i.e. only seal records were used for estimating seal survey effort). Data for penguins and flying seabirds were combined for the purposes of estimating effort, since surveys of flying seabirds typically also record penguins, and vice-versa. Since the level of survey effort is highly variable across the region, the patterns evident in the maps are necessarily influenced by the patterns in survey effort. While the grey background in the following figures allows surveyed areas to be distinguished from non-surveyed areas, the relative intensity of survey effort is not indicated (and is difficult to estimate from the available data). As such, it is possible that a species may be over-represented in a given region as an artefact of a greater, local survey effort. Although an effort was made to be as exhaustive as possible, there are still a large number of species that are not represented in the Atlas because there were very few, or no sightings (see list below). Similarly, vagrant species are not accounted for in the Atlas.

2. Penguins (Spheniscidae)

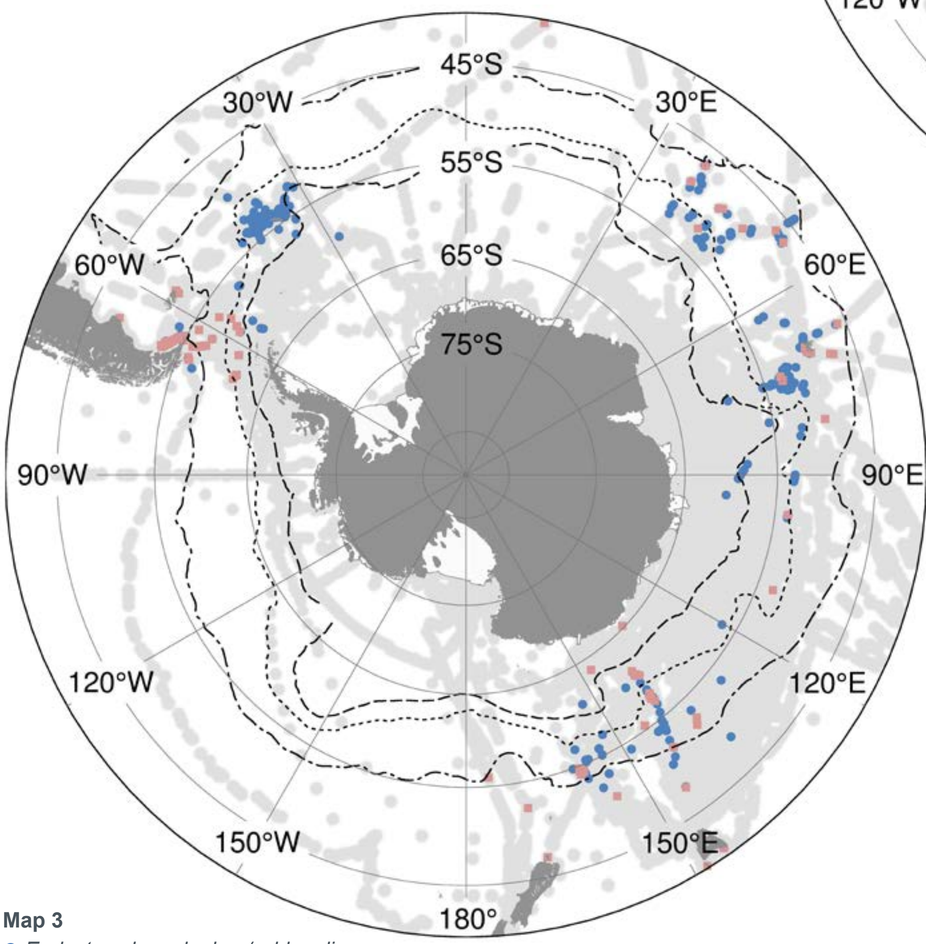
Although they are seabirds, penguins are treated separately from the other seabirds. Penguins lost the ability to fly when they evolved to become highly specialized divers. The ancestors of penguins were flying birds but penguins differ morphologically, physiologically and ecologically from flying seabirds in many aspects. Their dense bones and flipper-like wings allow them to dive repeatedly to great depths and exploit a much larger portion of the water column compared to most other seabirds (except for diving petrels and some shearwater species). A substantial proportion of their time at sea is spent underwater and this may affect the ability of observers to detect them compared with flying birds. Among the 18 penguin species, only nine are distributed within the boundaries of the Southern Ocean and were thus considered for the Atlas. These nine species belong to three genera: *Aptenodytes* (two species; emperor and king), *Pygoscelis* (three species; Adélie, gentoo, and chinstrap) and *Eudyptes* (four species; southern and northern rockhopper, macaroni, and royal). Officially the rockhopper penguins are now split into southern (*E. chrysocome*) and northern rockhoppers (*E. moseleyi*). These were considered to be one species until genetic analyses proved them to be distinct species (Banks *et al.* 2006). However, it is extremely difficult — if not impossible — to distinguish these two species at sea and so the rockhopper separation is not reflected in the Atlas. Royal (*E. schlegeli*) and macaroni penguins (*E. chrysolophus*) are pooled for the same reason.



Map 1
- *Pygoscelis adeliae*
- *Pygoscelis antarcticus*
- *Pygoscelis papua*



Map 2
- *Aptenodytes forsteri*
- *Aptenodytes patagonicus*



Map 3
- *Eudyptes chrysolophus/schlegeli*
- *Eudyptes chrysocome/filholi*

Penguins Maps 1–3 Map 1. Adélie Penguin: *Pygoscelis adeliae*, Chinstrap Penguin: *P. antarcticus* and Gentoo Penguin: *P. papua*. Map 2. Emperor Penguin: *Aptenodytes forsteri* and King Penguin: *A. patagonicus*. Map 3. Macaroni/Royal Penguins: *Eudyptes chrysolophus/schlegeli* and Southern/Eastern Rockhopper Penguins: *E. chrysocome/filholi*.

The Atlas does not detail the distribution of penguin colonies as this information can be found elsewhere (e.g. Borboroglu Garcia & Boersma 2013). Yet it is important to acknowledge that the location of penguin colonies is an important factor in explaining at-sea occurrences: most penguins breed on land and their foraging ranges at sea are limited during the breeding season as they have to commute back and forth to feed their chicks. The most important sub-Antarctic breeding sites are, clockwise from the southern tip of South America: the South Sandwich Islands (57°30'S, 27°00'W), the South Georgia group (54°30'S, 37°00'W), Bouvet Island (54°26'S, 03°24'E), the Prince Edward Islands (46°46'S, 37°51'E), the Crozet islands (46°25'S, 51°59'E), Kerguelen Islands (49°15'S, 69°35'E), Heard Island and McDonald Islands (53°04'S, 73°00'E), and Macquarie Island (54°38'S, 158°52'E). The New Zealand sub-Antarctic islands, including Antipodes Islands (49°40'S, 178°46'E), Auckland Islands (50°42'S, 166°05'E), Bounty Islands (47°45'S, 179°03'E), Campbell Island (52°32'S, 169°08'E) and Snares Islands (48°01'S, 166°32'E) and their endemic penguin species, such as the yellow-eyed penguin (*Megadyptes antipodes*) or the erect-crested penguin (*E. sclateri*), are not included in this synthesis. Although not a sub-Antarctic island in the strict sense we include Amsterdam Island and its rockhopper penguin populations.

Two species are genuine Antarctic species: the Adélie (Map 1) and the emperor penguin (Map 2). Emperor penguins are the only species that breed on the land-fast ice along the Antarctic coast during winter. When foraging during winter, emperor penguins have to travel to the edge of the fast ice to feed (Wienecke & Robertson 1997, Zimmer *et al.* 2008). However, the sighting data are biased towards the summer, which explains the limited extent of the emperor distribution in offshore waters to the north of the continent (Map 2). Adélie penguins breed on the Antarctic continent and nearby islands but their breeding season is in summer, roughly from October to March. The distribution of Adélie penguins therefore resembles that of emperor penguins (Map 1). Adélie penguins' foraging activity is heavily dependent on sea-ice conditions — so much so that they have been referred to as "creatures of the pack ice" (Ainley 2002). During incubation, they travel as far as 300 km from the continent (Clarke *et al.* 2006, Cottin *et al.* 2012). These distances reduce to less than 100 km once the eggs hatch, because the chicks require food frequently (e.g. Wienecke *et al.* 2000). Both emperor and Adélie penguin sightings are nearly continuously circumpolar in their distribution (without clear gaps), although survey effort was less extensive in the Weddell Sea and offshore from Marie Byrd Land and Queen Maud Land (Maps 1 and 2). Note the importance of the Peninsula region and the Scotia Arc for the *Pygoscelis* spp. as in this zone the three species overlap in their distribution (Map 1). Gentoo penguins *P. papua* are probably the most sub-Antarctic of the three pygoscelids, and, like king penguins and *Eudyptes* spp., their colonies are found on sub-Antarctic islands, scattered around the continent.

Overall, north of 65°S, penguins are distributed across the whole of the Southern Ocean, apart from two regions that seem less populated: the Amundsen Sea (120°–180°W) and the waters off Queen Maud Land (10°–40°E). Except for Bouvet Island, no sub-Antarctic islands are located in these sectors. However, survey effort was also the lowest in these regions and this may contribute to the smaller number of occurrences than elsewhere. In contrast, the South Georgia region appears to be attractive to a large number of penguin species (see also the distribution of flying seabirds). Most penguins can be considered to be coastal foragers for most of their breeding season, particularly when compared with long-range foragers, such as Procellariiformes. The distribution of the two *Eudyptes* species illustrates this well as most sightings occurred in relative proximity to the sub-Antarctic islands (Map 3). King penguins represent a notable exception to this trend as they are able to travel routinely up to 300 km during the incubation period in the austral summer (Bost *et al.* 1997) and cover distances up to 4000 km during the winter to reach the limits of the marginal sea ice zone (Bost *et al.* 2004). The primary foraging area of king penguins from the Kerguelen and Crozet islands is the Antarctic Polar Front (APF), the location of which varies within and between years and so constrains their foraging success, especially where the breeding colonies are situated far from the APF (e.g. Crozet, Map 2; Péron *et al.* 2012). However, the main foraging area during incubation of king penguins from Heard Island was approximately 200 km east of the island and at 53°S well south of the APF (Wienecke & Robertson 2002). As mentioned earlier, the diving activity of penguins probably explains the differences between their observations at sea and what is known about their at-sea distribution from biotelemetry. In this context, the time spent at the surface between dives may be paramount to the sighting of the penguins. King penguins stay at the surface for two to three minutes between deep dives, whereas the surface duration can be less than a minute in *Eudyptes* spp. Such a small window of observation could also explain the relatively small number of *Eudyptes* sightings (Map 3). Travelling penguins are easier to spot as they porpoise across the ocean surface.

The scale of the mapping in the Atlas is too coarse to reveal the oceanographic structures that are essential to penguins. Polynias have been identified as crucial access points to open water for some emperor penguins (Zimmer *et al.* 2008) while others forage in the pack ice (Wienecke & Robertson 1997). Eddies are oceanographic features that are important to Adélie (Cottin *et al.* 2012) and king penguins (Cotté *et al.* 2007), as, like the APF, they correspond to zones of upwelling where nutrients are brought to the surface and enhance productivity at all the levels of the food web. For these studies, the use of satellite tracking is paramount to elucidate the foraging range of penguins during winter as the difficulty of sampling the Southern Ocean during this period renders information on food availability scarce.

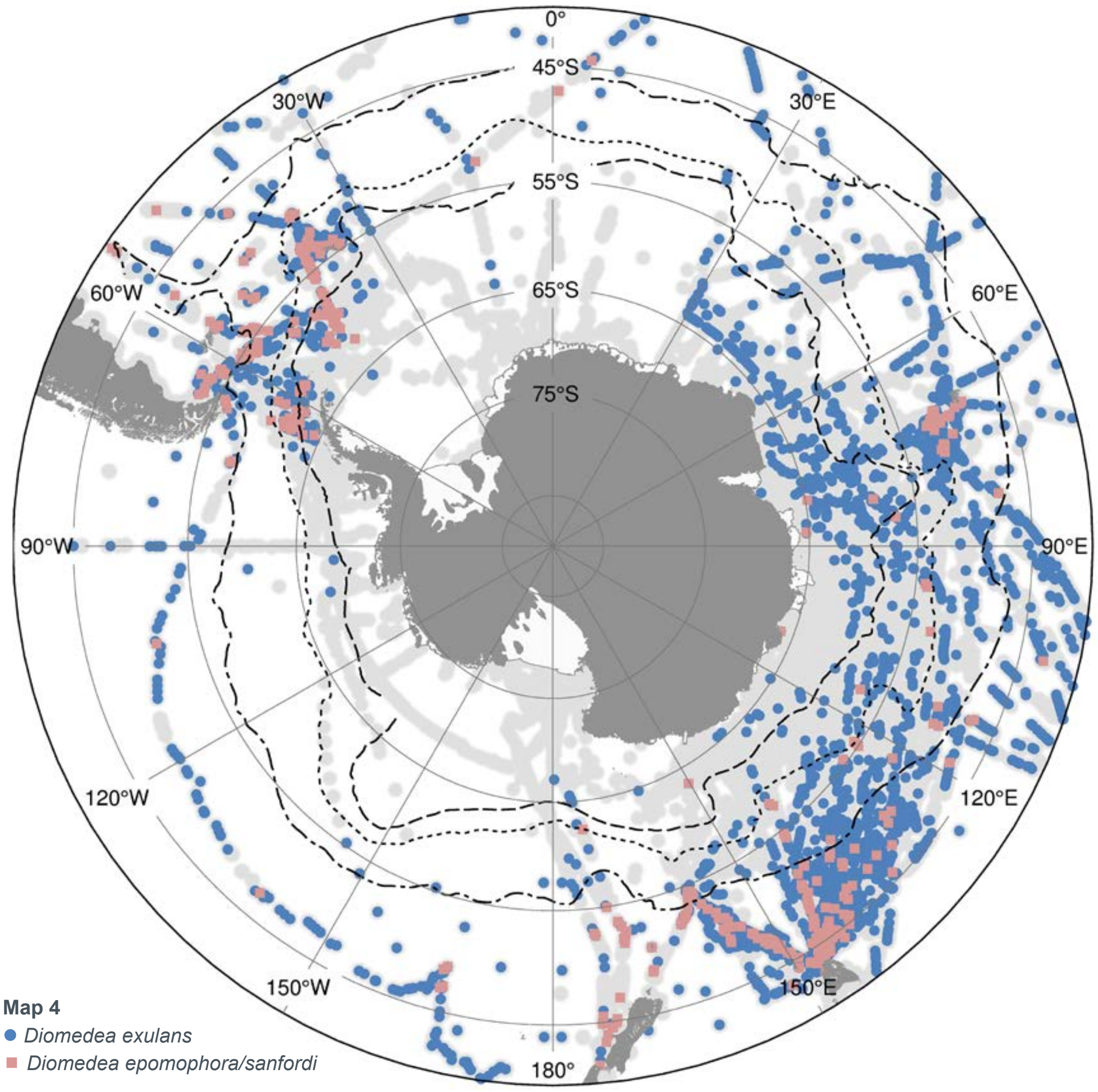
3. Albatrosses, petrels, skuas & terns (Procellariiformes, Suliformes and Charadriiformes)

Over 130 different species of flying seabird from nine families in three orders have been recorded in the Southern Ocean south of 40°S (Shirihai 2008). However, many of these are vagrants, occurring in small numbers at the extremes of their otherwise more temperate distributions. The families that are best represented in the Antarctic marine avifauna are Procellariiformes, including albatrosses (Diomedeidae), petrels, prions and shearwaters (Procellariidae), storm petrels (Hydrobatidae) and diving petrels (Pelecanoididae). The order Suliformes is represented by cormorants (Phalacrocoracidae) and the order Charadriiformes by skuas (Stercorariidae) and, to a lesser extent, the gulls and terns (Laridae). Most of the Procellariiformes are extremely wide ranging, travelling hundreds or thousands of kilometres from the colony during the breeding season to feed on patchily-distributed resources that include squid, fish or crustacea; they migrate even further during the non-breeding period (Phillips *et al.* 2008). They possess various unique physiological adaptations for these highly pelagic lifestyles: excess salt is excreted through the tubular nostrils, and many have an excellent sense of smell. With the exception of the diving petrels, they are able to reduce ingested prey to energetically dense stomach oil with low water content, so that they maximise energy delivery rates to the chick despite huge foraging ranges. Albatrosses and giant petrels also possess a tendon that locks the shoulder during gliding flight and reduces the need for muscular effort to hold the wing outstretched (Pennycuick 1982).

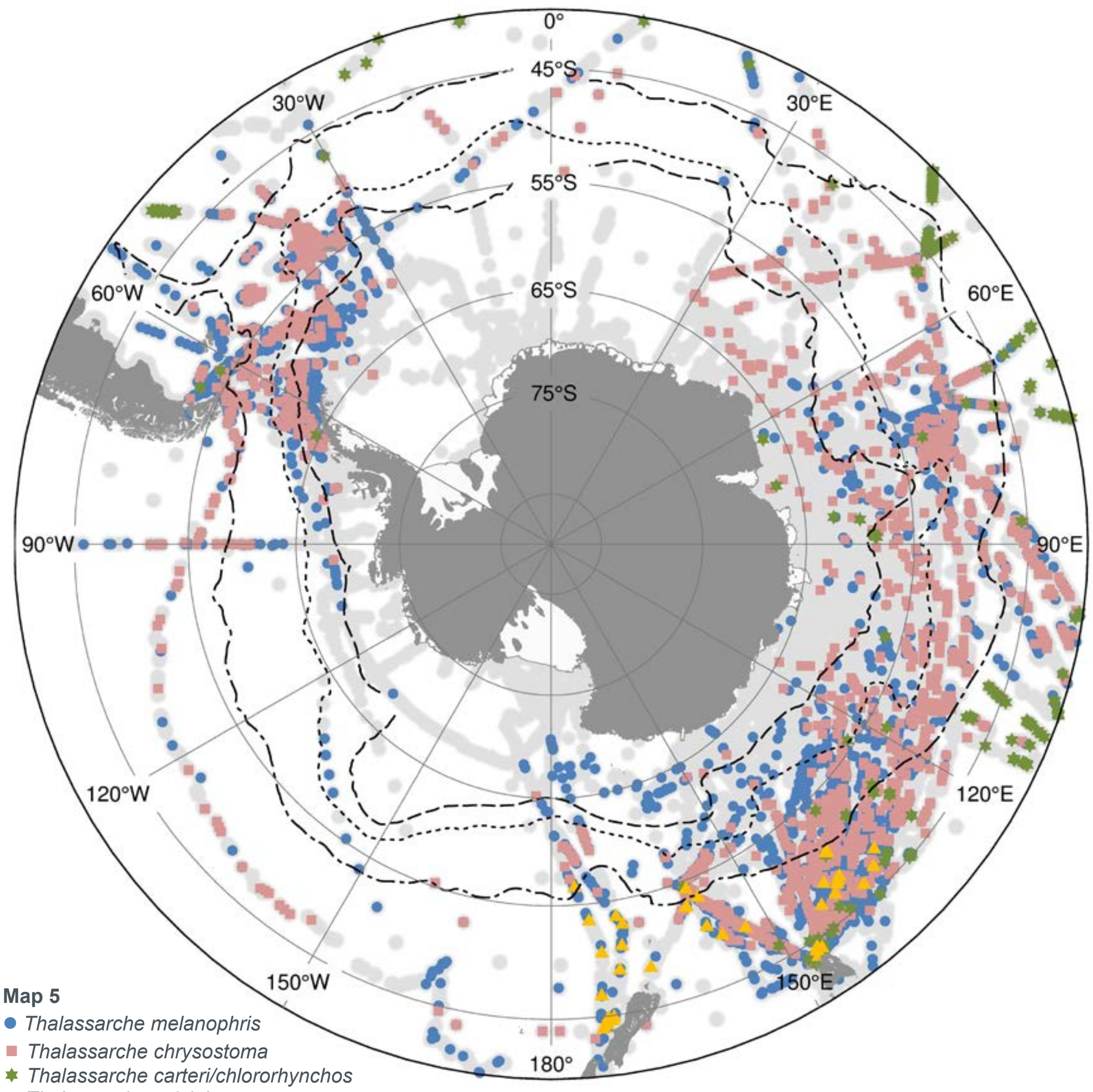
Photo 2 Sooty Albatross, *Phoebetria palpebrata*. Image © Alain De Broyer, Brussels.

The maps in this Atlas are of species recorded routinely in the open ocean south of the APF. This excludes cormorants and gulls that forage close to the coasts of the Antarctic continent or sub-Antarctic islands, and a number of species that breed on sub-Antarctic or sub-tropical islands. Others are trans-equatorial migrants from the Northern Hemisphere that use sub-Antarctic but rarely Antarctic waters. Sightings from some species have been pooled on the maps, including those of diving petrels (*Pelecanoides* spp.) and large skuas (*Stercorarius* spp.), as they are difficult to distinguish reliably at sea. Data from other species that have only recently been split taxonomically, including the royal albatrosses (formerly both were *Diomedea epomophora*) and yellow-nosed albatrosses (formerly both were *Thalassarche chlororhynchos*) are also pooled. Although the Atlas does not show the location of colonies, the distribution of suitable islands for breeding goes some way to explain the at-sea distribution patterns. The bulk of the observations on which these maps are based were made during the austral summer, and survey coverage in many regions was very low, particularly in sub-Antarctic and sub-tropical waters, and across large swathes of the southern Pacific Ocean (30°W, 30°E). Hence, although the maps extend to 35°S, they do not represent the complete at-sea distribution of any species. Nevertheless, inter-specific comparisons provide some interesting insights into large-scale distribution and habitat preferences.

Wandering albatrosses (*D. exulans*) have a circumpolar breeding distribution (Map 4) and clearly occur much further south in the Indian Ocean sector, but not in the south Atlantic, than their congeners, the northern (*D. sanfordi*) and southern royal albatrosses (*D. epomophora*), which breed at Campbell, Auckland or the Chatham Islands, or on the South Island of New Zealand (Map 4). None of these species is common in Antarctic waters south of Australia and New Zealand, or in the Pacific. Both black-browed (*T. melanophris*) and grey-headed (*T. chrysostoma*) albatrosses have circumpolar breeding distributions on sub-Antarctic islands (Map 5). Their distributions extend from south of the southern boundary of the Antarctic Circumpolar Current (ACC) to sub-tropical waters; the more northerly regions are used in particular during the non-breeding season (Croxall *et al.* 2005, Phillips *et al.* 2005b). Indian yellow-nosed albatrosses (*T. carteri*) breed in sympathy with black-browed and grey-headed albatrosses on some islands in the Indian Ocean, and also further north, without these species, at sub-tropical Amsterdam and St Paul islands. Atlantic yellow-nosed albatrosses breed further north than any other

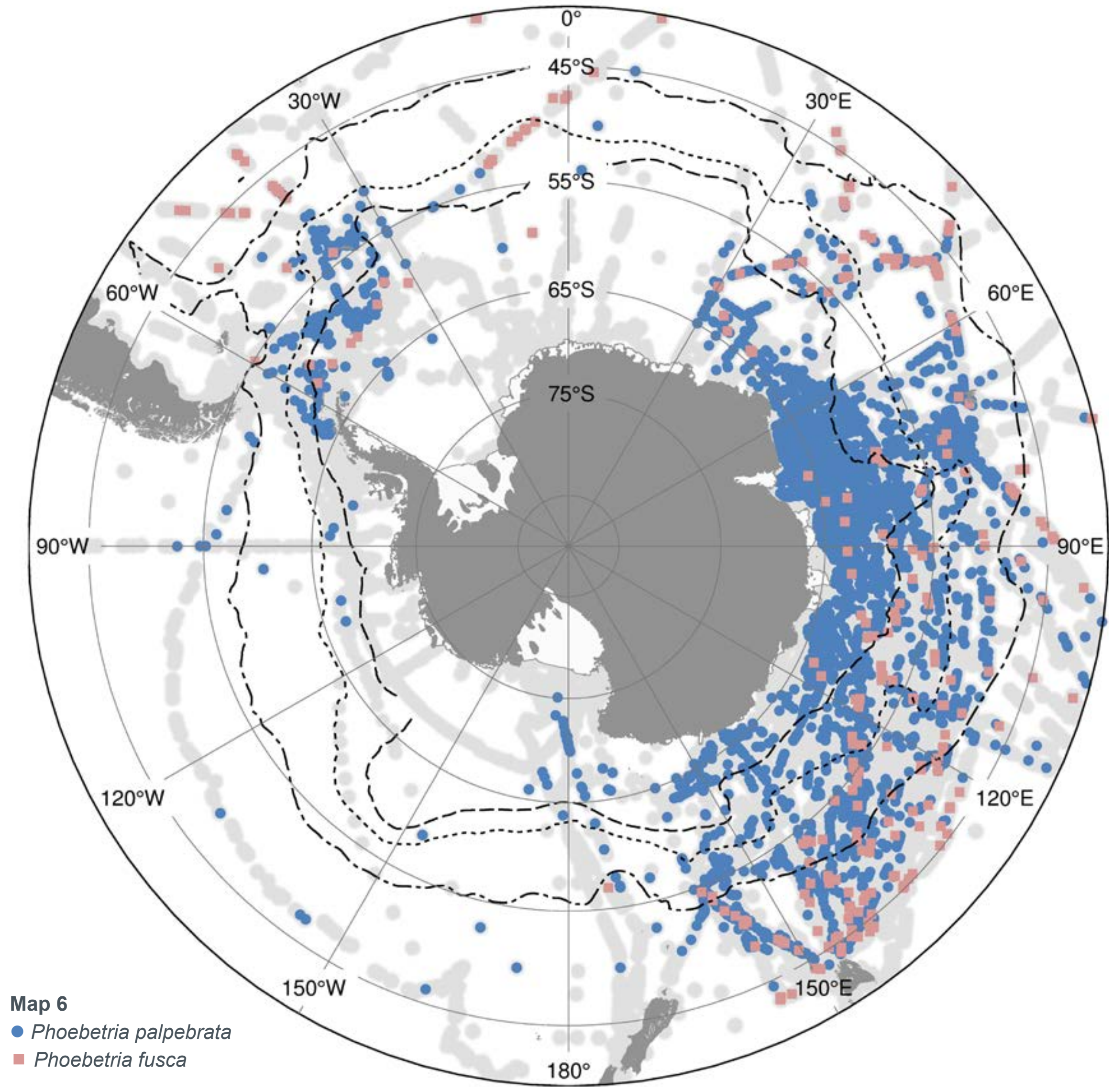


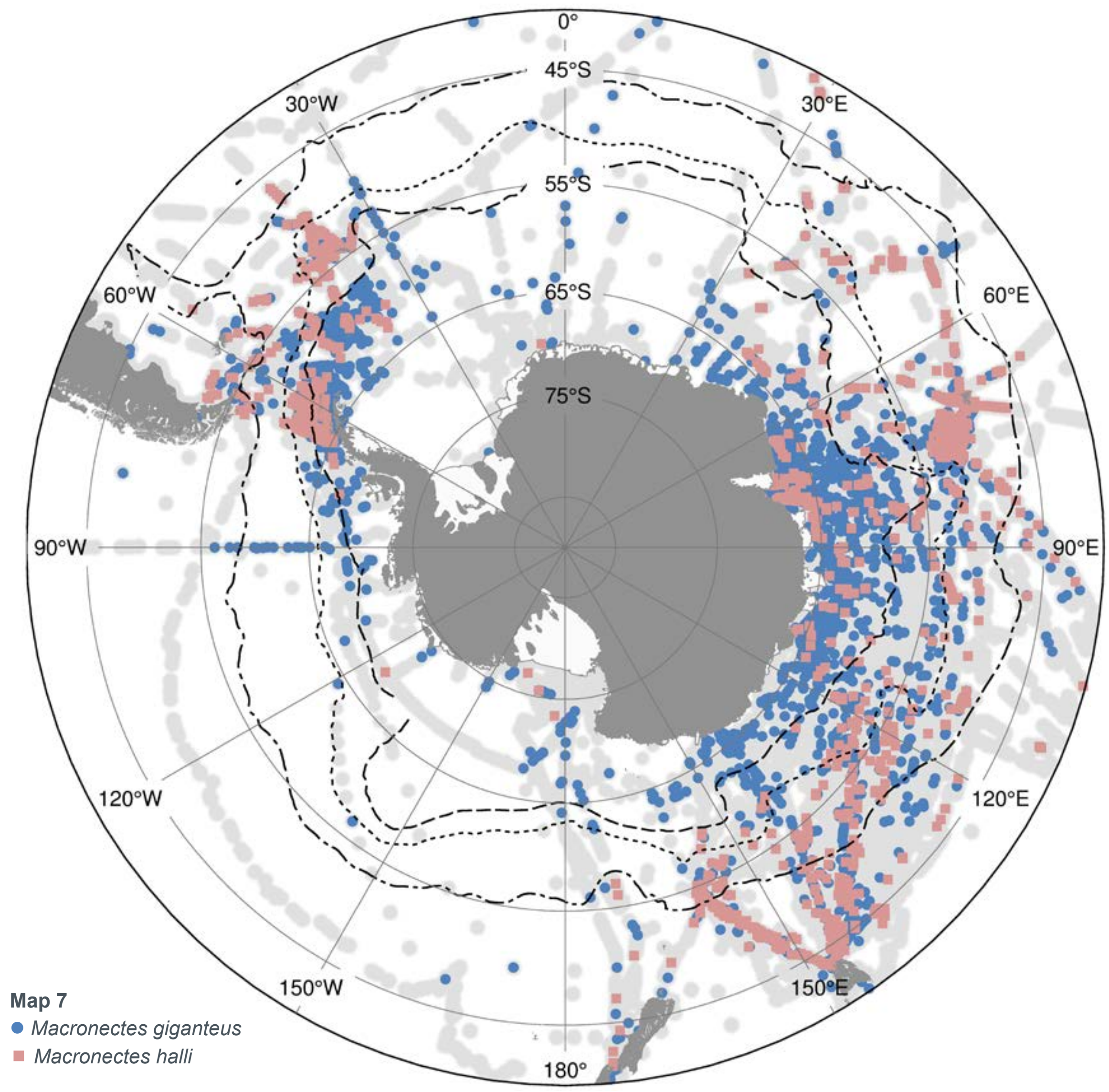
Map 4
- *Diomedea exulans*
- *Diomedea epomophora/sanfordi*



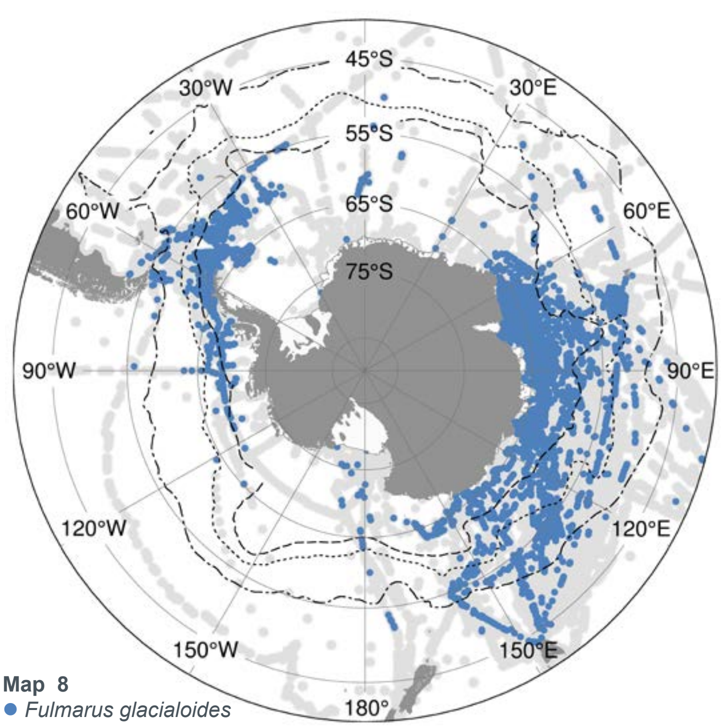
Map 5
- *Thalassarche melanophris*
- *Thalassarche chrysostoma*
- *Thalassarche carteri/chlororhynchos*
- *Thalassarche salvini*

Flying Birds Maps 4–5 Map 4. Wandering Albatross: *Diomedea exulans* and Southern/Northern Royal Albatross *D. epomophora/sanfordi*. Map 5. Black-browed Albatross: *Thalassarche melanophris*, Grey-headed Albatross: *T. chrysostoma*, Indian/Atlantic Yellow-nosed Albatross: *T. carteri/chlororhynchos* and Salvin's Albatross: *T. salvini*.

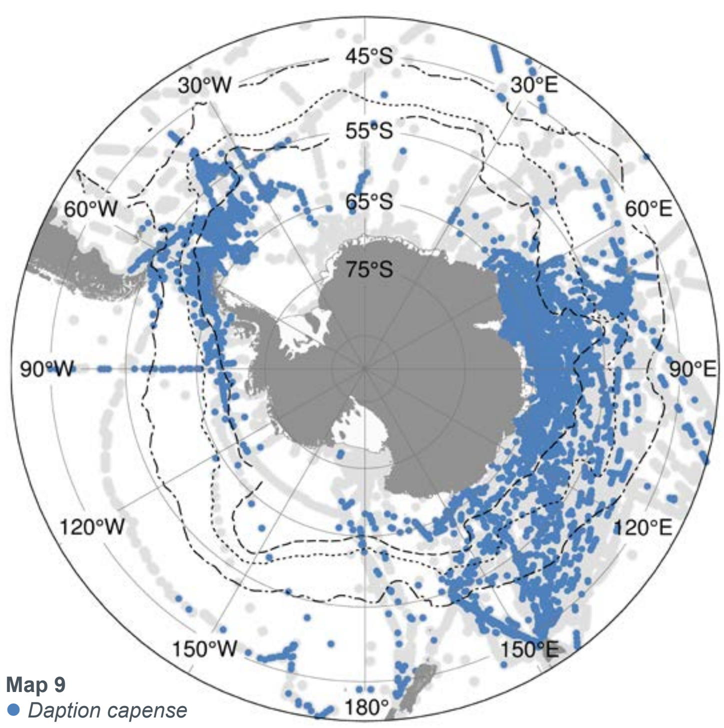




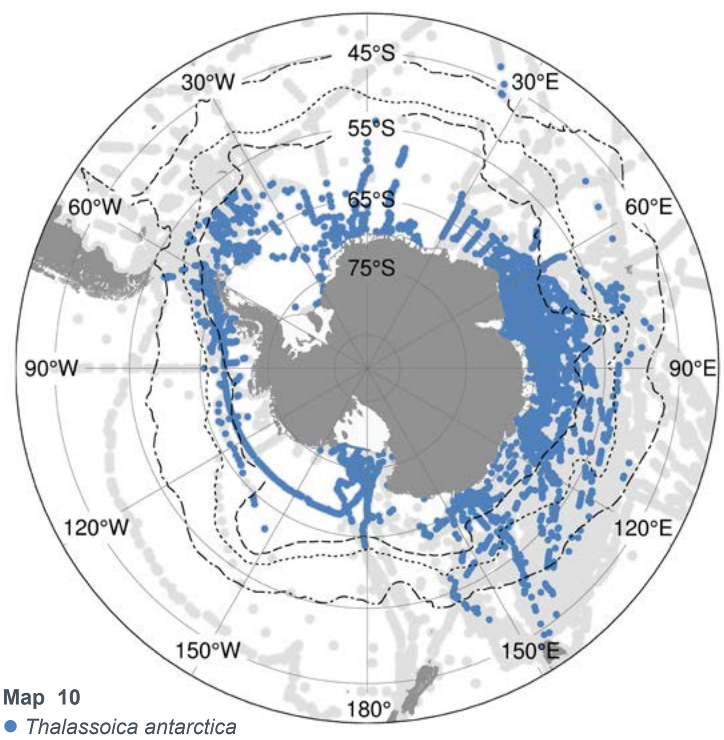
Flying Birds Maps 6–7 Map 6. Light-mantled Albatross: *Phoebetria palpebrata* and Sooty Albatross: *P. fusca*. Map 7. Southern Giant Petrel: *Macronectes giganteus* and Northern Giant Petrel: *M. halli*.



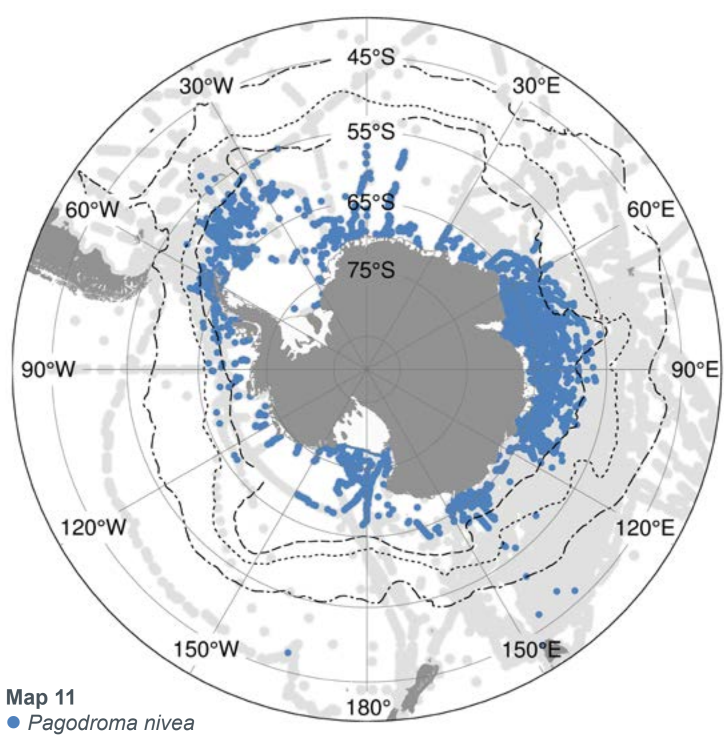
Map 8
● *Fulmarus glacialoides*



Map 9
● *Daption capense*



Map 10
● *Thalassoica antarctica*



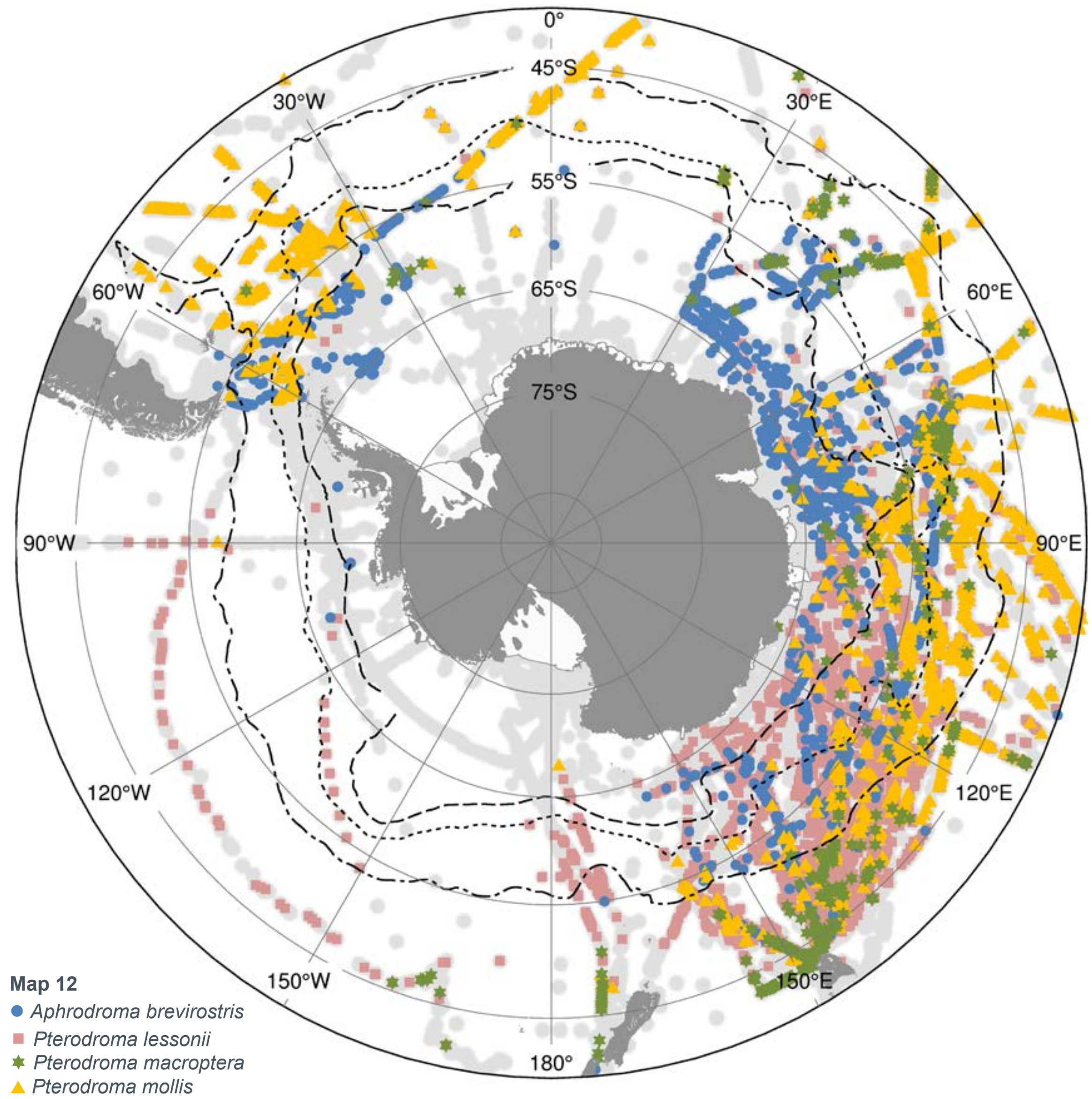
Map 11
● *Pagodroma nivea*

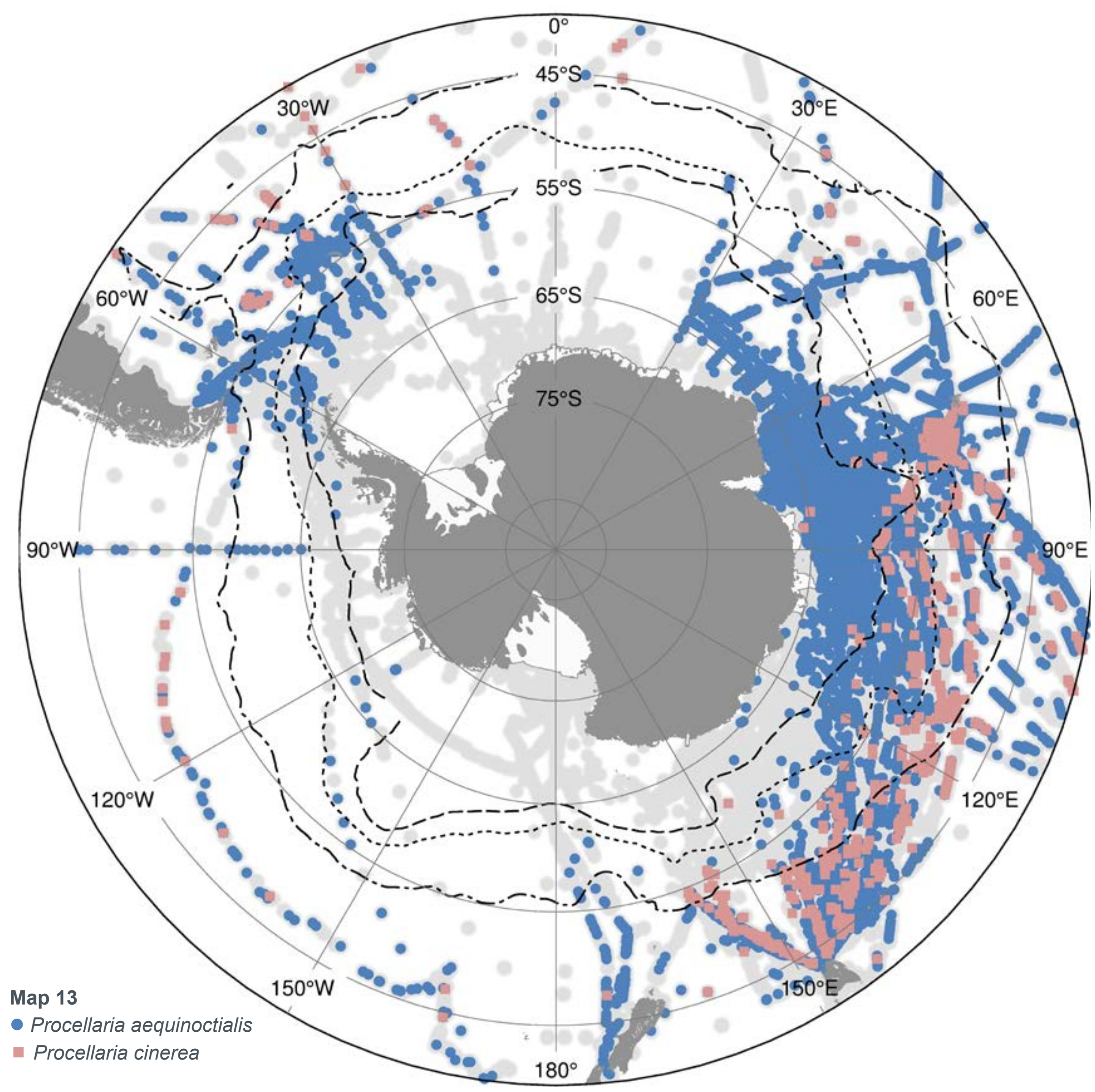
Flying Birds Maps 8–11 Map 8. Southern Fulmar: *Fulmarus glacialoides*. Map 9. Cape Petrel: *Daption capense*. Map 10. Antarctic Petrel: *Thalassoica antarctica*. Map 11. Snow Petrel: *Pagodroma nivea*.

mollymawk species in the South Atlantic, at the islands of Tristan da Cunha and Gough (Map 5). The at-sea distribution of the yellow-nosed albatrosses therefore reflects their preference for warmer waters (Pinaud & Weimerskirch 2007), although a few individuals were observed in and to the northeast of Prydz Bay, i.e. much further south than expected. The other species shown on map 5 is the Salvin's albatross (*T. salvini*) which breeds at the Bounty and Snares Islands, and remains largely in sub-tropical waters. Light-mantled albatrosses (*Phoebetria palpebrata*) routinely forage further south than any other albatross (Map 6), even in the marginal ice zone (Phillips *et al.* 2005a). This species breeds on sub-Antarctic islands in all Southern Ocean basins as far south as Heard and McDonald Islands. There is a tiny a colony at 62°S on King George Island in the South Shetland Islands. In general, these birds are more likely to be seen in Antarctic waters than their congener, the sooty albatross (*P. fusca*) (Pinaud & Weimerskirch 2007). The latter also has a circumpolar breeding distribution and is sympatric on a few sub-Antarctic islands in the Indian Ocean, but breeds on sub-tropical islands there and in the Atlantic.

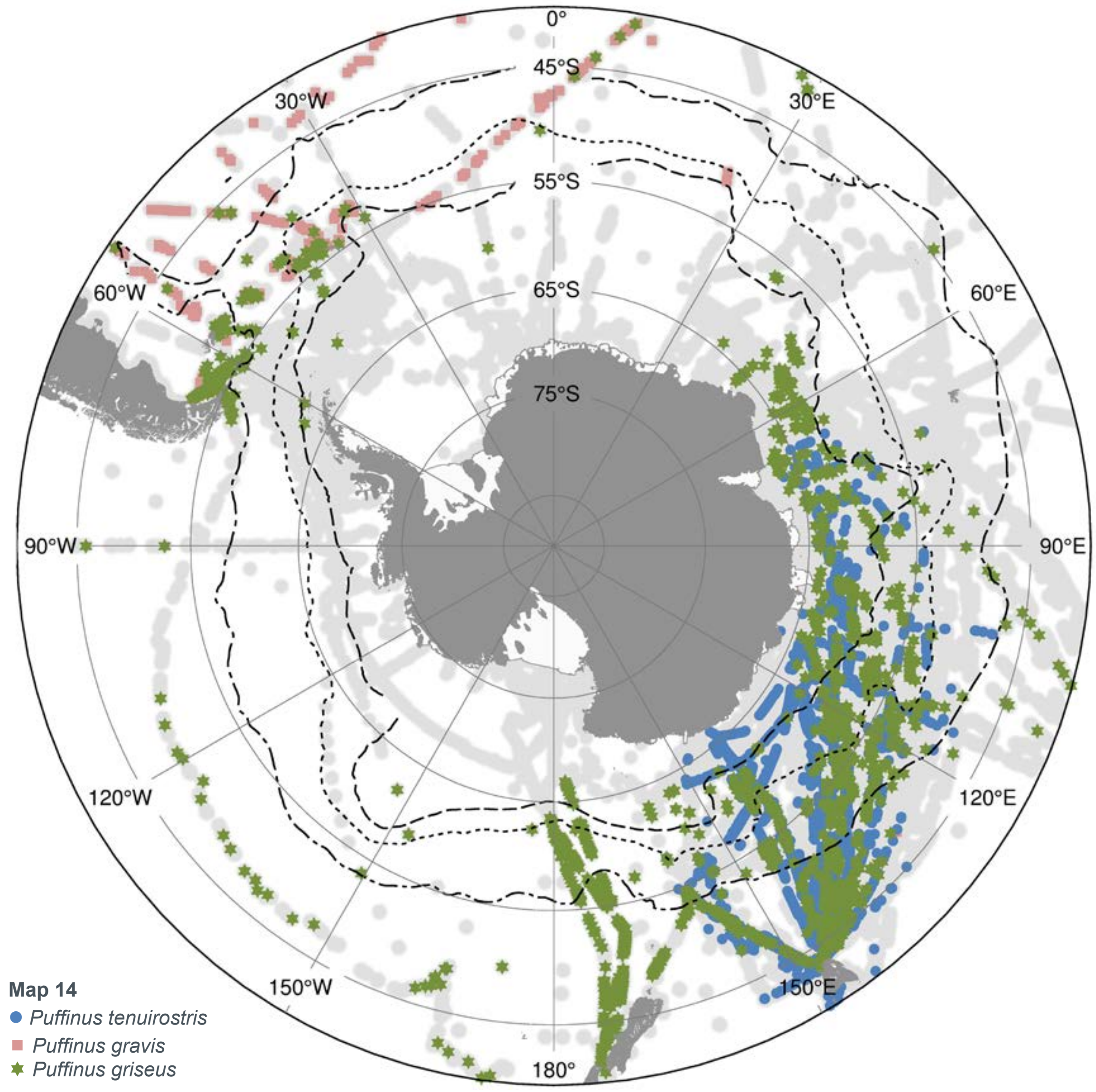
There are some revealing comparisons to be made among the fulmarine petrels (family *Procellariidae*). Both southern (*Macronectes giganteus)* and northern giant petrels (*M. halli*) have circumpolar breeding ranges (Map 7). The former has a particularly broad latitudinal range; colonies range from the Antarctic continent (~68°S) to Gough Island (40°S). During the early breeding season, males of both species feed extensively on terrestrial resources, including carrion. Later they switch to pelagic waters where the females usually feed. As the maps indicate, both species occur from sub-tropical to Antarctic waters but southern giant petrels are more likely to be seen as far south as coastal Antarctica. This is rare for northern giant petrels except at the Antarctic Peninsula and around Prydz Bay (presumably birds from Kerguelen). Southern fulmars (*Fulmarus glacialoides*) breed on the more southerly sub-Antarctic islands and on mainland Antarctica (Map 8). They are widespread at sea in both regions but less common in more northerly waters. Cape petrels (*Daption capense*) also have a wide latitudinal range in breeding distribution, to as far north as the Crozet Islands (47°S). In winter, they migrate to subtropical waters, giving them an even wider distribution at sea (Map 9). In contrast, both Antarctic (*Thalassoica antarctica*) (Map 10) and snow petrels (*Pagodroma nivea*) breed close to or on the Antarctic continent. Some snow petrels were sighted as far north as South Georgia (Map 11); they are more frequently recorded in Antarctic than sub-Antarctic waters and are more common than cape petrels or southern fulmars in the Ross Sea.

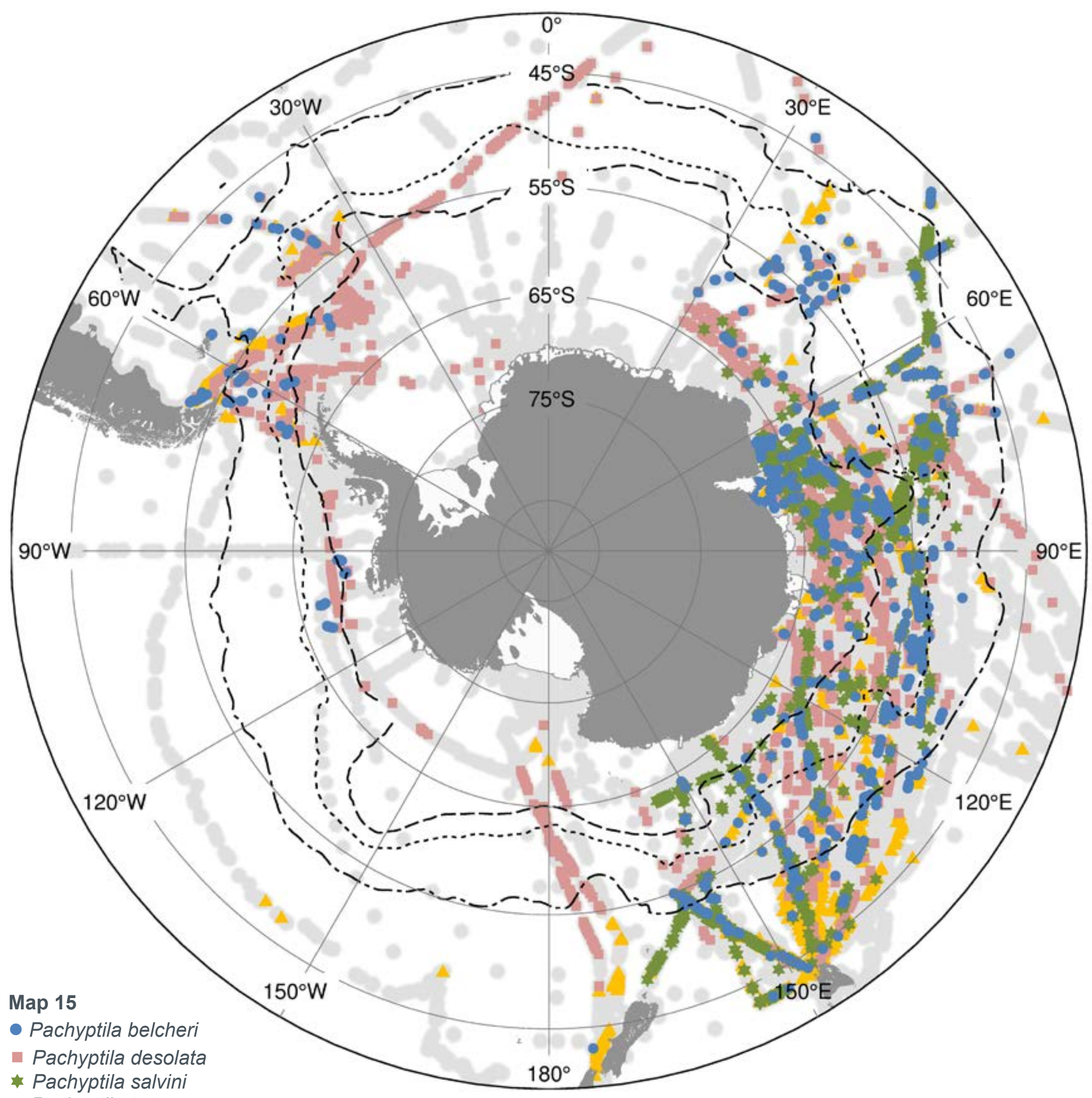
The map for the gadfly petrels *Pterodroma* spp. highlights that although the soft-plumaged petrel (*P. mollis*) and the great-winged petrel (*P. macroptera*) are most common in sub-tropical and sub-Antarctic waters, they also occur routinely in Antarctic regions (Map 12). It is tempting to infer from the rarity of sightings in the southern Pacific that neither species is a circumpolar migrant, but that would need to be confirmed with tracking work or much more extensive at-sea surveys. Although they breed at similar latitudes to soft-plumaged and great-winged petrels, Kerguelen petrels (*Aphrodroma brevirostris*) appear to be less common in sub-tropical and more common in Antarctic waters, particularly in the southwest Indian Ocean (Map 12). White-headed petrels (*P. lessonii*), which breed in the southwest Indian Ocean and at the New Zealand's sub-Antarctic islands, are widespread throughout sub-tropical



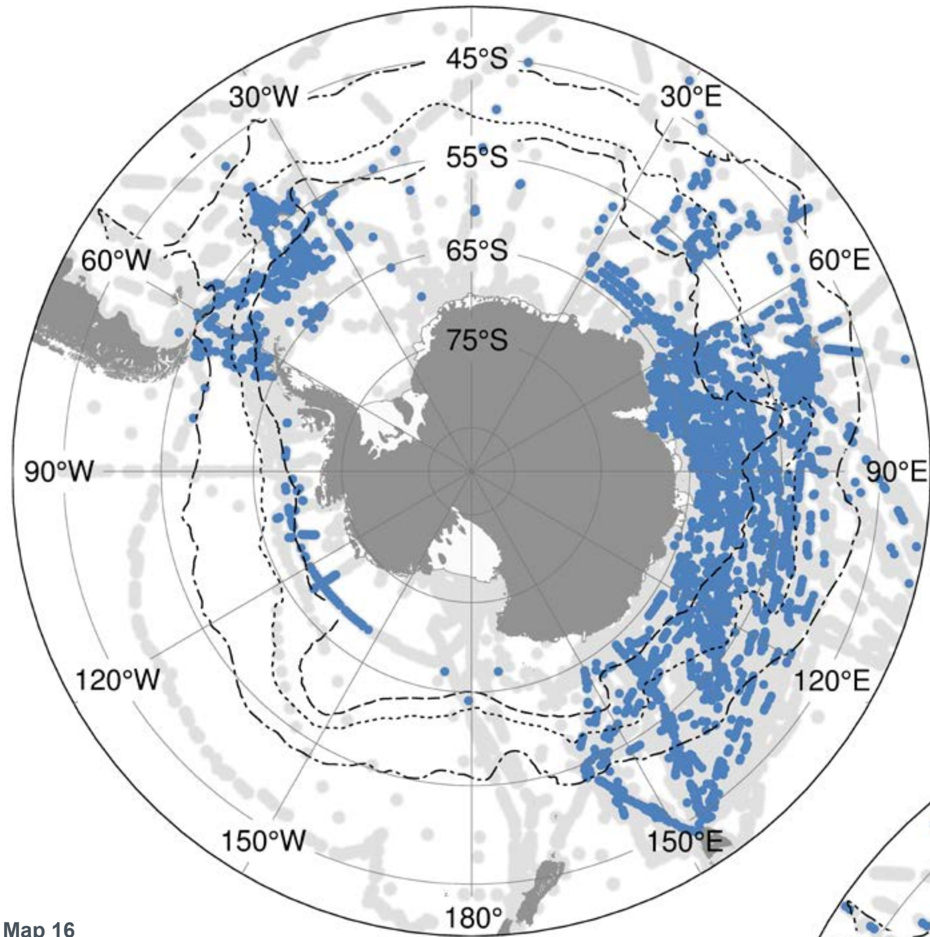


Flying Birds Maps 12–13 Map 12. Kerguelen Petrel: *Aphrodroma brevirostris*, White-headed Petrel: *Pterodroma lessonii*, Great-winged Petrel: *P. macroptera* and Soft-plumaged Petrel: *P. mollis*. Map 13. White-chinned Petrel: *Procellaria aequinoctialis* and Grey Petrel: *P. cinerea*.

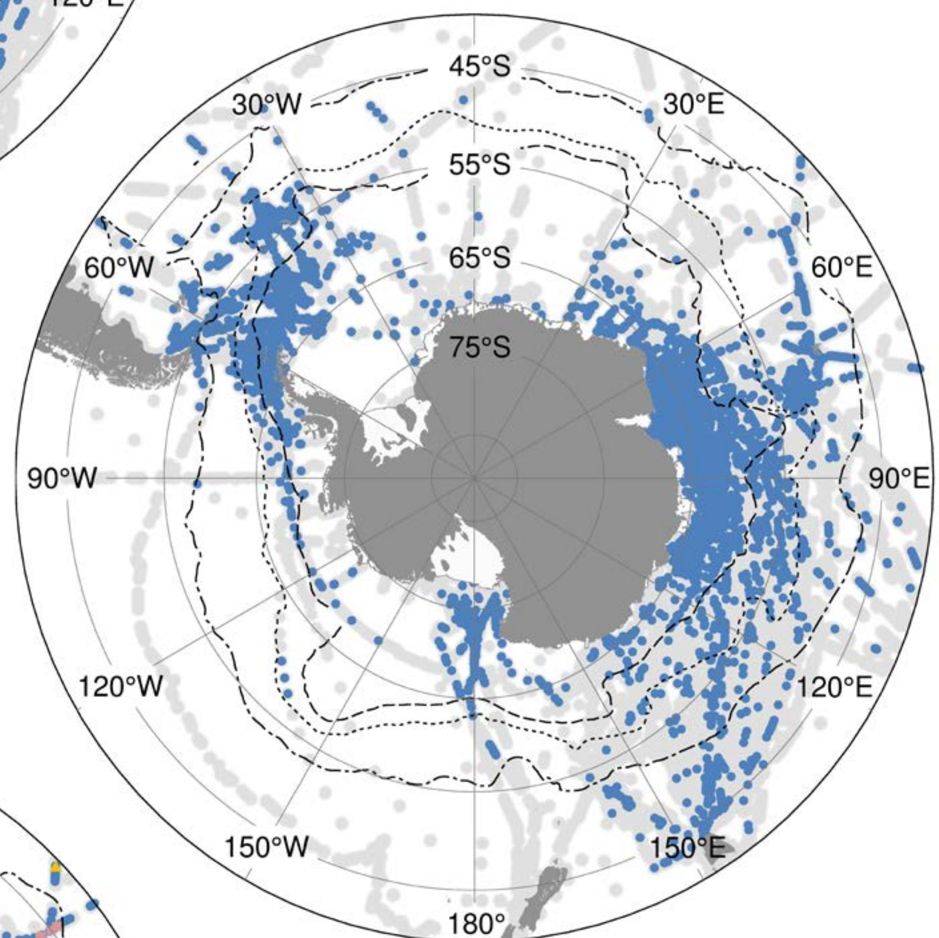




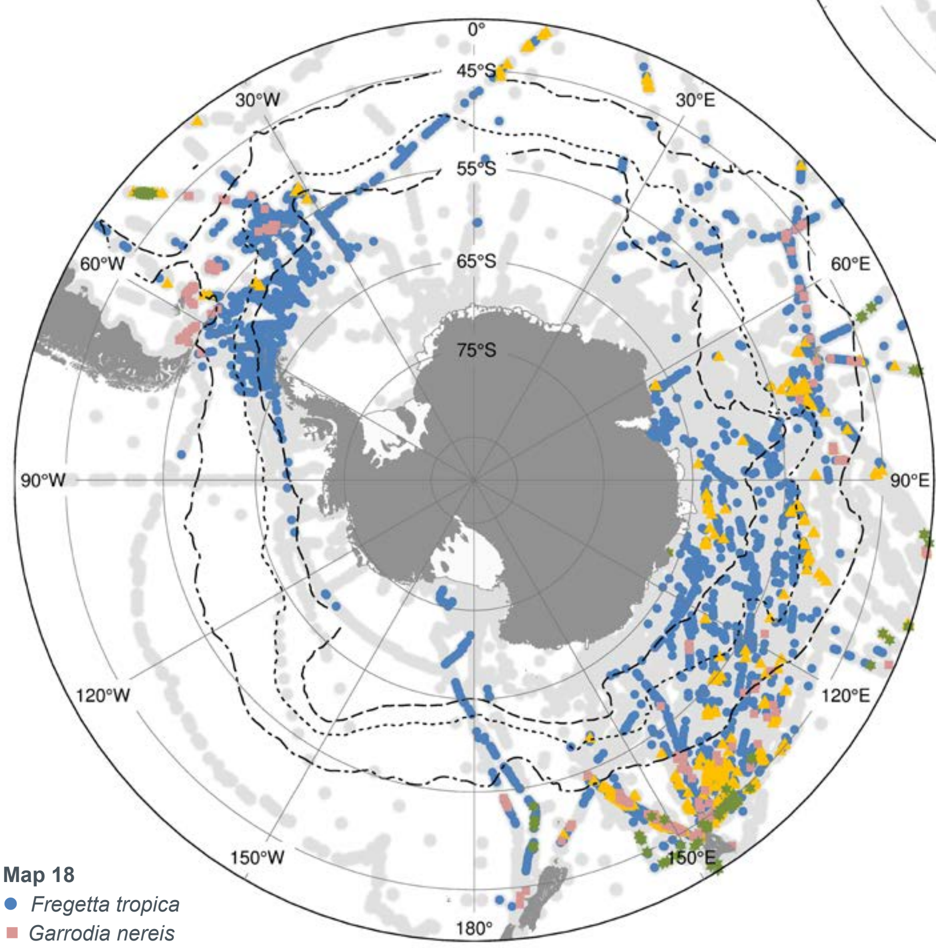
Flying Birds Maps 14–15 Map 14. Short-tailed Shearwater: *Puffinus tenuirostris*, Great Shearwater: *P. gravis* and Sooty Shearwater: *P. griseus*. Map 15. Slender-billed Prion: *Pachyptila belcheri*, Antarctic Prion: *P. desolata*, Salvin's Prion: *P. salvini* and Fairy Prion: *P. turtur*.



Map 16
● *Halobaena caerulea*

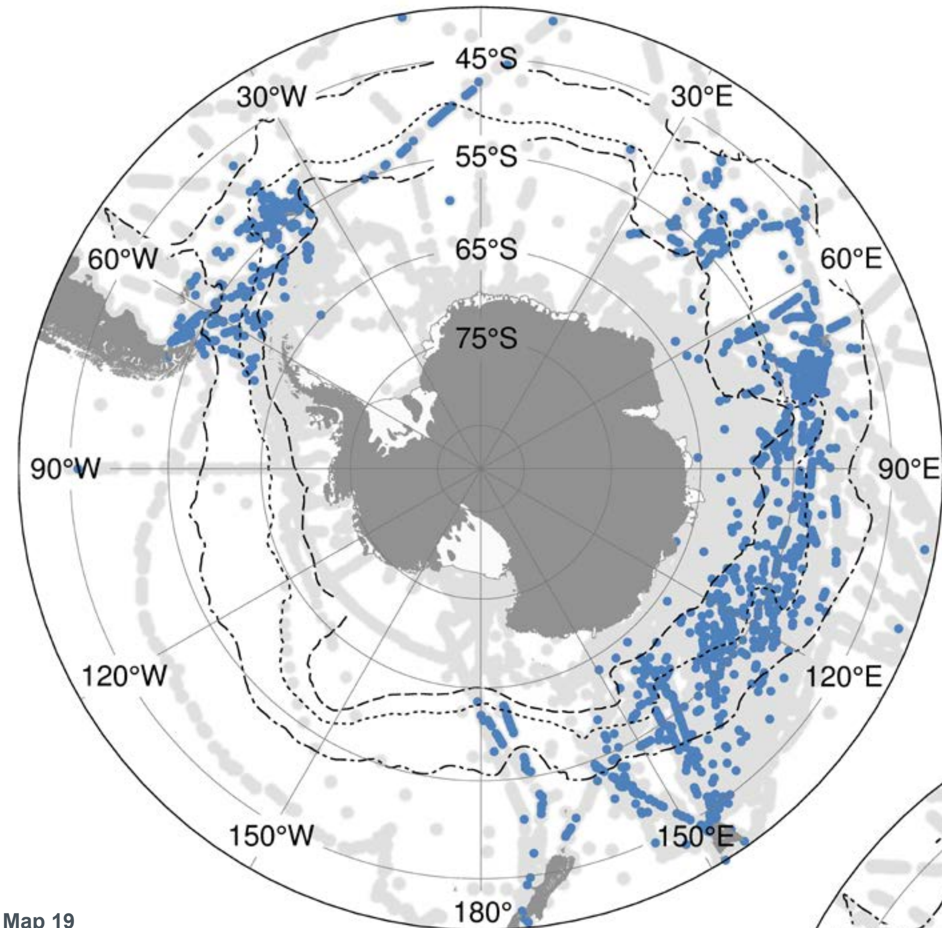


Map 17
● *Oceanites oceanicus*

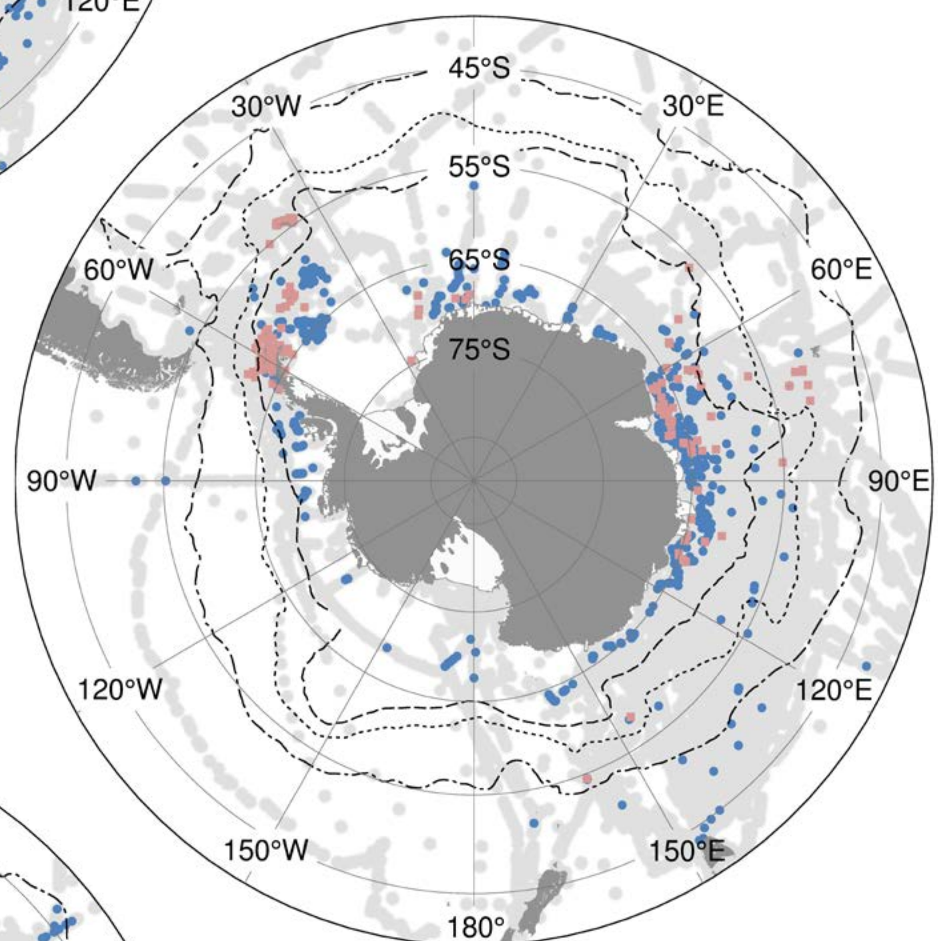


Map 18
● *Fregetta tropica*
■ *Garrodia nereis*
✱ *Pelagodroma marina*
▲ *Fregetta grallaria*

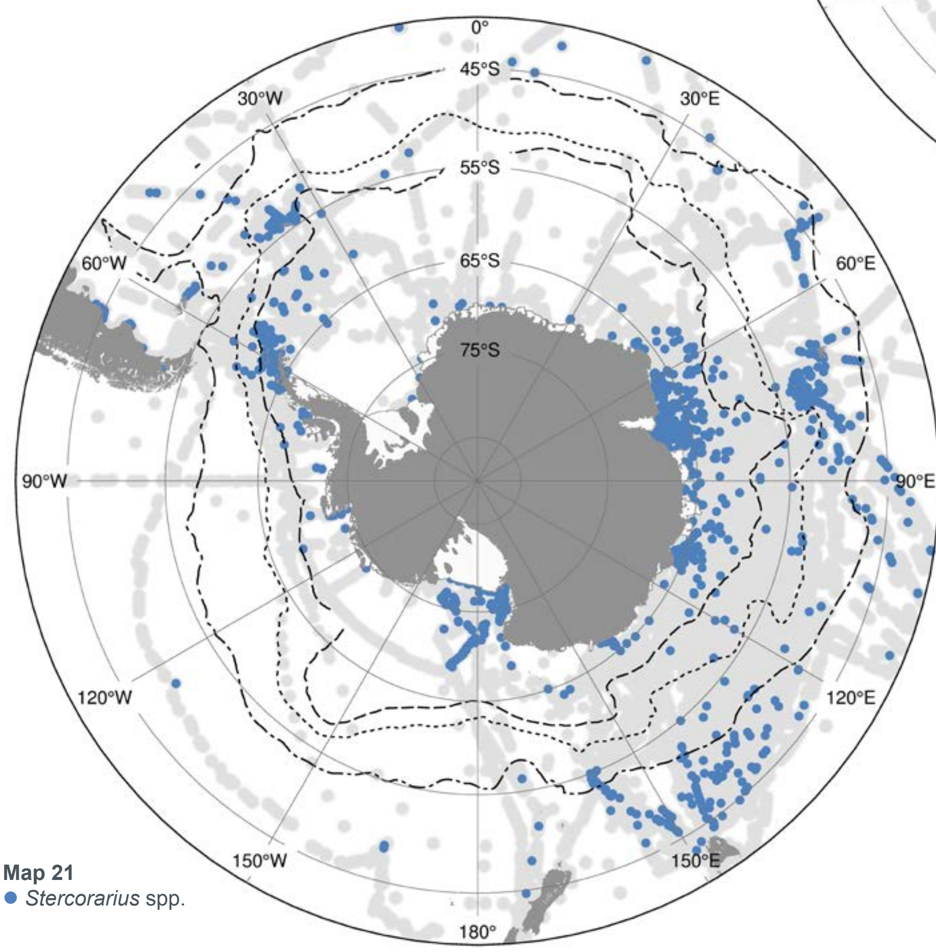
Flying Birds Maps 16–18 Blue Petrel: *Halobaena caerulea*. Map 17. Wilson's Storm Petrel: *Oceanites oceanicus*. Map 18. White-bellied Storm Petrel: *Fregetta grallaria*, Black-bellied Storm Petrel: *F. tropica*, Grey-backed Storm Petrel: *Garrodia nereis* and White-faced Storm Petrel: *Pelagodroma marina*.



Map 19
● Pelecanoididae



Map 20
● *Sterna paradisaea*
■ *Sterna vittata*



Map 21
● *Stercorarius* spp.

Flying Birds Maps 19–21 Map 19. Diving petrels: Pelecanoididae. Map 20. Arctic Tern: *Sterna paradisaea* and Antarctic Tern: *S. vittata*. map 21. Skuas: *Stercorarius* spp.

to Antarctic waters in the southeast Indian Ocean and Australasia. Moreover, they are the only gadfly petrel recorded routinely in the Pacific and may be circumpolar migrants (Map 12).

White-chinned petrels (*Procellaria aequinoctialis*) are very widespread at sea (Map 13); their distribution in most regions ranges from Antarctic to sub-tropical waters where they spend the non-breeding season (Phillips *et al.* 2006, Péron *et al.* 2010). The exception seems to be south of Australia and New Zealand where there are few records in Antarctic waters, suggesting that the subspecies *P. a. steadi* from Auckland, Antipodes and Campbell islands may differ from the other subspecies in its habitat preference. In contrast, grey petrels (*P. cinerea*) have a narrower, northerly distribution and are largely confined to sub-Antarctic waters.

Sightings of great shearwaters (*Puffinus gravis*) at sea were restricted to the south Atlantic, mainly but not exclusively, to sub-Antarctic and tropical waters (Map 14). Short-tailed (*P. tenuirostris*) and sooty (*P. griseus*) shearwaters from colonies in Australia, and Australia and New Zealand, respectively, frequently travel long distances to Antarctic waters. During chick-rearing, these trips reflect the dual foraging strategy used by adults to balance the demands of self-maintenance with those of provisioning chicks (Shaffer *et al.* 2009). The small number of sooty shearwaters in Antarctic waters in the southwest Atlantic and western Antarctic Peninsula indicates that birds breeding in the Falklands and southern Chile do not routinely use this strategy (Map 14).

The small Antarctic (*Pachyptila desolata*) thin-billed (*P. belcheri*) and Salvin's (*P. salvini*) prions (Map 15) and blue petrels (*Halobaena caerulea*, Map 16) are largely restricted to sub-Antarctic islands in terms of their breeding colonies; however, all appear to forage widely in sub-Antarctic and Antarctic waters (Maps 15 and 16). During the non-breeding period, thin-billed prions and blue petrels are distributed mainly in Antarctic waters, whereas most Antarctic prions migrate north of the APF (Phillips *et al.* 2009, Quillfeldt *et al.* 2013). The records of thin-billed prions in the southeast Indian Ocean suggest that birds from Crozet and Kerguelen, which are the closest populations, move east during the non-breeding period. Assuming they are not misidentifications, the sightings of fairy prions (*P. turtur*) in Antarctic waters (Map 15) are unexpected given that these species are much more typical of warm sub-Antarctic and cool sub-tropical waters.

Although even more diminutive than prions, many of the storm petrels (*Hydobatidae*) disperse over great distances from breeding colonies. Wilson's storm petrels (*Oceanites oceanicus*) are the smallest warm-blooded vertebrates that breed in Antarctica (Map 17). This is one of the most abundant and widespread seabird species in the world. Although seen routinely in the northern North Atlantic, stable isotope analyses of feathers suggest that many adults of breeding age remain year-round in the Southern Ocean (Phillips *et al.* 2009). The at-sea distribution of black-bellied storm petrels (*Fregatta tropica*) ranges from sub-tropical regions during the non-breeding period to Antarctic waters (Map 18). This compares with the closely related white-bellied storm petrel (*F. grallaria*) that is largely a sub-tropical species with a distribution that extends into sub-Antarctic waters (Map 18). The sightings at high latitudes in the southeast Indian Ocean may well be misidentifications. Records of white-bellied storm petrels in the Atlantic sector are further confused by the presence of a white-bellied form of the black-bellied storm petrel, which breeds at Tristan da Cunha and Gough islands (Flood & Fisher 2011). Grey-backed storm petrels (*Garrodia nereis*) have a more restricted at-sea distribution. Most sightings were made at low- to mid-latitudes, mainly around their sub-Antarctic breeding sites (Map 18). Similarly, white-faced storm petrels (*Pelagodroma marina*) seem to occur only in sub-tropical and tropical waters (Map 18).

Although the sightings are pooled because of the difficulty of species identification at sea, the distribution of diving petrels (*Pelecanoididae*) is intriguing in that these birds are sighted routinely much further from breeding colonies than usually depicted in standard field guides, particularly in the central to southeast Indian Ocean where there are no colonies between Heard Island and Tasmania (Map 19). This provides a tantalising hint that this may be a wintering area. The distribution of Antarctic terns (*Sterna vittata*) is largely a reflection of birds within relatively short distances of their breeding sites (Map 20). This contrasts with the wider distribution of Arctic terns (*S. paradisaea*) which breed during the boreal summer in northern temperate to Arctic regions, and make the longest known migration of any animal to Antarctic waters where they feed during the austral summer (Egevang *et al.* 2010).

Most sightings of the large Southern Hemisphere skuas (formerly *Catharacta* but now frequently assigned to *Stercorarius*, which is the same genus as the small, Northern Hemisphere skuas or jaegers) are concentrated around breeding sites; those for brown skuas (*S. antarctica)*, are largely the sub-Antarctic islands, extending in the Atlantic sector to the Antarctic peninsula, and for south polar skuas (*S. maccormicki)* are coastal areas and islands of the Antarctic Peninsula and continental Antarctica (Map 21). The records in more northerly waters, particularly southwest to southeast of Tasmania (Map 21), are probably of migrant south polar skuas *en route* to wintering areas off Japan.

4. Seals (Otariidae)

There are seven species of pinnipeds (seals) commonly found within the spatial domain of the Atlas. This includes two species of otariid (fur seals): Antarctic fur seals (*Arctophoca gazella*) and sub-Antarctic fur seals (*A. tropicalis*); and five species of phocid ("true seals"): leopard (*Hydrurga leptonyx*), Weddell (*Leptonychotes weddellii*), crabeater (*Lobodon carcinophaga,* previously *L. carcinophagus*), southern elephant (*Mirounga leonina*), and Ross seals (*Ommatophoca rossii*). There are other seal species that also occur in the area, such as Hooker's sea lions (*Phocarctos hookeri*) that breed on the New Zealand's sub-Antarctic islands (Auckland group and Campbell Island), as well as South American sea lions (*Otaria flavescens*) which breed along the coast of Patagonia. Neither of these is included in the Atlas because of insufficient sightings.

When at sea, seals are quite cryptic, being relatively small (compared to cetaceans), and only visible when on the surface to breathe or rest. In the pack ice some species, such as Weddell and crabeater seals, can often be seen hauled out on ice floes, but others, such as elephant seals, spend most of their time in the water and are rarely sighted. Only since the advent of satellite telemetry in the last two decades could the true extent of the use of the sea-ice zone by elephant seals and fur seals be determined.

4.1. Otariids

The current range of the two otariid species is a result of both historical and ecological factors. Both species were hunted to near extinction during the 19th century. Their populations started to recover in the 1950s, and since then populations at most sites have grown exponentially (Wynen *et al.* 2000). However, in some cases, such as Macquarie Island, it is unknown which species originally inhabited the islands. There is also no information on the initial population size from any site, so the extent to which current at-sea distributions resemble pre-exploitation distributions is unclear.

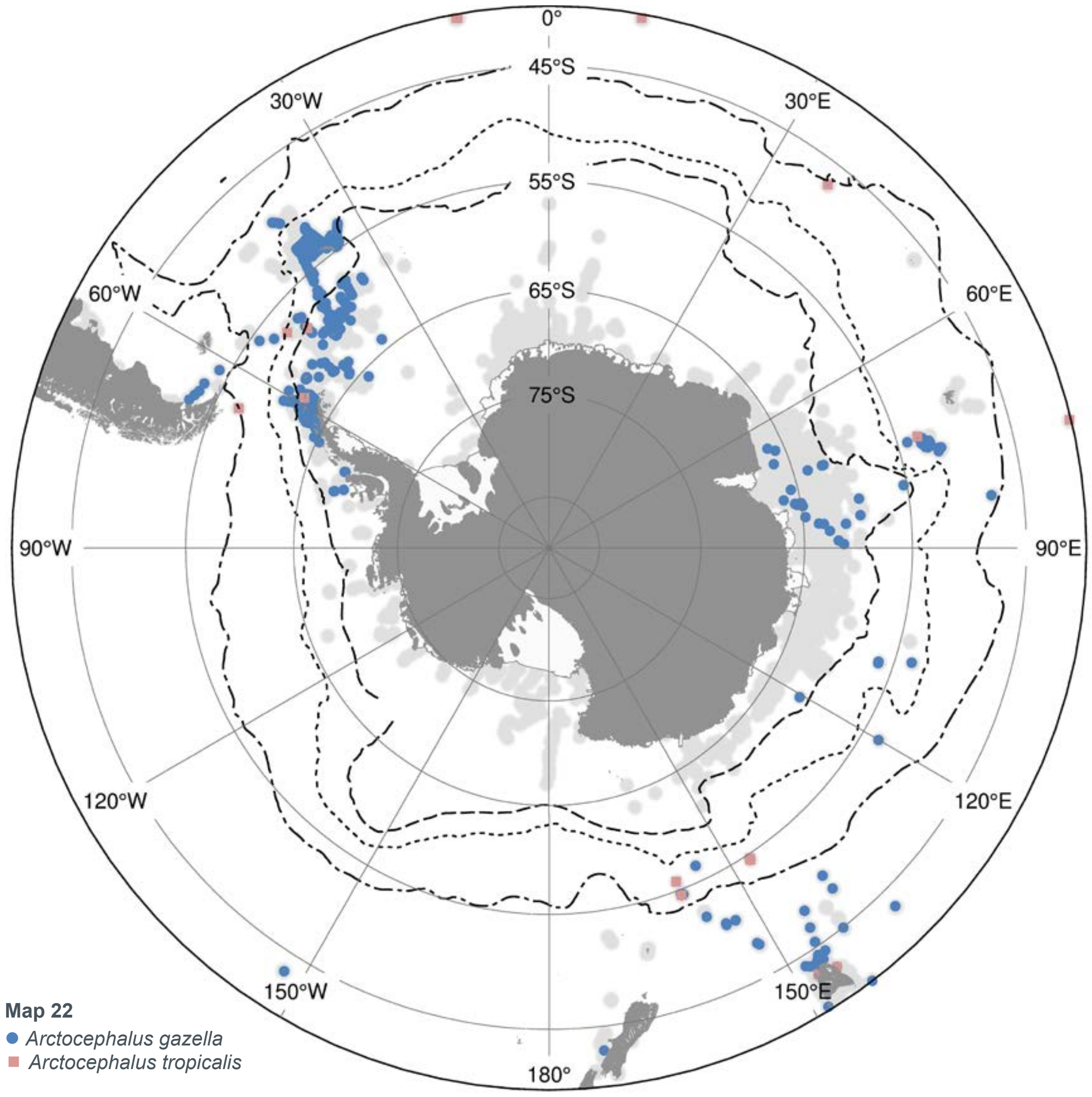
Both species give birth to pups on sub-Antarctic islands (or islands off the Antarctic Peninsula). Mothers alternate periods that can last several days ashore to suckle their young with foraging periods at sea to replenish their energy reserves. Thus, during the breeding season the animals remain relatively close to their breeding sites and only disperse during the non-breeding months (Map 22). For most fur seal species, including *A. tropicalis*, females suckle their pups for ten months (from December through to September) and so females commute between areas with predictable food resources (often associated with frontal regions) and the breeding islands where their pups are waiting. In some areas, the females travel several hundred kilometres and take over a week (Beauplet *et al.* 2004). Antarctic fur seals have the shortest lactation period of any otariid, lasting for only 4 months (December to April). The brevity of their lactation period is due to the high summer productivity and abundant marine resources at their high latitude breeding sites. This allows the mothers to supply sufficient energy in a short time to allow the pups to grow quickly and reach nutritional independence. This frees the adults to disperse more widely during the winter months.

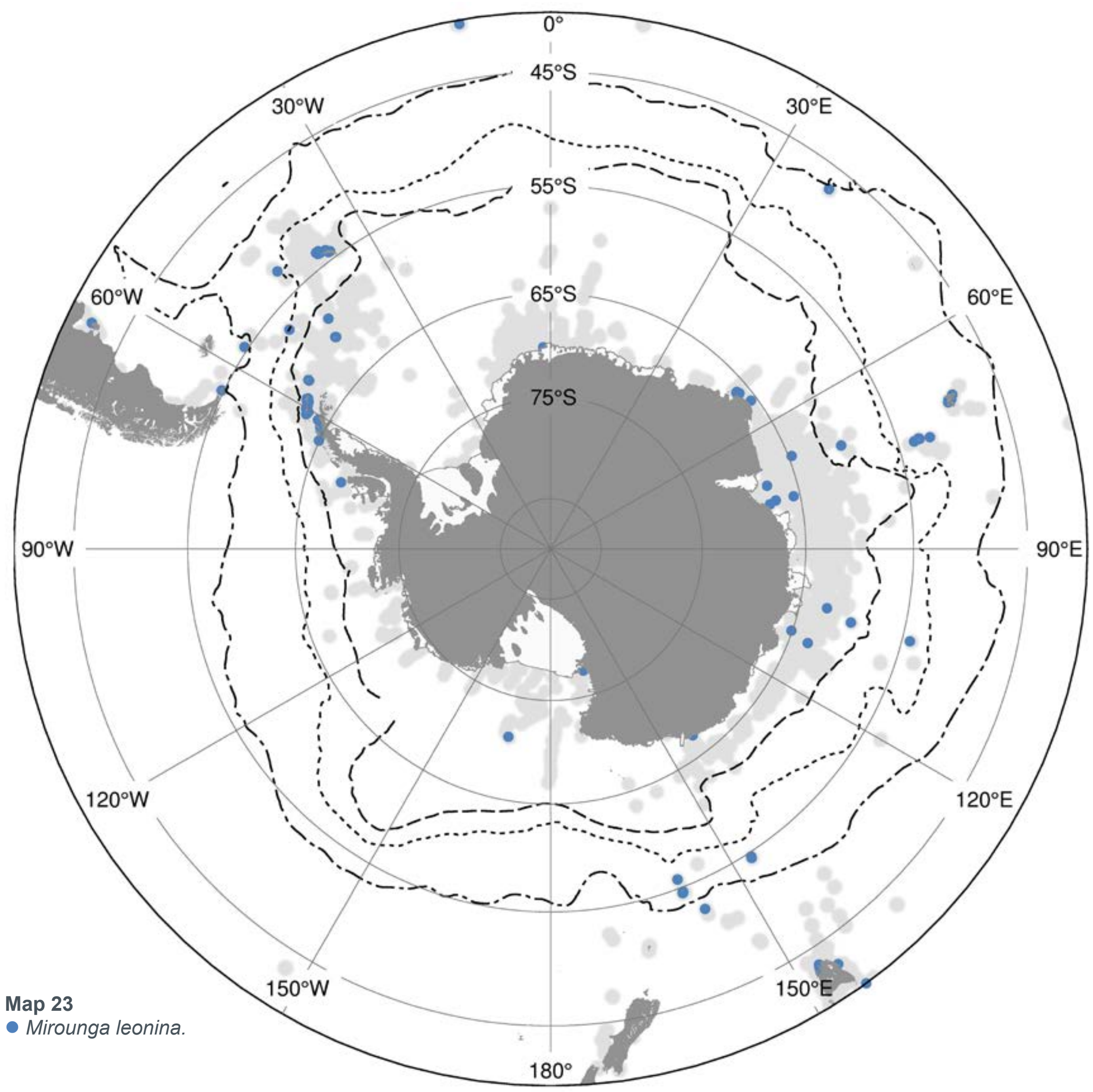
Sub-Antarctic fur seals breed on sub-Antarctic islands near or north of the APF. The scarcity of at-sea sightings of this species is a reflection of the relatively small sizes of the still-recovering populations, the northerly locations of their breeding sites and the fact that they focus their foraging between the sub-Antarctic and sub-tropical fronts where there is limited survey effort (Map 22). The sightings in the Pacific and Indian oceans are consistent with the major foraging areas for populations at Macquarie, Crozet, and Amsterdam islands. The sightings in the Drake Passage and south Atlantic are likely to be dispersing males (Map 22).

While Antarctic fur seals have a more southerly distribution, breeding on islands associated with the APF or the Antarctic Peninsula, they also breed in sympatry with sub-Antarctic fur seals in lower latitudes at a number of islands (The Prince Edward Islands, Crozet Islands, Macquarie Island) (Map 22). The population at South Georgia is very much the strong hold for this species, comprising more than 70% of the breeding stock (Murphy *et al.* 2007). The aggregation of at-sea sightings around South Georgia reflects this, while the sightings on the Western Antarctic Peninsula could be from either South Georgia or the smaller, but growing populations in the South Shetlands (Map 22). We know from satellite tracking data that males tend to use the northern regions of pack ice, and this can be seen in the sightings south of the ACC in the Indian Ocean. Other tracking studies have indicated that during the winter months, adult females disperse widely from the breeding sites, going to the ice edge or along the APF. This is not seen in the sightings data probably due to the lack of sighting effort in these regions in the winter months, as well as the cryptic nature of fur seals at sea.

4.2. Phocids

Southern elephant seals predominantly breed on sub-Antarctic islands near the APF, the South Shetland and South Sandwich islands although there are also populations in Tierra del Fuego and on the Valdés Peninsula in Patagonia (Map 23). Outside the brief breeding season in October, adults disperse widely. A large number of tracking studies showed that the Antarctic continental shelf and the pack ice are important regions for these seals, as is the APF (Bailleul *et al.* 2007, Biuw *et al.* 2007). There are clear age- and sex-related differences in distribution. The much larger adult males tend to use the continental shelf and remain there throughout the winter months, despite the encroaching sea-ice. While many adult females use the shelf during summer and autumn, they leave it as the sea ice advances, remaining in looser pack ice or leaving the sea-ice zone altogether to forage in open water to the north. Juvenile elephant seals tend to remain in open water, moving further south as they get older. Individual elephant seals demonstrate a high degree of foraging site fidelity; animals return to the same areas to feed in subsequent years, indicating that they learn which areas have reliable prey resources (Bradshaw *et al.* 2004). Southern elephant seals are deep diving specialists that regularly dive to 500 m (and often much deeper with dives in excess of 1500 m being common, and more rarely to >2000 m). The seals spend only two to three minutes on the surface between dives which last 20–30 minutes (the maximum recorded is 12 min), and this lack of time on the surface may to some extent





Seals Maps 22–23 Map 22. Antarctic Fur Seal: *Arctocephalus gazella* and Sub-Antarctic Fur Seal *A. tropicalis*. Map 23. Southern Elephant Seal: *Mirounga leonina*

Photo 3 Young Southern Elephant Seal, *Mirounga leonina*, Marion Island, 2012. Image © Yan Ropert-Coudert, Université de Strasbourg & CNRS.

account for the lack of at-sea sightings in map 26.

Weddell seals are a coastal breeding species, giving birth in October in loose aggregations of animals associated with semi-permanent cracks in the fast ice. Adult males and females remain in these groups during the five-week breeding season, rarely moving far from the cracks, which are their only access to the water and prey. Outside the short breeding season, they are free to disperse more widely (Map 24), but they tend to remain in areas of either fast ice, or dense pack ice (Heerah *et al.* 2013). In some cases they use their teeth to maintain breathing holes in the fast-ice during winter. Other adults — at least in the Ross Sea region — disperse more widely, moving several hundred kilometres offshore from the coastal breeding sites, although they tend to remain in areas of high ice concentration, and rarely move off the continental shelf. Less is known about the movements of juvenile and sub-adult Weddell seals; it is possible that more northerly sightings from the Pacific and Indian oceans could be of these younger age classes that potentially can move further from the coast (Map 24). Otherwise, the at-sightings presented in map 24 illustrate the highly coastal and circumpolar nature of Weddell seal habitat.

Crabeater seals also have a circumpolar distribution (Map 25) and occupy sea-ice habitats ranging from coastal fast ice out to the ice edge. The ubiquitous nature of this species in the sea ice is illustrated in map 25. This is also a result of the great abundance of this species, which is by far the most numerous of the Southern Ocean seals (Southwell *et al.* 2008). The diet of crabeater seals is dominated by Antarctic krill (*Euphausia superba*), and the finer-scale distribution patterns of the seals are influenced by the local distribution of the krill. In eastern Antarctica, the seals tend to be near the continental shelf break or to its north (Wall *et al.* 2007). At the western Antarctic Peninsula, where the southern branch of the ACC front (SACCF) and the APF are very close, the seals are found almost exclusively over the continental shelf (Burns *et al.* 2004).

Leopard seals are another pack-ice breeding species with a circumpolar distribution (Map 26), although they exploit a more diverse range of habitats than crabeater or Weddell seals. When feeding on penguins and fur seals during the summer months, leopard seals are found inshore around breeding colonies. However, leopard seals also eat fish, squid, and krill when in the pack-ice zone. In comparison with the crabeater seals, leopard seals may be less common in the Ross Sea or eastern Weddell Sea. Certainly, the hundreds of kilometres of ice shelf in these areas lack penguin colonies and this may help explain the rarity of leopard seals sightings in those regions (Map 23). Leopard seals are also known to travel out of sea ice to sub-Antarctic islands and even the continental landmasses in the mid latitudes. For instance, numerous sightings were made in Tierra del Fuego although no breeding activity has been recorded there to date (Acevedo & Martinez 2013). These movements north of the SACCF occur near Heard, Macquarie Islands and South Georgia (Map 23), but they are also relatively common near Kerguelen Island and Marion Island (Bester & Roux 1986).

Ross seals are the most poorly studied of the Antarctic seals, largely due to their relatively low densities and preference for breeding in heavy pack ice, which makes ship-based studies difficult. During mid-summer they seem to prefer the denser ice types more prevalent in the inner ice pack, but they are also present in open pack ice within the inner reaches, and occasionally on fast ice. Although absent from the outer pack at this time, it has recently been found that they also make prolonged and repeated foraging trips far to the north into the open water. Such trips ostensibly result in their rare sightings in lower latitudes, such as at Heard Island and southern Australia (Bester & Hofmeyr 2007). Very few individuals have been satellite tracked making the observational studies summarised here our primary source of information regarding their distribution and habitat use. The data presented here suggest that Ross seals are relatively common in the southern Pacific and Indian oceans, particularly in the areas between the Antarctic continental shelf and the SACCF (Map 27). It is remarkable how few sightings there are between 150°E and 30°E despite considerable survey effort (Map 27). However, differences in survey techniques, observation platforms and timing of surveys mean that it is difficult to be sure that this is a true reflection of the distribution and abundance of this species.

5. Whales and dolphins (Cetacea)

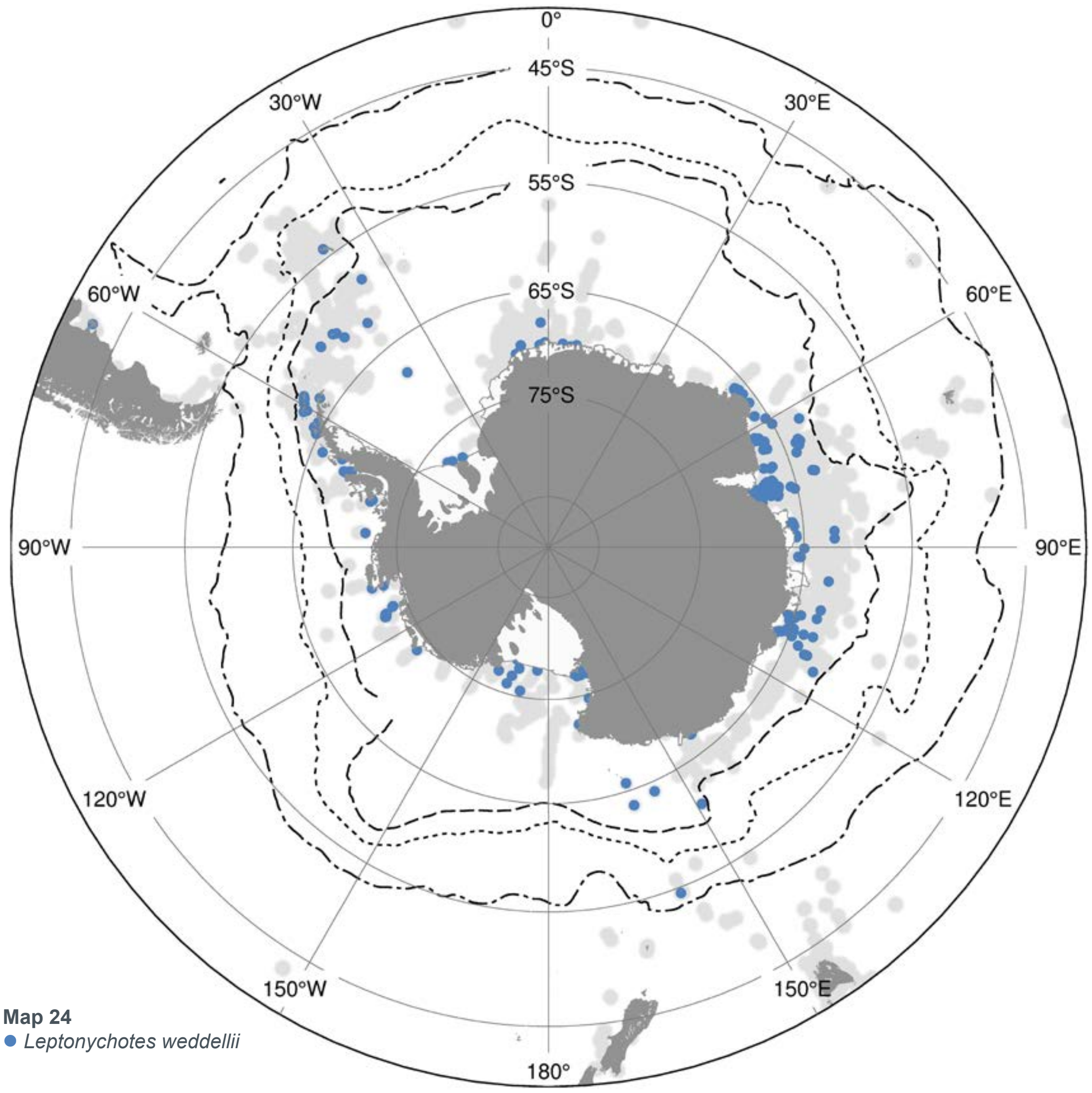
Whales or cetaceans are divided into two super families, the Mysticeti (or baleen whales) and Odontoceti (or toothed whales). In the Southern Ocean, there is considerably more information on baleen whales, since they are larger, more conspicuous animals, than the smaller dolphins and generally discreet, deep-diving beaked whales. In addition, baleen whales have been exploited to near extinction over the last two centuries and consequently catch data constitute an important source of information regarding the distribution and biology of the target species. Current sources of information on cetaceans include circumpolar surveys designed to evaluate abundances with line transect-based methods, such as the IWC International Decade of Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR-SOWER), multidisciplinary marine science voyages including a cetacean observation component (e.g. the Australian Baseline Research on Oceanography, Krill and the Environment voyages), and sightings collected from platforms of opportunity, such as tourist or supply vessels. Strandings are also a key source of data, especially for Odontoceti. Other techniques for cetacean studies include acoustics, photo-identification, genetic and biochemical analysis from biopsy samples, satellite telemetry, and bio-logging (Boyd *et al.* 2010).

In the present Atlas, we focus on at-sea sightings using the data available in the SCAR-MarBIN database or available upon request from the International Whaling Commission (IWC), such as the IDCR-SOWER data. Consequently, the Atlas does not intend to be exhaustive (e.g. it does not include the Japanese Antarctic Research Program data). Most observations were made during the austral summer, when at-sea surveys are generally conducted in the Southern Ocean. Therefore, the distribution maps tend to be summer biased. For baleen and sperm whales we discuss current distributions in relation to the International Whaling Commission's (IWC) historical catch data of commercial whaling, also included in this Atlas (Allison 2013).

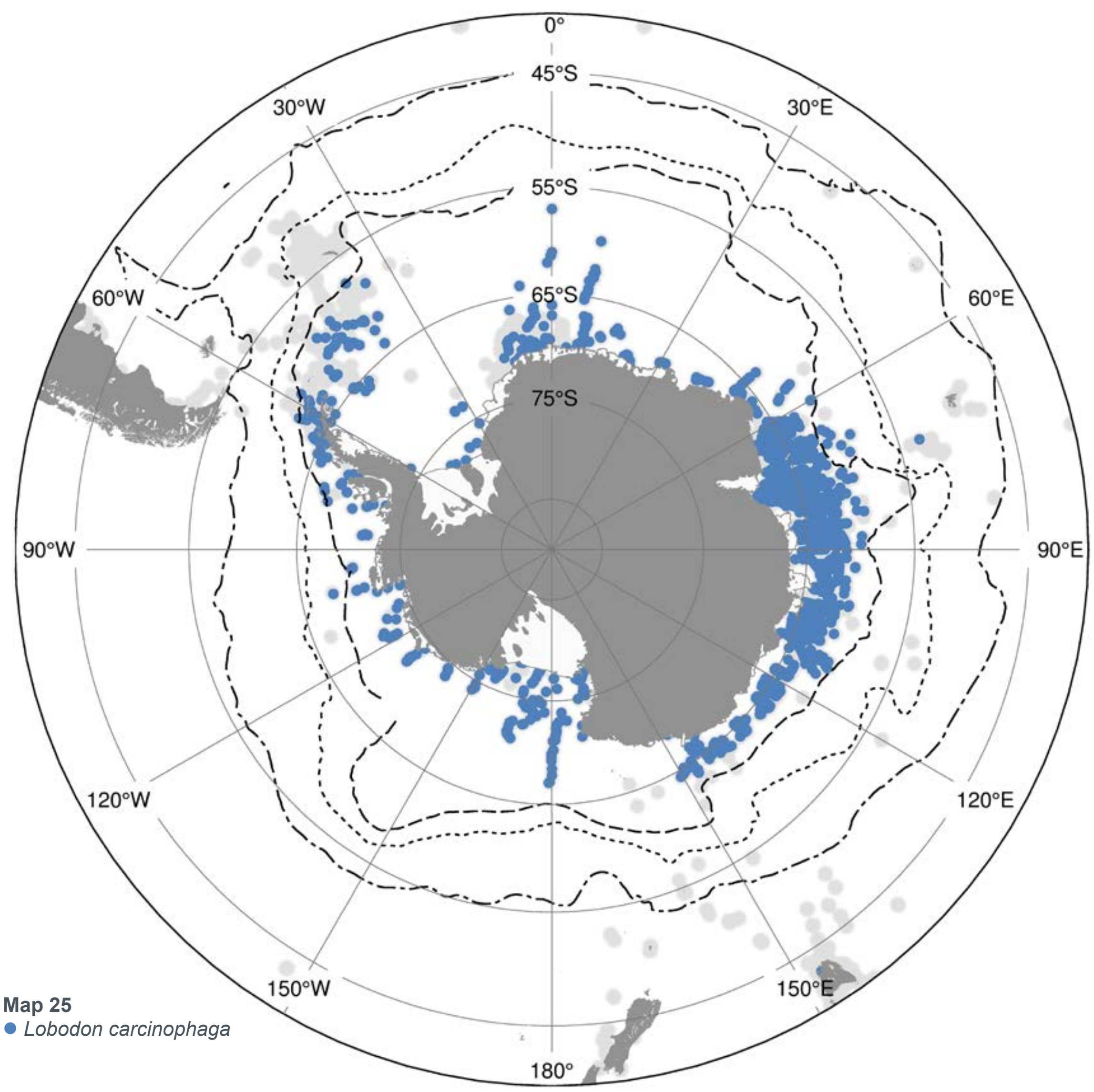
Baleen whales of the Southern Ocean feed almost entirely on krill and other zooplankton, which they filter out from the water using their baleen plates. Feeding can be continuous while swimming at the surface (skimming of southern right whales) or can occur by engulfing of large amounts of water and food, which is sieved trough the baleen plates by pressure of the tongue (other baleen whales). Baleen whales generally breed in temperate or tropical regions during the austral winter and feed in cold, high latitude waters during summer. However, there is a latitudinal gradient among the different species of baleen whales in terms of their preferential feeding grounds and distance from the ice edge, as detailed below. Balaenopteridae (rorquals) swim much faster that the slow Balaenidae (right whales), and therefore were not exploited until the onset of industrial whaling when steam boat and harpoon guns first appeared around 1860.

The most pagophilic ("ice-loving") species is the Antarctic minke whale (*Balaenoptera bonaerensis)*, the smallest whale among the rorquals (Map 28). In addition, an unnamed subspecies of the common minke whale (*B. acutorostrata)*, the dwarf minke whale, has also been described in high latitude waters but it represents less than 1% of the Antarctic minke whale numbers. Minke whales are found at 10–20°S in winter but congregate close to and within the pack ice in summer, where they feed on Antarctic krill but also on more inshore euphausiids, such as *Euphausia crystallorophias* or *E. frigida*. Abundance estimation has been the matter of considerable debate but the IWC recently agreed on a population of ca. 500,000 (International Whaling Commission 2012). Because of their small size, minke whales were not exploited by commercial whaling until the 1970s, after which they replaced the heavily depleted larger species as target for whaling fleets (Map 29). The catches declined drastically after the moratorium on commercial whaling came into force in 1986 but they are currently the primary target species of the Japanese scientific whaling in the Southern Ocean, with 200 to 500 animals taken each year.

The Antarctic blue whale (*Balaenoptera musculus intermedia)* has a circumpolar distribution (Map 30). It is a krill specialist that is found at high latitudes in summer, generally close to the ice edge. The smaller subspecies, the

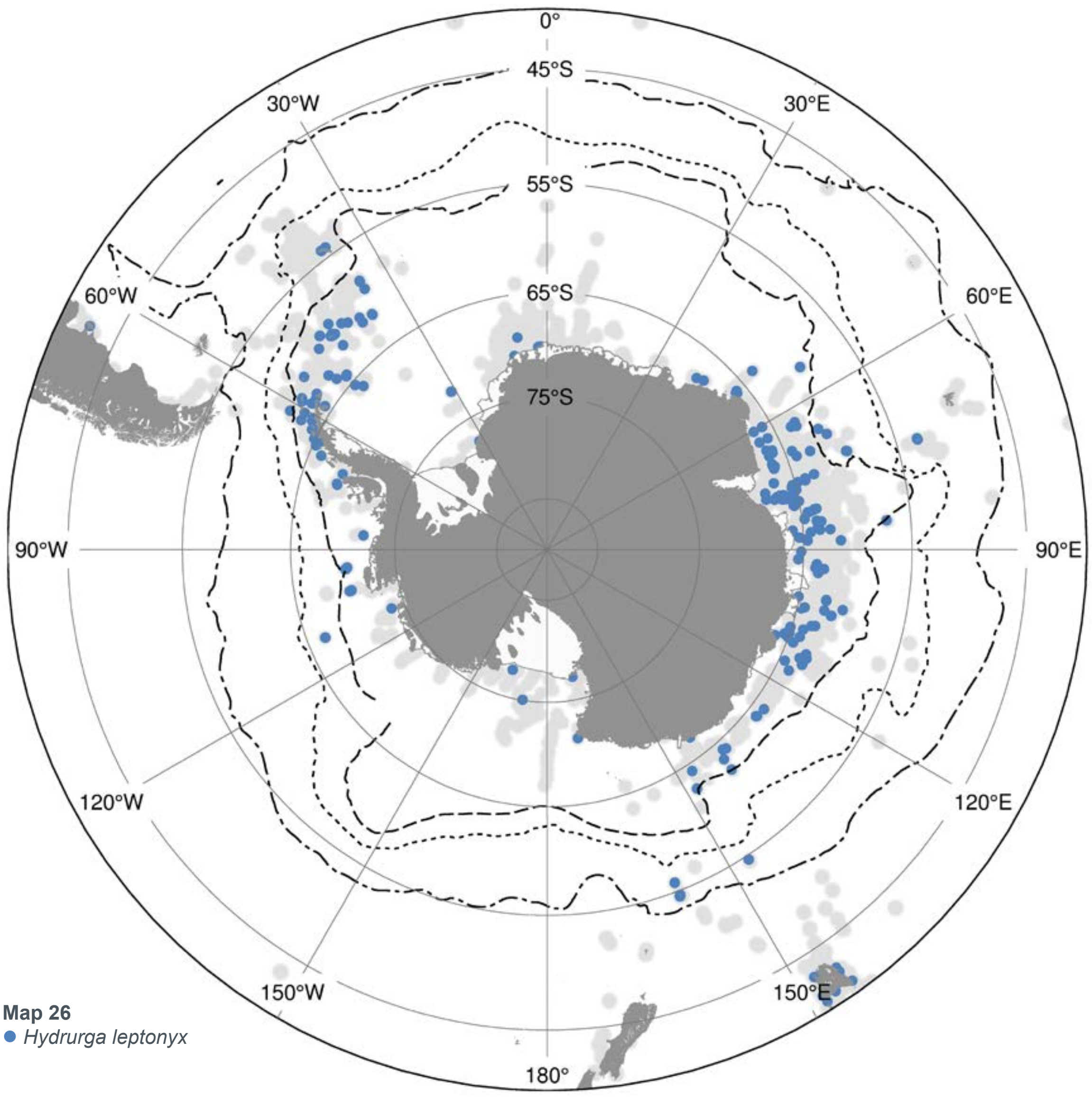


Map 24
● *Leptonychotes weddellii*

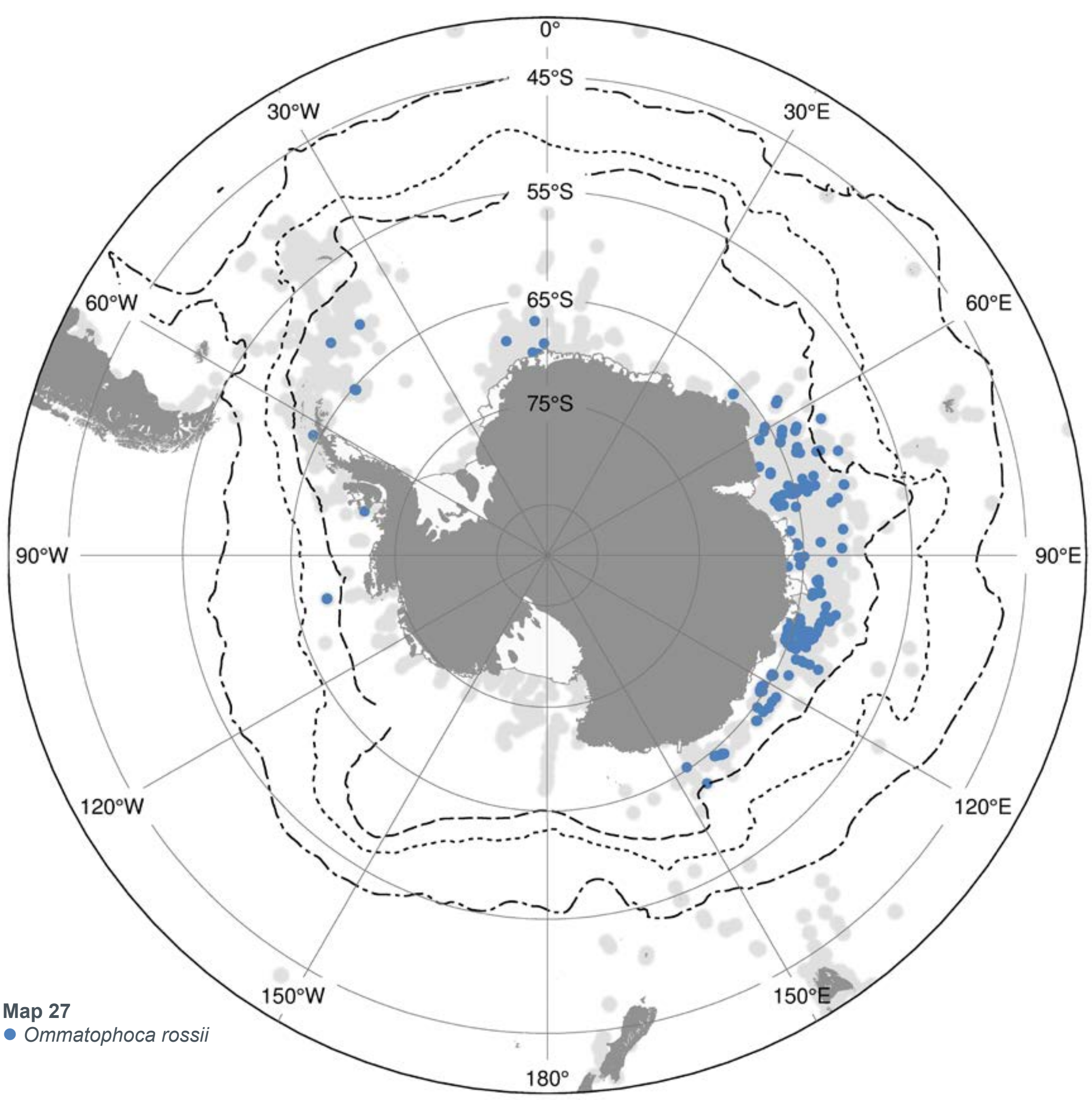


Map 25
● *Lobodon carcinophaga*

Seals Maps 24–25 Map 24. Weddell Seal: *Leptonychotes weddellii*. Map 25. Crabeater Seal: *Lobodon carcinophaga*.



Map 26
● *Hydrurga leptonyx*



Map 27
● *Ommatophoca rossii*

Seals Maps 26–27 Map 26. Leopard Seal: *Hydrurga leptonyx*. Map 27. Ross Seal: *Ommatophoca rossii*.

pygmy blue whale (*B. m. brevicauda)* generally occurs north of 54°S around the Indian Ocean and from southern Australia to New Zealand (Branch *et al.* 2007). Historical mark-recapture studies showed that Antarctic blue whales are capable of large-scale longitudinal movements (>100°). They generally migrate to lower latitudes in winter, but some overwinter around Antarctica (Branch *et al.* 2007). A comparison of the relatively recent sightings map and the historical catches map for *B. m. intermedia* (Map 31) reveals that this species — the largest, most profitable whale on Earth — has been hunted to near extinction, from an estimated pre-exploitation level of 239,000 in 1904 to as low as 360 individuals in 1973 (Branch *et al.* 2004). The most recent population estimate of Antarctic blue whales is around 2700, with an annual rate of increase of 7.3%. Its current summer distribution is restricted to high latitudes close to the ice-edge while it used to be found at much lower latitudes (up to the APF) when its population was larger during the whaling period (Branch *et al.* 2007).

Fin whales (*B. physalus)* are the second largest whales and present a circumpolar distribution in summer. Although they can be encountered at high latitudes along the ice-edge, they are less closely associated with sea ice than minke and blue whales (Map 32). Fin whales occur mostly north of 60°S. The spatial distribution of fin whales catches varies across ocean basins (Map 33); individuals can be encountered further north (up to 45°S) in the south Atlantic and southern Indian Ocean sectors (Leaper *et al.* 2008) than in other sectors. Migration to lower latitudes in winter has been reported. Fin whales have been heavily exploited, with as many as 700,000 individuals taken in the Southern Hemisphere during the 20th century, and were reduced to a few thousand (Clapham & Baker 2002). Because their feeding grounds extend further north than the areas surveyed by SOWER (which cover latitudes south of 60°S), current population estimates are incomplete. Circumpolar abundance is estimated with a low precision from 4000–8000 individuals, with indications of positive population trends (Branch & Butterworth 2001).

Sei whales (*B. borealis)* feed at higher latitudes (40°–60°S) than other Balaenopteridae whales, as both the sightings (Map 34) and catches maps (Map 35) reveal. They are rarely seen south of 60°S, especially in the south Atlantic and southern Indian oceans. They are not krill specialist and their diet includes various zooplanktonic prey, such as amphipods and decapods (Leaper *et al.* 2008). Because they primarily range in the vast, poorly surveyed sub-Antarctic waters sei whales are rarely sighted at sea, precluding any reliable estimation of abundance.

Humpback whales (*Megaptera novaeangliae)* are highly migratory animals that travel seasonally between low latitude breeding grounds and circumpolar feeding grounds (Map 36). They are probably the best-known Mysticeti because they tend to breed in low latitude coastal or inshore waters, providing unique opportunity for detailed ecological and demographic studies. Consequently, their population structure is well understood and seven breeding stocks are clearly defined for the Southern Hemisphere (Leaper *et al.* 2008). However, the summer distribution of those breeding stocks when whales are in the feeding grounds remains the subject of intensive research (Gales *et al.* 2011). Like fin whales, humpback whales feed on krill around the Antarctic continent. High densities are found around the Antarctic Peninsula, in the southern Indian Ocean, and north of the Ross Sea and lower numbers occur in the South Pacific (see Branch 2011). Catches were also lower in the eastern South Pacific and the South Atlantic than elsewhere (Map 37). The past abundance was positively related to the extent of the seasonal marginal sea ice zone (Cotté & Guinet 2011). Humpback whale populations of the Southern Ocean are increasing at rates of 4–10% per annum depending on the breeding stock. The current total population is estimated to be more than 55,000 (Branch 2011).

Southern right whales (*Eubalaena australis*) are the only members of the Balaenidae family in the Southern Ocean. They breed in warm and temperate waters around continental and island coastlines. Breeding populations are reported off South Africa, Australia/New Zealand, and the eastern coast of South America (Leaper *et al.* 2008); a small population occurs also off Chile.

Photo 4 Humpback whale, *Megaptera novaeangliae,* eastern Weddell Sea, *Polarstern*, ANT XXIV-2 (ANDEEP-SYSTCO). Image © Henri Robert, RBINS.

While recent sightings are rare (Map 38), they indicate summer occurrence in sub-Antarctic waters at around 40–50°S along the sub-Antarctic front in the southern Indian Ocean and south Atlantic, but also further south (55–65°S) in the southwest Atlantic and southern Indian Ocean. Their diet is entirely zooplanktonic and includes copepods and krill. Being slow swimmers that float when killed, southern right whales were the first large whales to be hunted well before the onset of industrial whaling and as such it became nearly extinct in the 1930s. It has been protected since then, although it was illegally hunted by the Soviet whaling fleet in the 1960s. The current population is around 12,000 and increases at a rate of ca. 7% per annum.

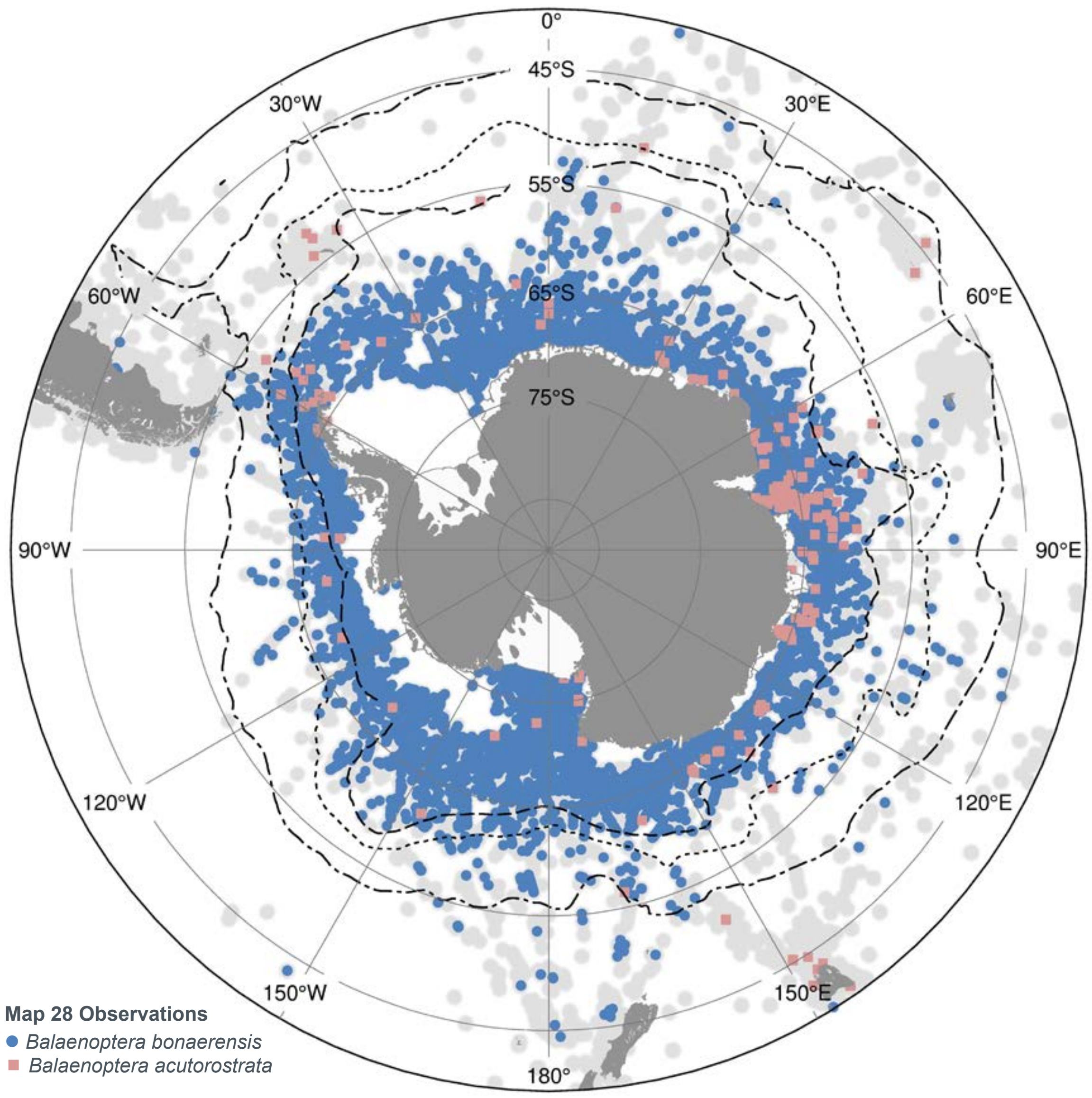
Sperm whales (*Physeter macrocephalus)* are the largest of the *Odontoceti* and the deepest cetacean divers. Present in all the world's oceans (Map 39), they feed mostly on squids but also on mesopelagic and large demersal fish, such as toothfish and sharks. Their large size and distinctive blow make them conspicuous at sea, resulting in numerous recent sightings as seen on the map. They are the most sexually dimorphic cetaceans; mature males attain a much larger size and weight than females (Whitehead 2002). There is a clear sexual segregation in at-sea distribution. Females generally occur north of 40°S, while males inhabit the higher latitudes. Mature males are found as far south as 74°S in the Ross Sea and regularly south of 66°S. Males go back to warmer waters to mate but the timing of their migration is not well understood. Sightings around the Kerguelen and Crozet Plateaus indicate substantial interactions with longline fishery of Patagonian toothfish *Dissostichus eleginoides* (Chazeau *et al.* 2012). Sperm whales were exploited at levels comparable to other great whales. Catches occurred in the frontal zones of the ACC, and around the continent at 55°–65°S during the era of industrial whaling after World War II (Map 40). Spermaceti, the valuable oil contained in their colossal head, was the primary goal of the 19th century whalers, along with the blubber, while the whole animal was used during the 20th century. The current population estimates of sperm whales south of 60°S is around 10,000, while it comprises several hundreds of thousands of individuals worldwide, with no clear information on population trends (Branch & Butterworth 2001, van Waerebeek *et al.* 2004).

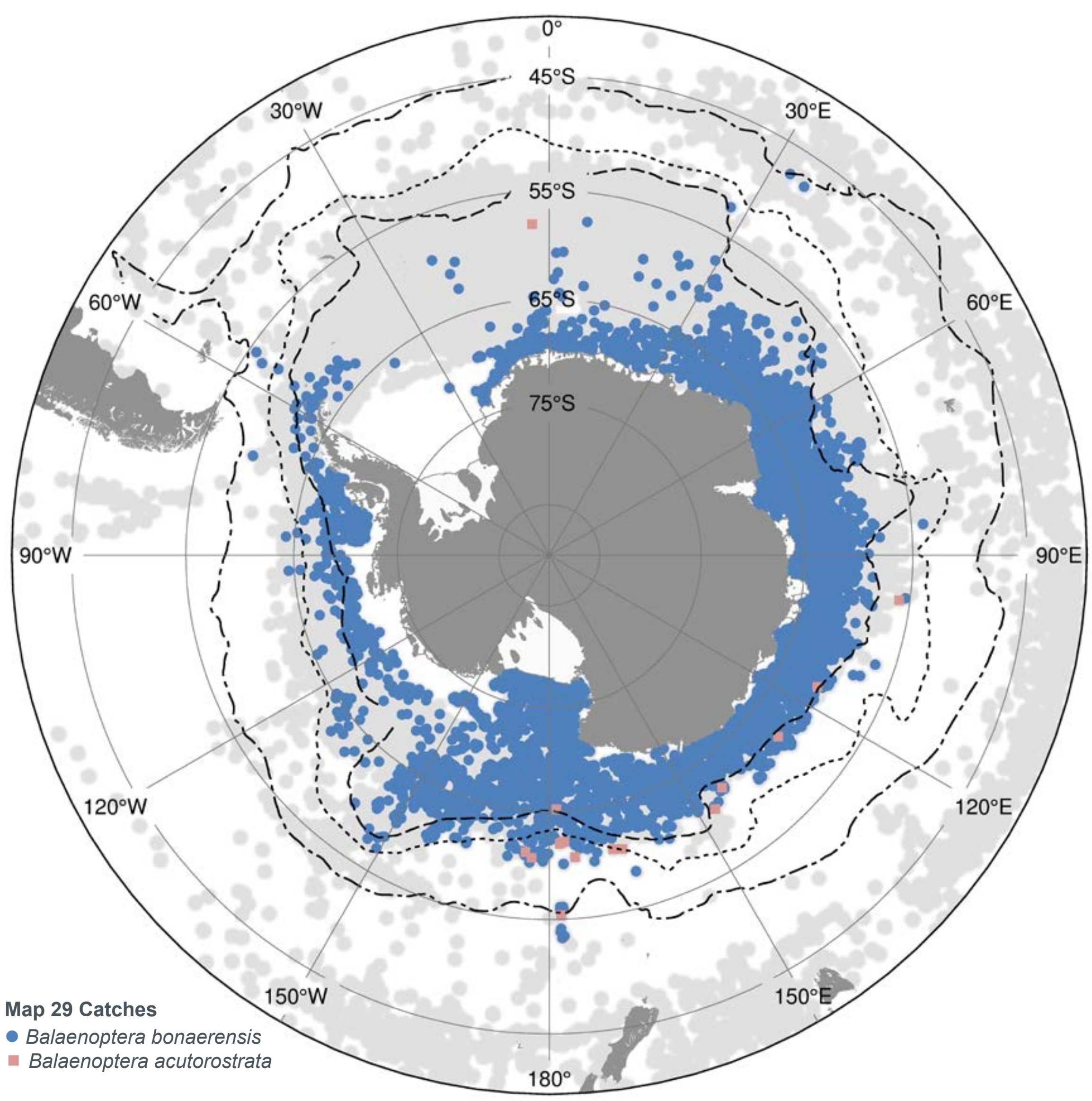
Killer whales (*Orcinus orca)* are present in all of the world's oceans (Map 41). They have been divided into several ecotypes in each hemisphere. In the Southern Ocean, four types have been described based on morphology, diet and distribution but their classification as "ecotypes" (Pitman *et al.* 2011) instead of "morphotypes" is disputed (de Bruyn *et al.* 2013). In the Southern Ocean, killer whales feed with various degrees of specialization on a range of prey including fish, penguins, seals and cetaceans and have no known predators. Map 41 does not distinguish between eco/morpho-types, but shows that killer whales inhabit different habitats (Antarctic pack ice, open ocean, coastlines and plateaus of sub-Antarctic islands). Killer whales have been marginally caught by Soviet whaling ships in the 1980s until they were protected by the IWC moratorium. As for sperm whales, killer whale sightings around the Kerguelen and Crozet islands were made by fishery observers, while the whales were depredating longline fisheries of Patagonian toothfish (Chazeau *et al.* 2012; Map 41). In the 1990s the Crozet population suffered from intentional mortality by poaching ships. Sightings around Crozet, obtained from land-based observations or during fishing operations, allowed the scientific community to estimate the population decline at around 60% (Guinet & Tixier 2011). The global population south of the APF is around 80,000.

Long finned pilot whales (*Globicephala melas edwardii)* are squid feeders that occur in the whole Southern Ocean, in sub-Antarctic waters but also around the continent as far south as 66°S (Map 42). Observations are less frequent in the eastern south Atlantic and the western south Pacific; only a few sightings were reported north of the Ross Sea (van Waerebeek *et al.* 2004). These whales may occur in large pods, a feature also observed in the North Atlantic subspecies *G. melas melas*. They have not been exploited and their population is estimated around 200,000 south of the Polar Front (Kasamatsu & Joyce 1995).

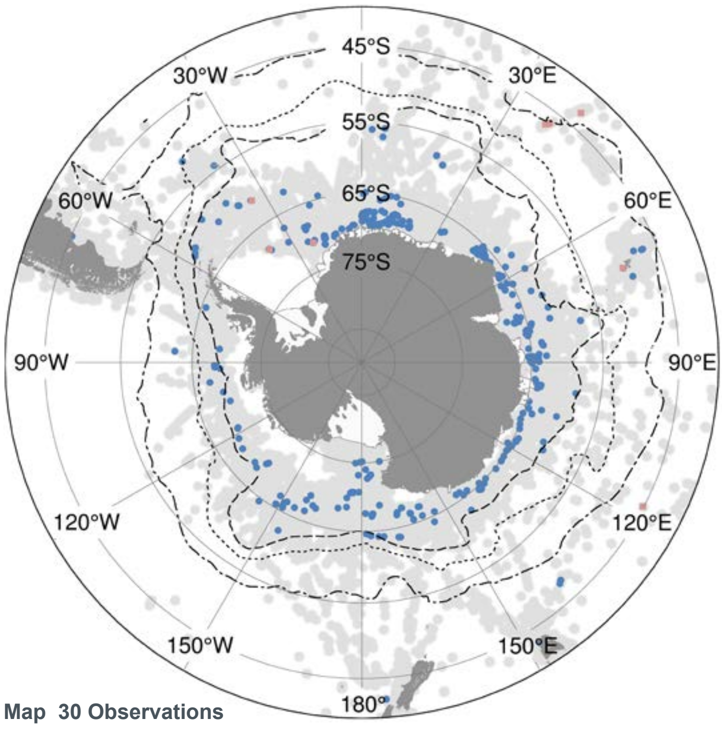
Three dolphin species of the genus (*Lagenorhynchus*) occur in the Southern Ocean (Map 43). Hourglass dolphins (*L. cruciger*) are the only small dolphins occurring in Antarctic waters. They have a circumpolar distribution and are found in the open waters of the ACC, but also over the circumpolar shelf slope and close to sea ice. Feeding on fish, squid and crustaceans, the population is estimated at 140,000 (Kasamatsu & Joyce 1995). Dusky dolphins (*L. obscurus*) do not generally venture south of the APF. They are mainly observed in coastal waters around the southern tip of South America (with occurrences in the Drake Passage and around the Falklands Islands), New Zealand and Tasmania (Map 43). Some rare sightings were made around oceanic islands in the southern Indian Ocean and south Atlantic (van Waerebeek *et al.* 2004). Peale's dolphins (*L. australis*) are confined to coastal waters around southern Chile and southern Argentina, with some incursions in the Drake Passage as far south as 60°S (Map 43). They feed on fish, squid and octopus associated with kelp forest. Their propensity to stay inshore made this species a target for fishermen for bait for crab fishery, a practice that is now prohibited but may still occur illegally (Hammond *et al.* 2008a).

Other small Odontoceti of the Southern Ocean include Commerson's dolphins (*Cephalorhyncus commersonii)*, southern right whale dolphins (*Lissodelphis peronei)*, and spectacled porpoises (*Phocoena dioptrica*). Commerson's dolphins are an inshore species that occurs in two morphologically and genetically distinct populations (Map 44). The first one is located along the east coast of southern South America and around the Falklands Islands, and

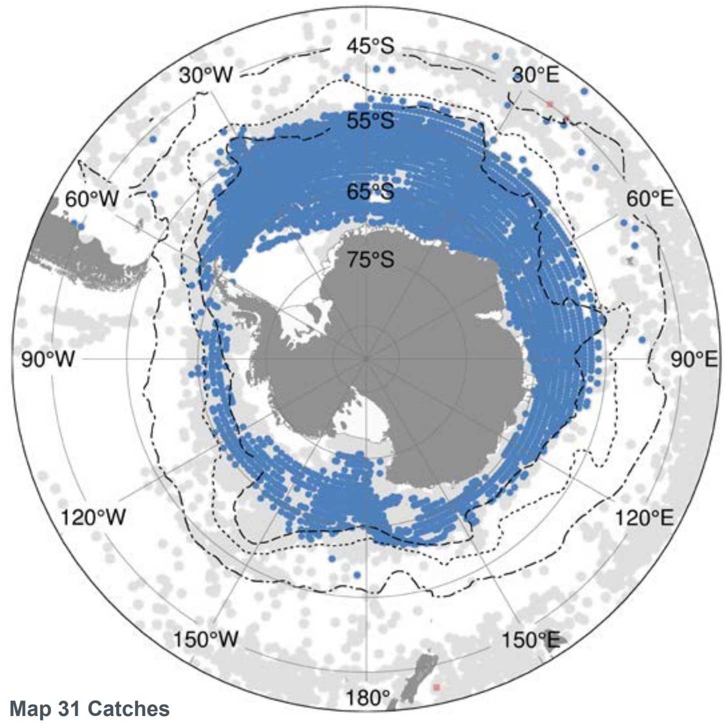




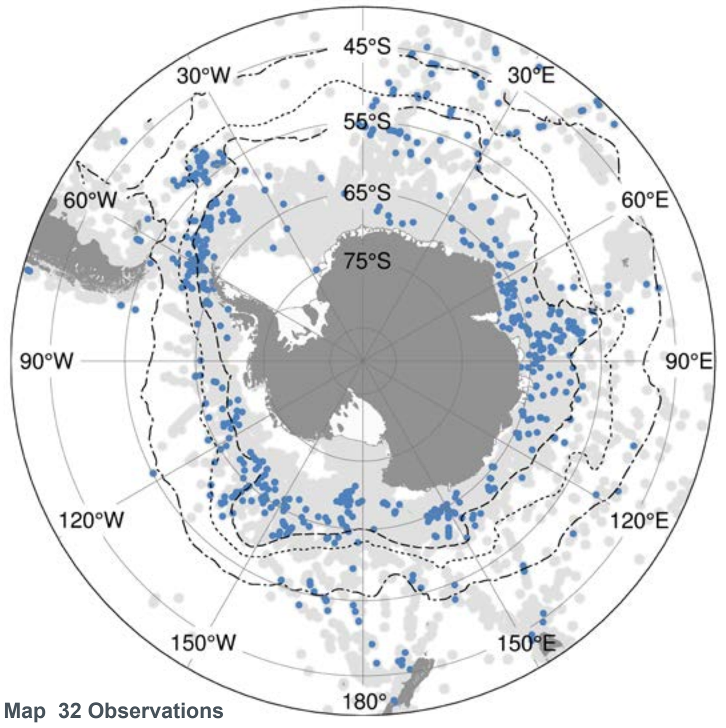
Whales and Dolphins Maps 28–29 Map 28. Observations of Antarctic Minke Whales: *Balaenoptera bonaerensis* and Common Minke Whales: *B. acutorostrata*. Map 29. Catches of Antarctic and Common Minke Whales (Allison 2013).



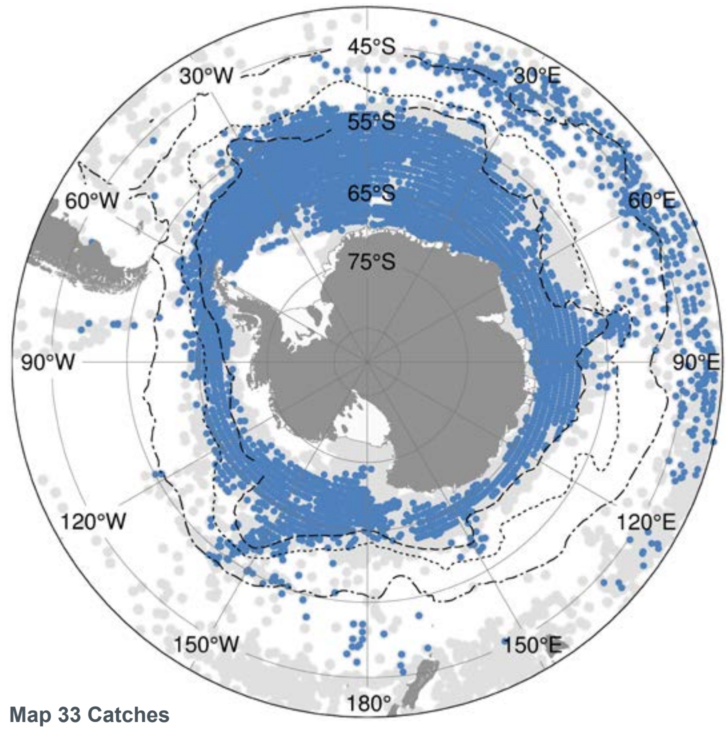
Map 30 Observations
● *Balaenoptera musculus intermedia*
■ *Balaenoptera musculus brevicauda*



Map 31 Catches
● *Balaenoptera musculus intermedia*
■ *Balaenoptera musculus brevicauda*



Map 32 Observations
● *Balaenoptera physalus*



Map 33 Catches
● *Balaenoptera physalus*

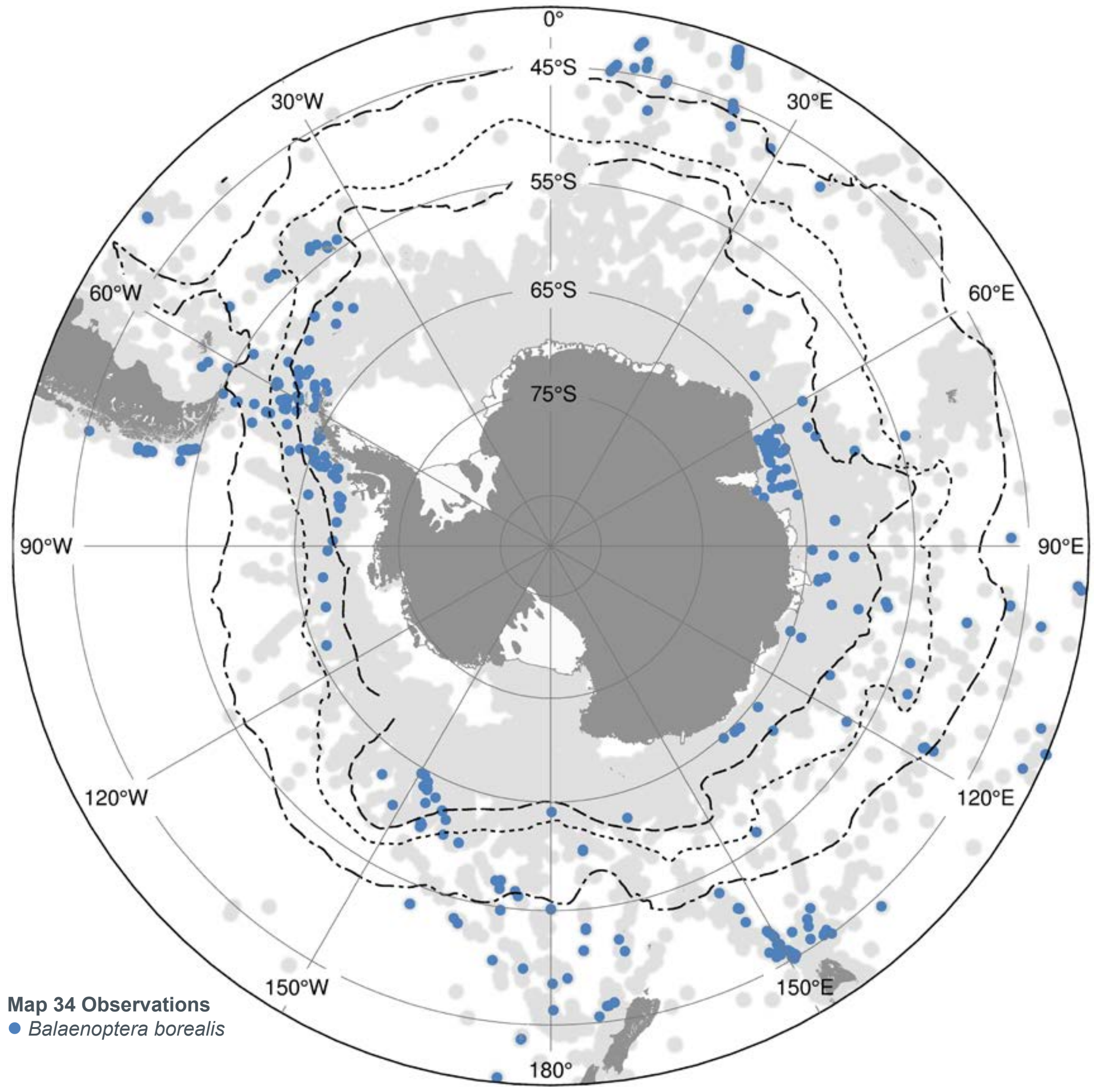
Whales and Dolphins Maps 30–33 Map 30. Observations of Antarctic Blue Whales: *Balaenoptera musculus intermedia* and Pygmy Blue Whales: *B. musculus brevicauda*. Map 31. Catches of Antarctic and Pygmy Blue Whales (Allison 2013). Map 32. Observations of Fin Whales: *B. physalus*. Map 33. Catches of Fin Whales (Allison 2013).

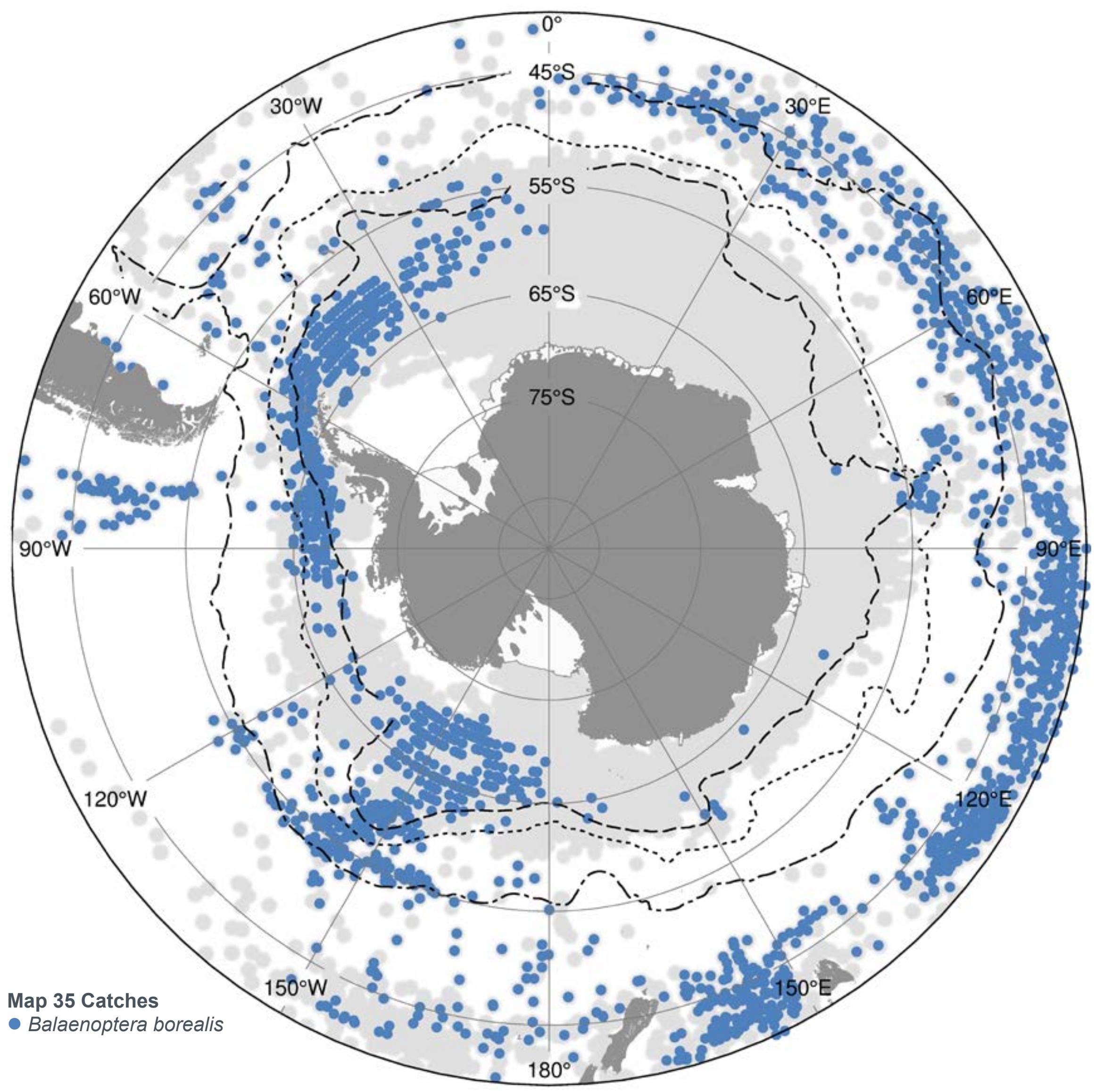
rarely spreads into the Drake Passage (van Waerebeek *et al.* 2004). The second population occurs around the Kerguelen Islands. As with their northern counterpart, southern right whale dolphins have no dorsal fin. This small species occurs in deep waters between 30°S and 60°S, off the Chilean coastline where it is very common, but also in circumpolar oceanic waters, preying on fish and squid (Map 44). Spectacled porpoises are rarely sighted at sea. They occur both along coastlines of sub-Antarctic islands, and in the open ocean as far south as 64°S. Although this is not visible on map 44, spectacled porpoises can also be seen off the east coast of southern South America. Threats include accidental catches in gillnets or trawls and capture for crab baits (Hammond *et al.* 2008b).

Beaked whales are probably the most difficult whales to identify at sea at the species level because of poorly understood field marks, and similarities in morphology among some species. This is further complicated by their often elusive behaviour linked to their deep diving habits. Some species are rarely if ever sighted a sea, and so the only information is provided by strandings. As a result, their distribution range is poorly known or uncertain (MacLeod *et al.* 2006). Because they are rare, sightings for the three *Mesoplodon* species *M. bowdini, M. hectorii*, and *M. densirostris*, as well as for shepherd's beaked whale (*Tasmacetus sheperdi*) were not included in the Atlas.

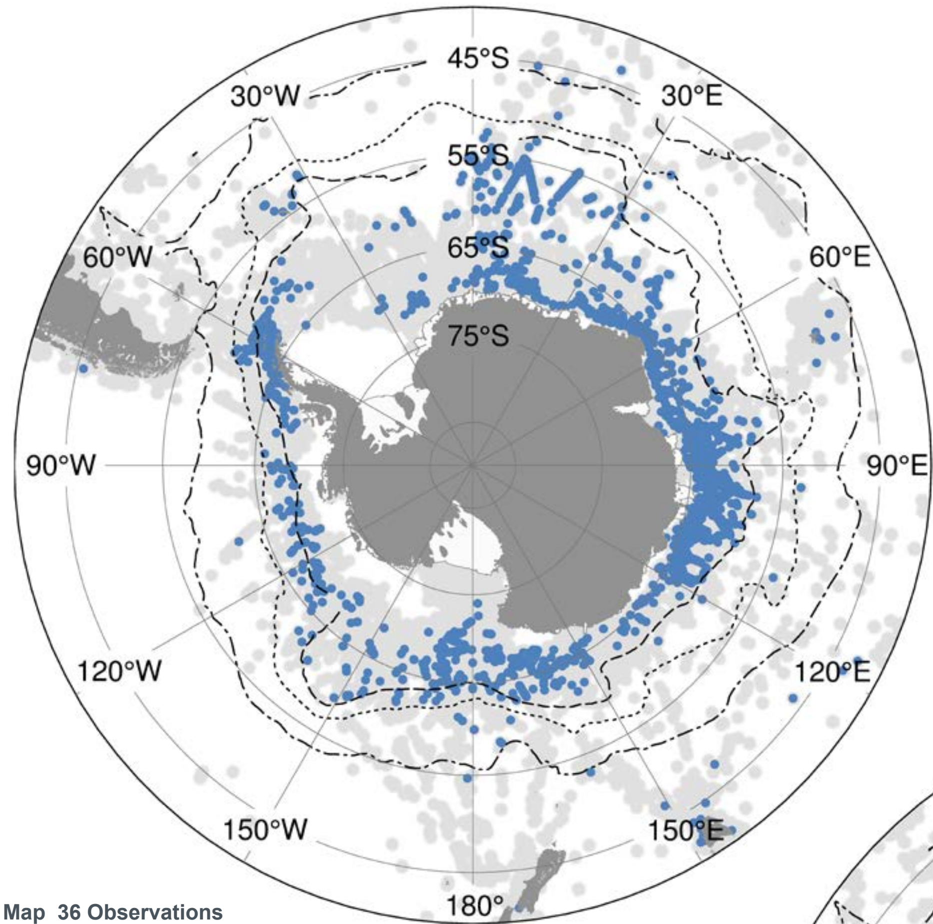
The southern bottlenose whale (*Hyperoodon planifrons*) is the most abundant Ziphiidae species in the Southern Ocean, with an estimated 54,000–72,000 individuals south of 60°S (Branch & Butterworth 2001). It has a circumpolar distribution and ranges from sub-tropical waters (30°S) to the sea-ice edge, but is most common between 58°S and 70°S in summer (Map 45). The whales show a strong seasonality as they move northwards of the Antarctic continent at the end of summer. Preying on squid, they are most commonly encountered over deep waters (deeper than 1000 m; van Waerebeek *et al.* 2004). Arnoux's beaked whales (*Berardius arnuxii)* and their Northern Hemisphere counterparts Baird's beaked whale (*B. bairdii)* are the largest among the beaked whales. Arnoux's beaked whales are found in the whole Southern Ocean from 30°S to the Antarctic continent. Many sightings occur along the sea ice edge or within sea-ice as far south in the Ross Sea (Map 45). With breath holding capacities exceeding an hour, Arnoux's beaked whales most probably feed on squid at great depths (Hobson & Martin 1996). No abundance estimates are available but they are much rarer than the sympatric southern bottlenose whales (van Waerebeek *et al.* 2004). Cuvier's beaked whales (*Ziphius cavirostris)* are the most widespread beaked whales, occurring in all oceans and seas including the Mediterranean Sea. In the Southern Ocean, sightings are few but they have been reported as far south as 65°S (Map 45). They are deep divers, generally exploring waters deeper that 1000 m, presumably feeding on bathy-pelagic prey, such as squid (van Waerebeek *et al.* 2004). Little is known about their abundance in the Southern Ocean, but they probably stand among the most common beaked whales worldwide (Taylor *et al.* 2008). Both Gray's beaked whales (*Mesoplodon grayi)* and strap-toothed beaked whales (*M. layardii)* are distributed in sub-Antarctic and Antarctic waters all around the continent (Map 45). Gray's beaked whales were sighted further south along the coastline (Antarctic Peninsula).

Both species feed on oceanic and bathy-pelagic squid. No abundance data are available, but based on the number of strandings (particularly around New Zealand for *M. grayii*), both species are probably not as uncommon as other species of the *Mesoplodon* genus (MacLeod *et al.* 2006).

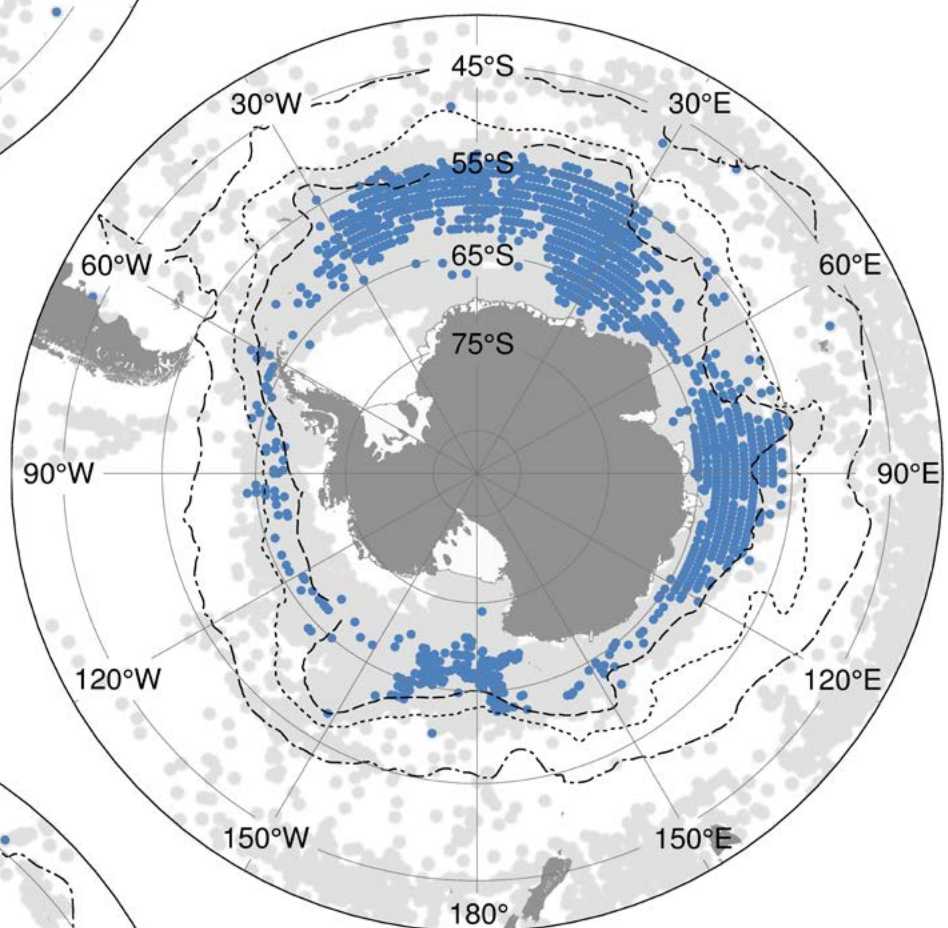




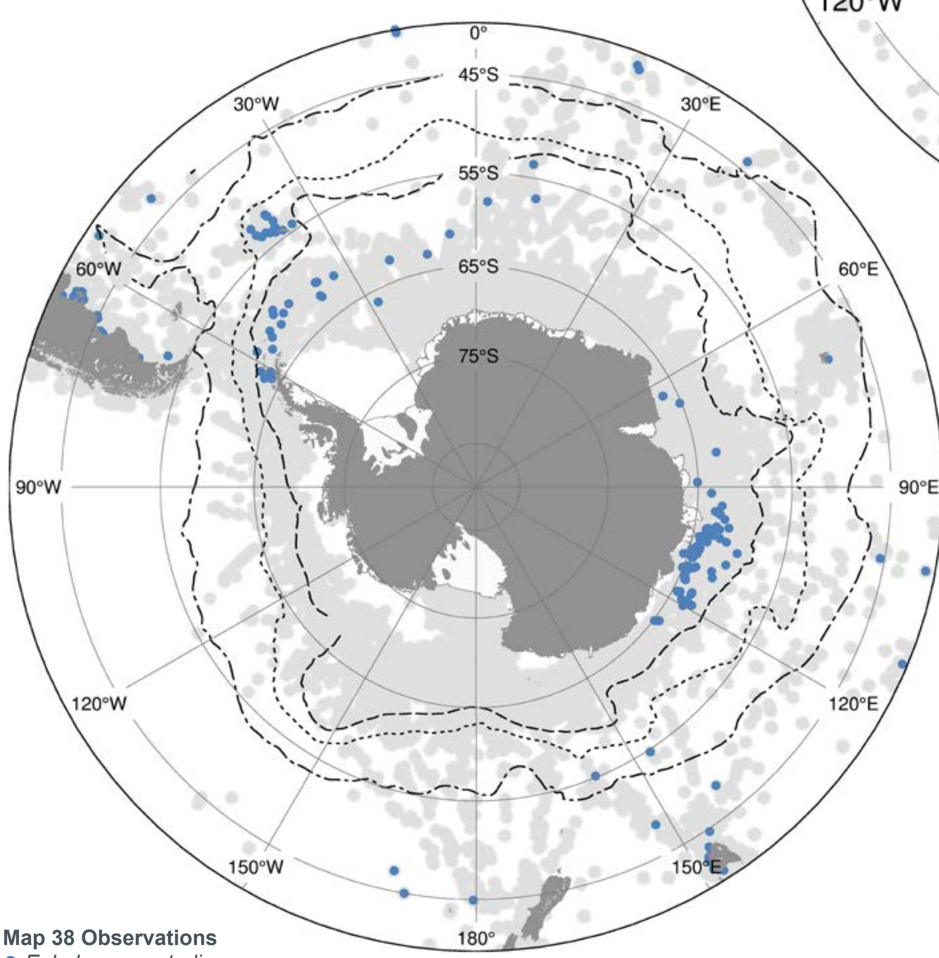
Whales and Dolphins Maps 34–35 Map 34. Observations of Sei Whales: *Balaenoptera borealis*. Map 35. Catches of Sei Whales (Allison 2013).



Map 36 Observations
● *Megaptera novaeangliae*

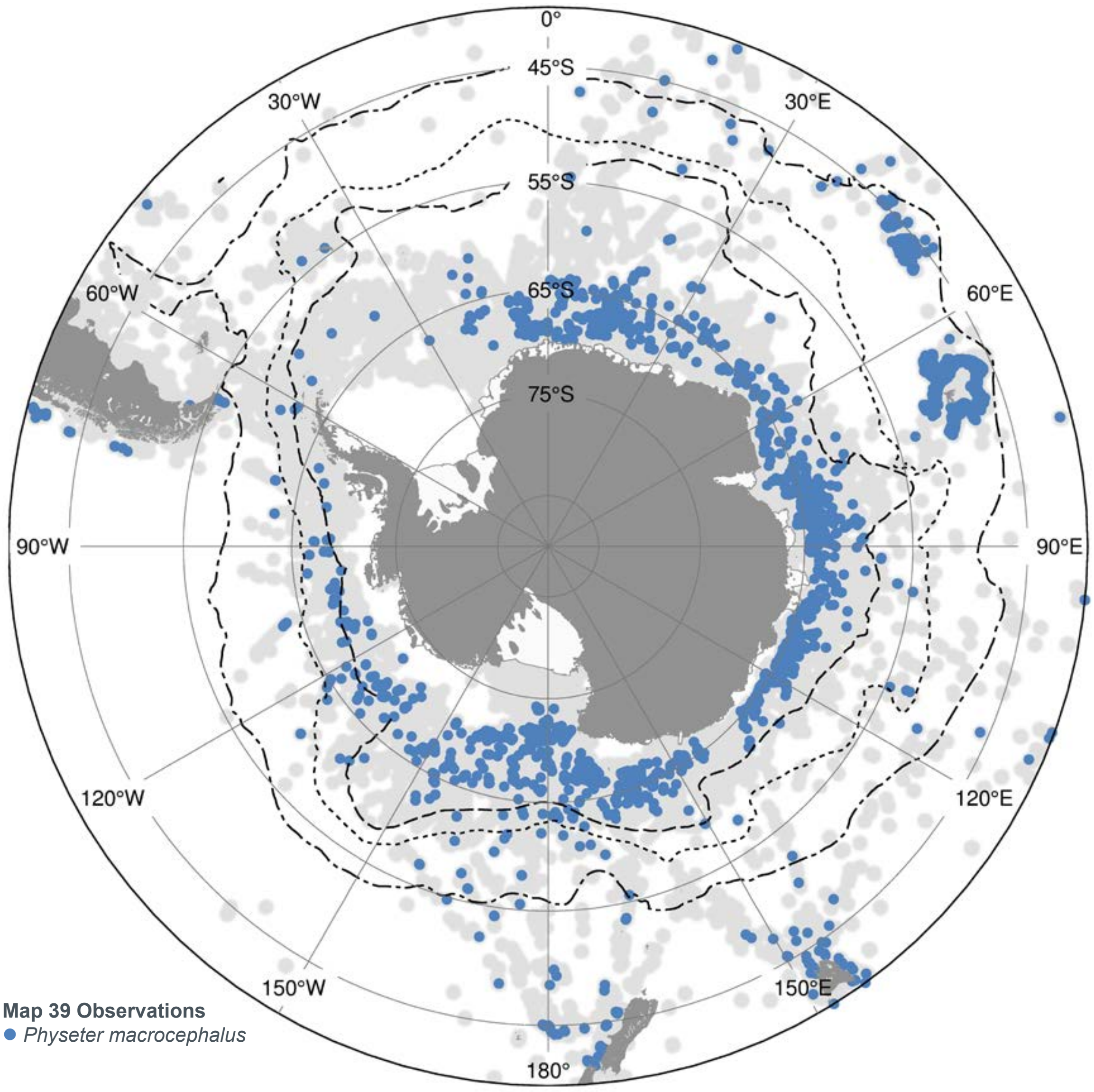


Map 37 Catches
● *Megaptera novaeangliae*

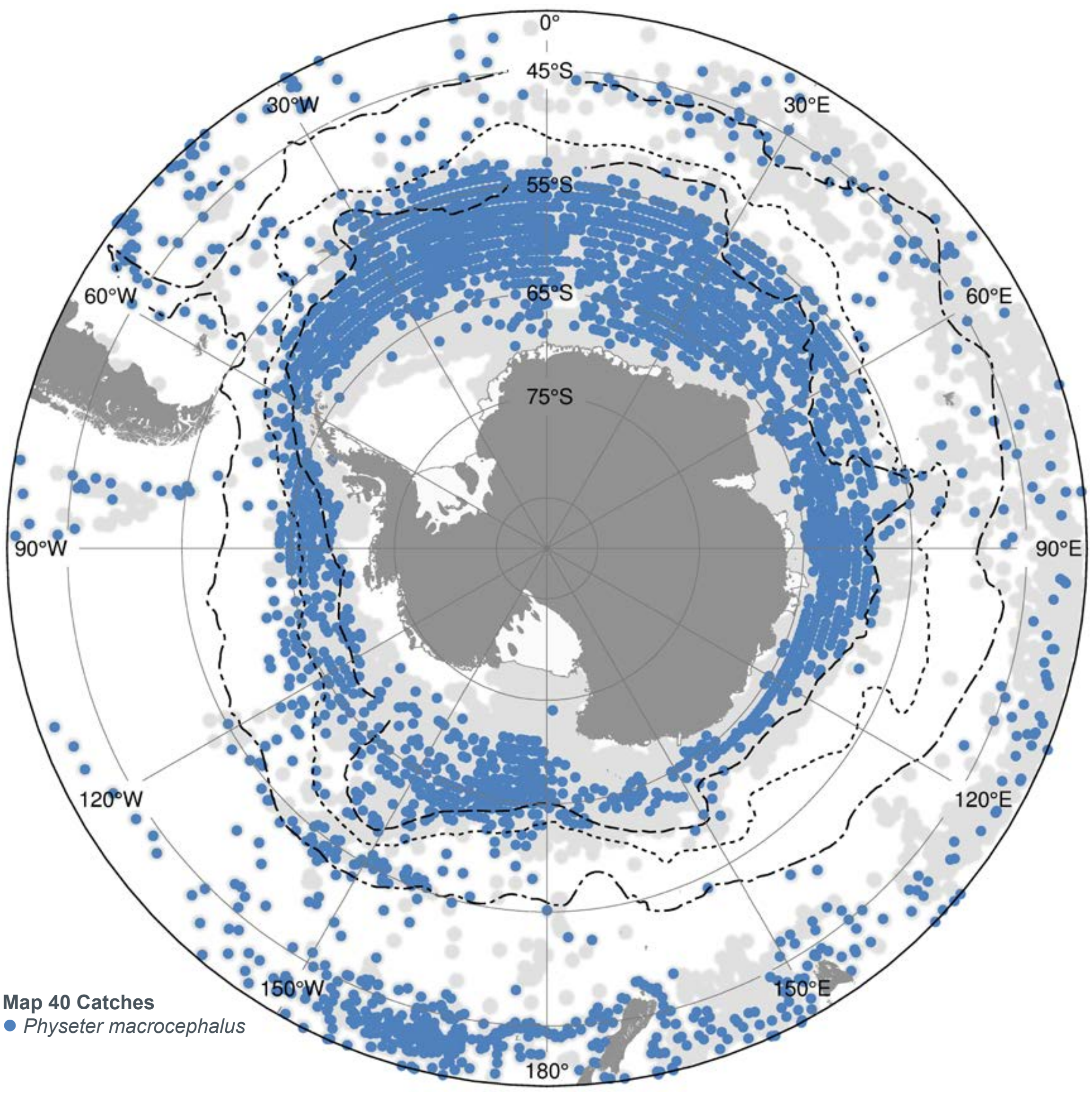


Map 38 Observations
● *Eubalaena australis*

Whales and Dolphins Maps 36–38 Map 36. Observations of Humpback Whales: *Megaptera novaeangliae*. Map 37. Catches of Humpback Whales (Allison 2013). Map 38. Observations of Southern Right Whales: *Eubalaena australis*.

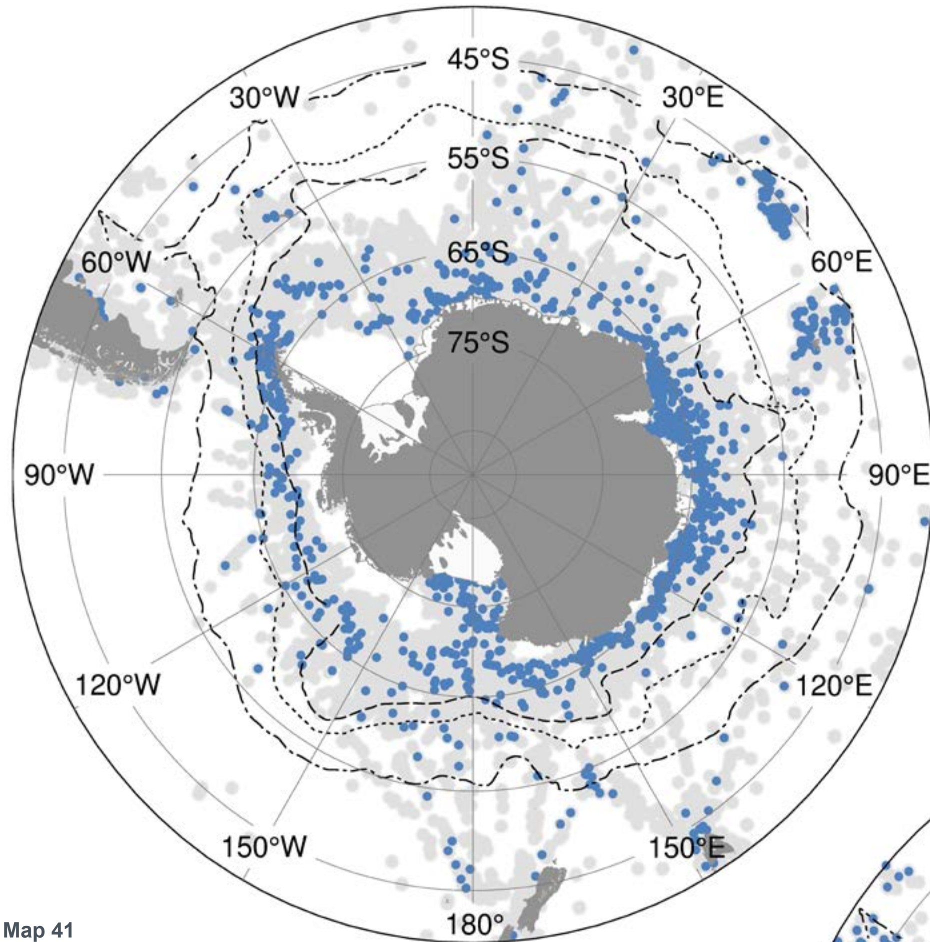


Map 39 Observations
● *Physeter macrocephalus*

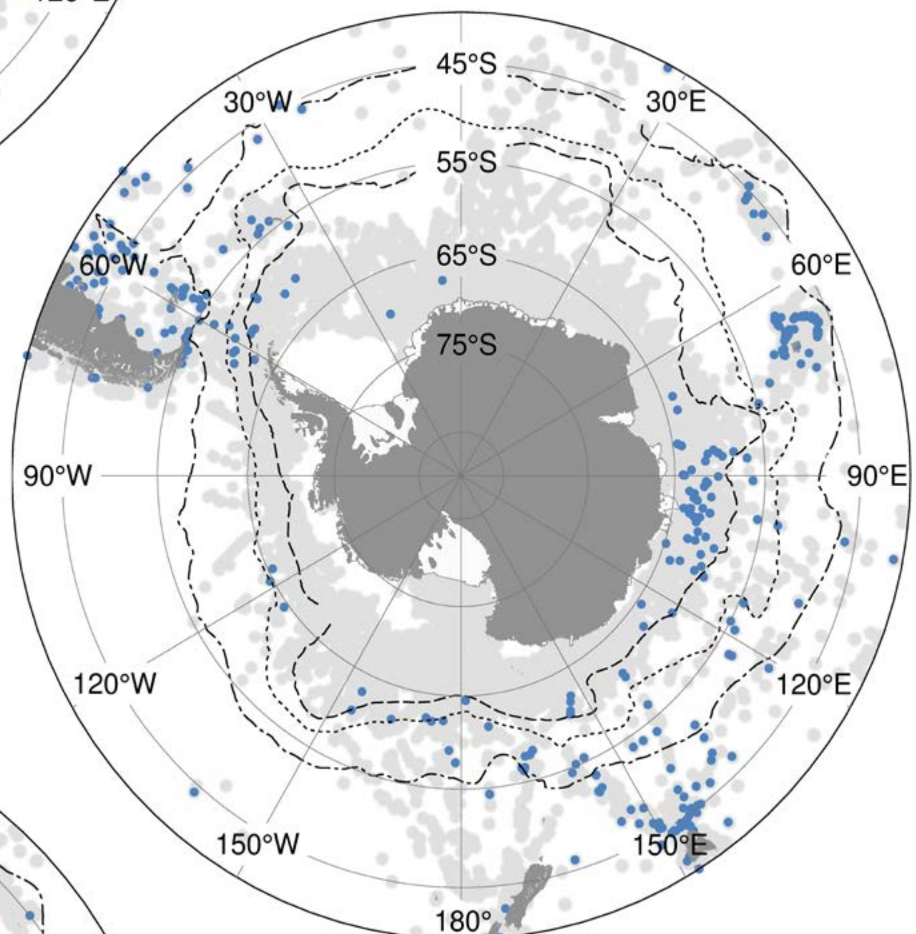


Map 40 Catches
● *Physeter macrocephalus*

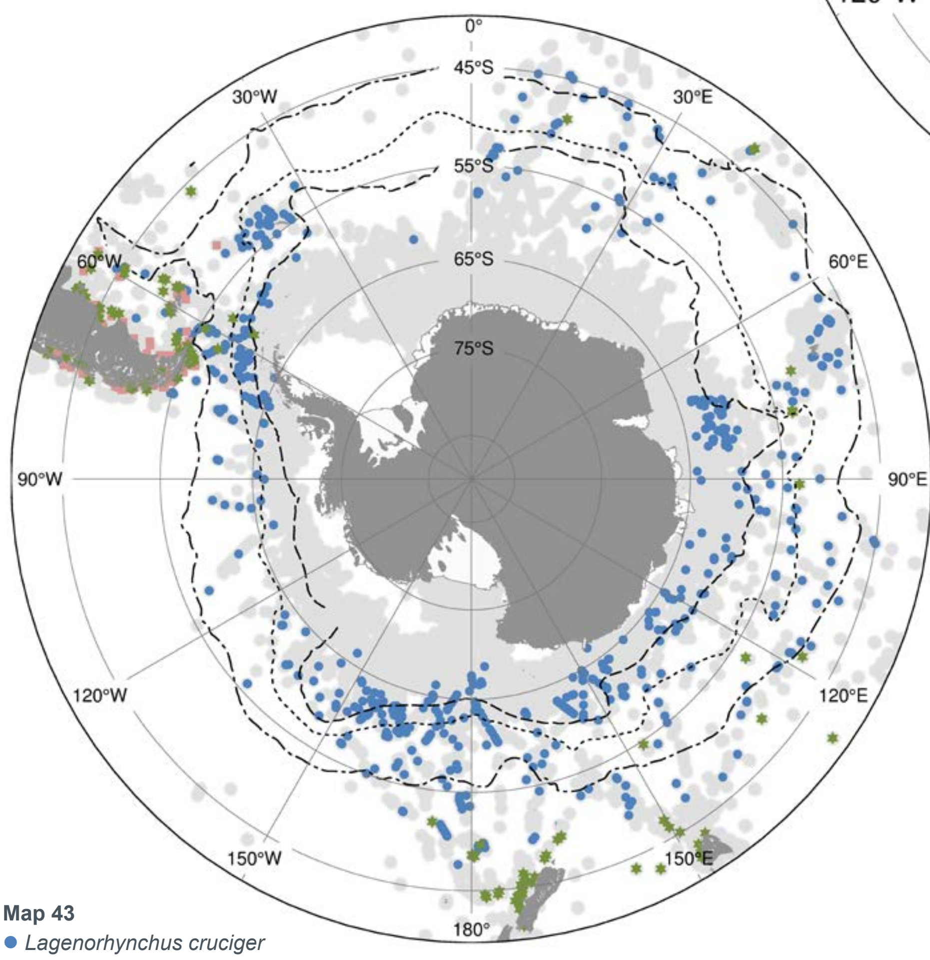
Whales and Dolphins Maps 39–40 Map 39. Observations of Sperm Whales: *Physeter macrocephalus*. Map 40. Catches of Sperm Whales (Allison 2013).



Map 41
- *Orcinus orca*



Map 42
- *Globicephala melas edwardii*



Map 43
- *Lagenorhynchus cruciger*
- *Lagenorhynchus australis*
- *Lagenorhynchus obscurus*

Whales and Dolphins Maps 41–43 Map 41. Killer Whale: *Orcinus orca*. Map 42. Southern Longfinned Pilot Whale: *Globicephala melas edwardii*. Map 43. Hourglass dolphins: *Lagenorhynchus cruciger*, Peale's dolphins: *L. australis*, Dusky dolphins: *L. obscurus*.

Acknowledgments

This is CAML contribution # 142. Part of the cetacean sightings data in the atlas were obtained from the international surveys carried out under the auspices of the International Whaling Commission from 1978/79 to 2009/10, most recently known as the Southern Ocean Whale and Ecosystem Research Programme or SOWER cruises (see www.iwc.int/sower). The catch data were obtained from the IWC's catch database. The sightings and catch data were kindly provided by the IWC Secretariat (secretariat@iwc.int) and extracted from its sightings (DESS version 3.64, April 2011) and catch (Version 5.5, February 2013) databases.

References

Acevedo, J., Martinez, F., 2013. Residence of *Hydrurga leptonyx* in Magallanes: a potential Subantarctic population that inhabit in Chile? *Polar Biology*, **36**, 453–456. doi:10.1007/s00300-012-1275-3.

Ainley, D.G., 2002. The Adélie Penguin: Bellwether of Climate Change. New York: Columbia University Press, 310 pp.

Allison, C., 2013. IWC individual catch database Version 5.5; Accessed on 12 February 2013

Bailleul, F., Charrassin, J.B., Monestiez, P., Roquet, F., Biuw, M., Guinet, C., 2007. Successful foraging zones of southern elephant seals from the Kerguelen Islands in relation to oceanographic conditions. *Philosophical Transactions of the Royal Society B-Biological Sciences*, **362**, 2169–2181. doi:10.1098/rstb.2007.2109.

Banks, J., Van Buren, A., Cherel, Y., Whitfield, J.B., 2006. Genetic evidence for three species of rockhopper penguins, *Eudyptes chrysocome*. *Polar Biology*, **30**, 61–67. doi: 10.1007/s00300-006-0160-3.

Beauplet, G., Dubroca, L., Guinet, C., Cherel, Y., Dabin, W., Gagne, C., Hindell, M.A., 2004. Foraging ecology of sub-Antarctic fur seals *Arctocephalus tropicalis* breeding on Amsterdam Island: seasonal changes in relation to maternal characteristics and pup growth. *Marine Ecology Progress Series*, **273**, 211–225.

Bester, M.N., Hofmeyr, G.J.G., 2007. Ross Seal. In: Riffenburgh, B. (ed.). Encyclopedia of the Antarctic. New York: Taylor & Francis Books Inc., pp. 815–816.

Bester, M.N., Roux, J.P., 1986. Summer presence of leopard seals *Hydrurga leptonyx* at the Courbet Peninsula, Iles Kerguelen. *South African Journal of Antarctic Research*, **16**, 29–32.

Biuw, M., Boehme, L., Guinet, C., Hindell, M., Costa, D., Charrassin, J.B., Roquet, F., Bailleul, F., Meredith, M., Thorpe, S., Tremblay, Y., McDonald, B., Park, Y.H., Rintoul, S.R., Bindoff, N., Goebel, M., Crocker, D., Lovell, P., Nicholson, J., Monks, F., Fedak, M.A., 2007. Variations in behavior and condition of a Southern Ocean top predator in relation to in situ oceanographic conditions. *Proceedings of the National Academy of Sciences of the United States of America*, **104**, 13705–13710. doi:10.1073/pnas.0701121104.

Borboroglu, G.P., Boersma, P.D., 2013. Penguins - natural history and conservation. Seattle: University of Washington Press, 360 pp.

Bost, C.A., Charrassin, J.B., Clerquin, Y., Ropert-Coudert, Y., Le Maho, Y., 2004. Exploitation of distant marginal ice zones by king penguins during winter. *Marine Ecology-Progress Series*, **283**, 293–297. doi:10.3354/meps283293.

Bost, C.A., Georges, J.Y., Guinet, C., Cherel, Y., Pütz, K., Charrassin, J.B., Handrich, Y., Zorn, T., Lage, J., Le Maho, Y., 1997. Foraging habitat and food intake of satellite-tracked king penguins during the austral summer at Crozet Archipelago. *Marine Ecology-Progress Series*, **150**, 21–33. doi:10.3354/meps150021.

Boyd, I.L., Bowen, W.D., Iverson, S.J., 2010. Marine Mammal Ecology and Conservation: A Handbook of Techniques. Oxford: Oxford University Press, 450 pp.

Bradshaw, C.J.A., Hindell, M.A., Sumner, M.D., Michael, K.J., 2004. Loyalty pays: potential life history consequences of fidelity to marine foraging regions by southern elephant seals. *Animal Behaviour*, **68**, 1349–1360. doi:10.1016/j.anbehav.2003.12.013.

Branch, T.A., 2011. Humpback abundance south of 60°S from three complete circumpolar sets of surveys. *Journal of Cetacean Research and Management (Special Issue)*, **3**, 53–69.

Branch, T.A., Butterworth, D.S., 2001. Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. *Journal of Cetacean Research and Management*, **3**, 251–270.

Branch, T.A., Matsuoka, K., Miyashita, T., 2004. Evidence for increases in Antarctic blue whales based on Bayesian modelling. *Marine Mammal Science*, **20**, 726–754. doi:10.1111/j.1748-7692.2004.tb01190.x.

Branch, T.A., Stafford, K.M., Palacios, D.M., Allison, C., Bannister, J.L., Burton, C.L.K., Cabrera, E., Carlson, C.A., Galletti Vernazzani, B., Gill, P.C., Hucke-Gaete, R., Jenner, K.C.S., Jenner, M.N.M., Matsuoka, K., Mikhalev, Y.A., Miyashita, T., Morrice, M.G., Nishiwaki, S., Sturrock, V.J., Tormosov, D., Anderson, R.C., Baker, A.N., Best, P.B., Borsa, P., Brownell Jr, R.L., Childerhouse, S., Findlay, K.P., Gerrodette, T., Ilangakoon, A.D., Joergensen, M., Kahn, B., Ljungblad, D.K., Maughan, B., McCauley, R.D., McKay, S., Norris, T.F., Oman, W., Dolphin Research, G., Rankin, S., Samaran, F., Thiele, D., Van Waerebeek, K., Warneke, R.M., 2007. Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Review*, **37**, 116–175. doi:10.1111/j.1365-2907.2007.00106.x.

Burns, J.M., Costa, D.P., Fedak, M.A., Hindell, M.A., Bradshaw, C.J.A., Gales, N.J., McDonald, B., Trumble, S.J., Crocker, D.E., 2004. Winter habitat use and foraging behavior of crabeater seals along the Western Antarctic Peninsula. *Deep-Sea Research Part II-Topical Studies in Oceanography*, **51**, 2279–2303.

Chazeau, C., Gasco, N., Martin, A., Pruvost, P., Duhamel, G., 2012. Pecheker dataset, Muséum National d'Histoire Naturelle, Paris. Accessed on 2 July 2012.

Clapham, P.J., Baker, C.S., 2002. Modern whaling. In: Perrin, W.F., Würsig, B., Thewissen, J.G.M. (eds.). Encyclopedia of Marine Mammals. New York: Academic Press, pp. 1328–1332.

Clarke, J., Emmerson, L.M., Otahal, P., 2006. Environmental conditions and life history constraints determine foraging range in breeding Adélie penguins. *Marine Ecology-Progress Series*, **310**, 247–261. doi:10.3354/meps310247.

Cotté, C., Guinet, C., 2011. The importance of a seasonal ice zone and krill density in the historical abundance of humpback whale catches in the Southern Ocean. *Journal of Cetacean Research and Management (Special Issue)*, **3**, 101–106.

Cotté, C., Park, Y.-H., Guinet, C., Bost, C.A., 2007. Movements of foraging king penguins through marine mesoscale eddies. *Proceedings of the Royal Society B: Biological Sciences*, **274**, 2385–2391. doi:10.1098/rspb.2007.0775.

Cottin, M., Raymond, B., Kato, A., Amélineau, F., Le Maho, Y., Raclot, T., Galton-Fenzi, B., Meijers, A., Ropert-Coudert, Y., 2012. Foraging strategies of male Adélie penguins during their first incubation trip in relation to environmental conditions. *Marine Biology*, **159**, 1843–1852. doi:10.1007/s00227-012-1974-x.

Croxall, J.P., Silk, J.R.D., Phillips, R.A., Afanasyev, V., Briggs, D.R., 2005. Global circumnavigations: tracking year-round ranges of nonbreeding albatrosses. *Science*, **307**, 249–250. doi: 10.1126/science.1106042.

de Bruyn, P.J.N., Tosh, C.A., Terauds, A., 2013. Killer whale ecotypes: is there a global model? *Biological Reviews*, **88**, 62–80. doi: 10.1111/j.1469-185X.2012.00239.x.

Egevang, C., Stenhouse, I.J., Phillips, R.A., Petersen, A., Fox, J.W., Silk, J.R.D., 2010. Tracking of Arctic terns *Sterna paradisaea* reveals longest animal migration. *Proceedings of the National Academy of Sciences*, **107**, 2078–2081. doi:10.1073/pnas.0909493107.

Flood, B., Fisher, A., 2011. Multimedia identification guide to North Atlantic Seabirds: Storm-petrels & Bulwer's Petrel. Penryn, Cornwall: Pelagic Birds & Birding Multimedia Identification Guides, 212 pp.

Gales, N., Bannister, J.L., Findlay, K., Zerbini, A., Donovan, G.P., 2011. Humpback Whales: Status in the Southern Hemisphere. *The Journal of Cetacean Research and Management (Special Issue)*, **3**, 1–317.

Guinet, C., Tixier, P., 2011. Crozet: killer whales in a remote but changing environment. *Journal of the American Cetacean Society*, **40**, 33–38.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S., Wilson, B., 2008a. *Lagenorhynchus australis*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S., Wilson, B., 2008b. *Phocoena dioptrica*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2.

Heerah, K., Andrews-Goff, V., Williams, G., Sultan, E., Hindell, M.A., Patterson, T., Charrassin, J.-B., 2013. Ecology of Weddell seals during winter: Influence of environmental parameters on their foraging behaviour. *Deep-Sea Research Part II-Topical Studies in Oceanography*, **88–89**, 23–33. doi:10.1016/j.dsr2.2012.08.025.

Hobson, R.P., Martin, A.R., 1996. Behaviour and dive times of Arnoux's beaked whales, *Berardius arnuxii*, at narrow leads in fast ice. *Canadian Journal of Zoology*, **74**, 388–393. doi:10.1139/z96-045.

International Whaling Commission, 2012. Annex H – Report of the Sub-Committee on In-Depth Assessment. *Journal of Cetacean Research and Management*, **14**, Supplement April 2013.

Kasamatsu, F., Joyce, G.G., 1995. Current status of Odontocetes in the Antarctic. *Antarctic Science*, **7**, 365–379. doi: 10.1017/S0954102095000514.

Leaper, R., Bannister, J.L., Branch, T.A., Clapham, P., Donovan, G., Matsuoka, K., Reilly, S., Zerbini, A., 2008. A review of abundance, trends and foraging parameters of baleen whales in the Southern Hemisphere. *Paper SC/60/EM3, IWC Scientific Committee*.

MacLeod, C.D., Perrin, W.F., Pittman, R., Barlow, J., Balance, L., D'Amico, A., Gerrodette, T., Joyce, G., , Mullin, K.D., Palka, D.L., Waring, G.T., 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). *Journal of Cetacean Research and Management*, **7**, 271–286.

Murphy, E.J., Watkins, J.L., Trathan, P.N., Reid, K., Meredith, M.P., Thorpe, S.E., Johnston, N.M., Clarke, A., Tarling, G.A., Collins, M.A., Forcada, J., Shreeve, R.S., Atkinson, A., Korb, R., Whitehouse, M.J., Ward, P., Rodhouse, P.G., Enderlein, P., Hirst, A.G., Martin, A.R., Hill, S.L., Staniland, I.J., Pond, D.W., Briggs, D.R., Cunningham, N.J., Fleming, A.H., 2007. Spatial and temporal operation of the Scotia Sea ecosystem: a review of large-scale links in a krill centred food web. *Philosophical Transactions of the Royal Society B-Biological Sciences*, **362**, 113–148. doi:10.1098/rstb.2006.1957.

Pennycuick, C.J., 1982. The Flight of Petrels and Albatrosses (Procellariiformes), Observed in South Georgia and its Vicinity. *Philosophical Transactions of the Royal Society B-Biological Sciences*, **300**, 75–106. doi:10.1098/rstb.1982.0158.

Péron, C., Delord, K., Phillips, R.A., Charbonnier, Y., Marteau, C., Louzao, M., Weimerskirch, H., 2010. Seasonal variation in oceanographic habitat and behaviour of white-chinned petrels *Procellaria aequinoctialis* from Kerguelen Island. *Marine Ecology-Progress Series*, **416**, 267–284. doi: 10.3354/meps08785.

Péron, C., Weimerskirch, H., Bost, C.A., 2012. Projected poleward shift of king penguins' (*Aptenodytes patagonicus*) foraging range at the Crozet Islands, southern Indian Ocean. *Proceedings of the Royal Society B: Biological Sciences*. doi:10.1098/rspb.2011.2705.

Phillips, R.A., Bearhop, S., McGill, R.A.R., Dawson, D.A., 2009. Stable isotopes reveal individual variation in migration strategies and habitat preferences in a suite of seabirds during the nonbreeding period. *Oecologia*, **160**, 795–806. doi:10.2307/40310080.

Phillips, R.A., Croxall, J.P., Silk, J.R.D., Briggs, D.R., 2008. Foraging ecology of albatrosses and petrels from South Georgia: two decades of insights from tracking technologies. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **17**, S6–S21. doi:10.1002/aqc.906.

Phillips, R.A., Silk, J.R.D., Croxall, J.P., 2005a. Foraging and provisioning strategies of the light-mantled sooty albatross at South Georgia: competition and co-existence with sympatric pelagic predators. *Marine Ecology-Progress Series*, **285**, 259–270. doi: 10.3354/meps285259.

Phillips, R.A., Silk, J.R.D., Croxall, J.P., Afanasyev, V., 2006. Year-round distribution of white-chinned petrels from South Georgia: relationships with oceanography and fisheries. *Biological Conservation*, **129**, 336–347. doi:10.1016/j.biocon.2005.10.046.

Phillips, R.A., Silk, J.R.D., Croxall, J.P., Afanasyev, V., Bennett, V.J., 2005b. Summer distribution and migration of nonbreeding albatrosses: individual consistencies and implications for conservation. *Ecology*, **86**, 2386–2396. doi:10.1890/04-1885.

Pinaud, D., Weimerskirch, H., 2007. At-sea distribution and scale-dependent foraging behaviour of petrels and albatrosses: a comparative study. *Journal of Animal Ecology*, **76**, 9–19. doi:10.1111/j.1365-2656.2006.01186.x.

Pitman, R.L., Durban, J.W., Greenfelder, M., Guinet, C., Jorgensen, M., Olson, P.A., Plana, J., Tixier, P., Towers, J.R., 2011. Observations of a distinctive morphotype of killer whale (*Orcinus orca*), type D, from sub-Antarctic waters. *Polar Biology*, **34**, 303–306. doi:10.1007/s00300-010-0871-3.

Quillfeldt, P., Masello, J.F., Navarro, J., Phillips, R.A., 2013. Year-round distribution suggests spatial segregation of two small petrel species in the South Atlantic. *Journal of Biogeography*, **40**, 430–441. doi:10.1111/jbi.12008.

Shaffer, S.A., Weimerskirch, H., Scott, D., Pinaud, D., Thompson, D.R., Sagar, P.M., Moller, H., Taylor, G.A., Foley, D.G., Tremblay, Y., Costa, D.P., 2009. Spatio-temporal habitat use by breeding sooty shearwaters *Puffinus griseus*. *Marine Ecology-Progress Series*, **391**, 209–220. doi:10.3354/meps07932.

Shirihai, H., 2008. The Complete Guide to Antarctic Wildlife: Birds and Marine Mammals of the Antarctic Continent and the Southern Ocean. 2nd Edition, Princeton & Oxford: Princeton University Press, 544 pp.

Southwell, C.J., Paxton, C.G.M., Borchers, D.L., Boveng, P.L., Nordøy, E.S., Blix, A.S., de la Mare, W.K., 2008. Estimating population status under conditions of uncertainty: the Ross seal in East Antarctica. *Antarctic Science*, **20**, 123-133. doi:10.1017/S0954102007000879.

Taylor, B.L., Baird, R., Barlow, J., Dawson, S.M., Ford, J., Mead, J.G., Notarbartolo di Sciara, G., Wade, P., Pitman, R.L., 2008. *Ziphius cavirostris*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2.

Van Waerebeek, K., Leaper, R., Baker, A.N., Papastavrou, V., Thiele, D., 2004. Odontocetes of the Southern Ocean Sanctuary. *Paper SC/56/SOS1, IWC Scientific Committee*.

Wall, S.M., Bradshaw, C.J.A., Southwell, C.J., Gales, N.J., Hindell, M.A., 2007. Crabeater seal diving behaviour in eastern Antarctica. *Marine Ecology-Progress Series*, **337**, 265–277.

Whitehead, H., 2002. Sperm whale. In: Perrin, W.F., Würsig, B., Thewissen, J.G.M. (eds.). Encyclopedia of Marine Mammals. New York: Academic Press, pp. 1165–1172.

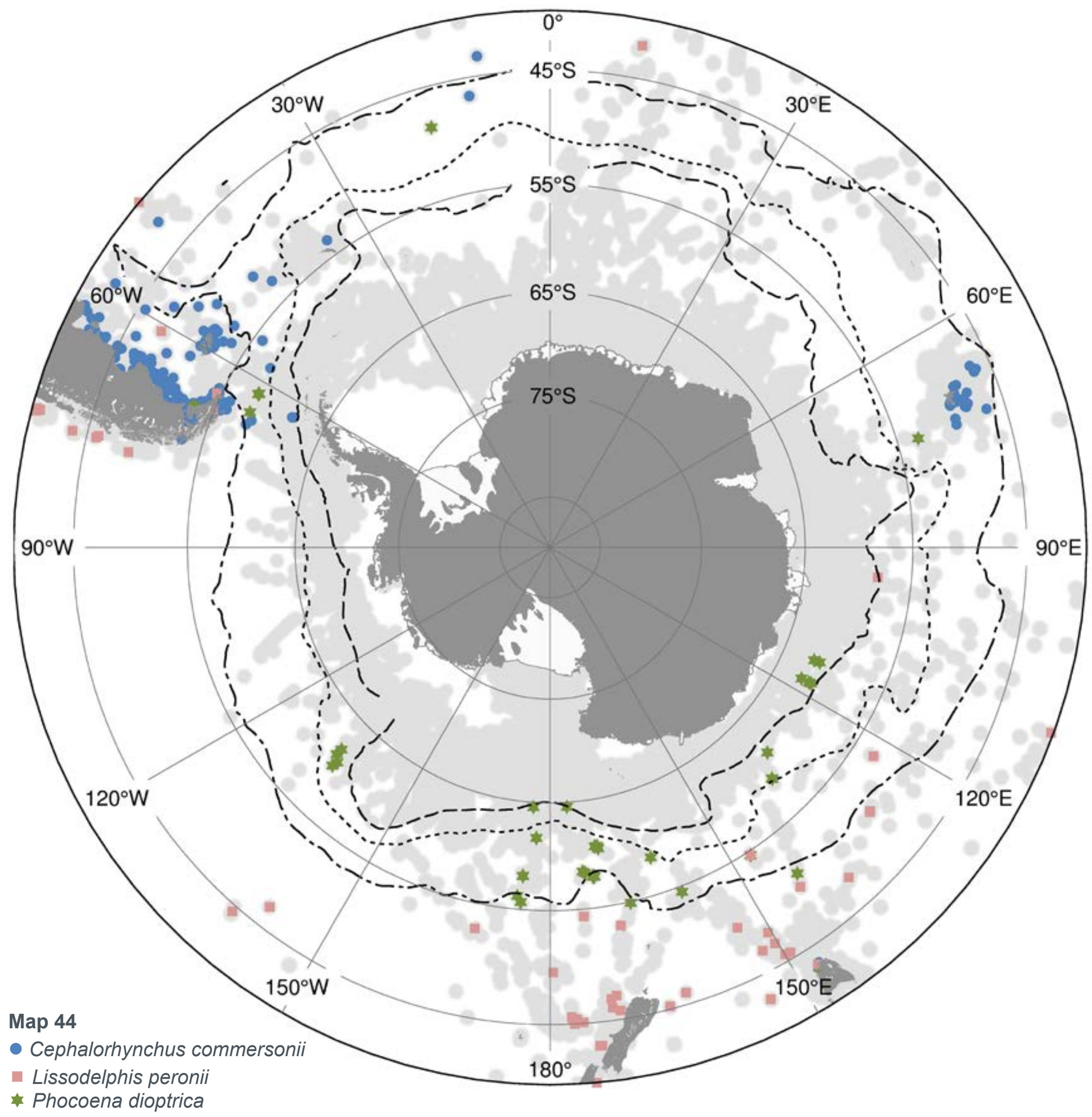
Wienecke, B.C., Lawless, R., Rodary, D., Bost, C.A., Thomson, R., Pauly, T., Robertson, G., Kerry, K.R., Le Maho, Y., 2000. Adélie penguin foraging behaviour and krill abundance along the Wilkes and Adélie Land coasts, Antarctica. *Deep Sea Research Part II: Topical Studies in Oceanography*, **47**, 2573–2587. doi:10.1016/S0967-0645(00)00036-9.

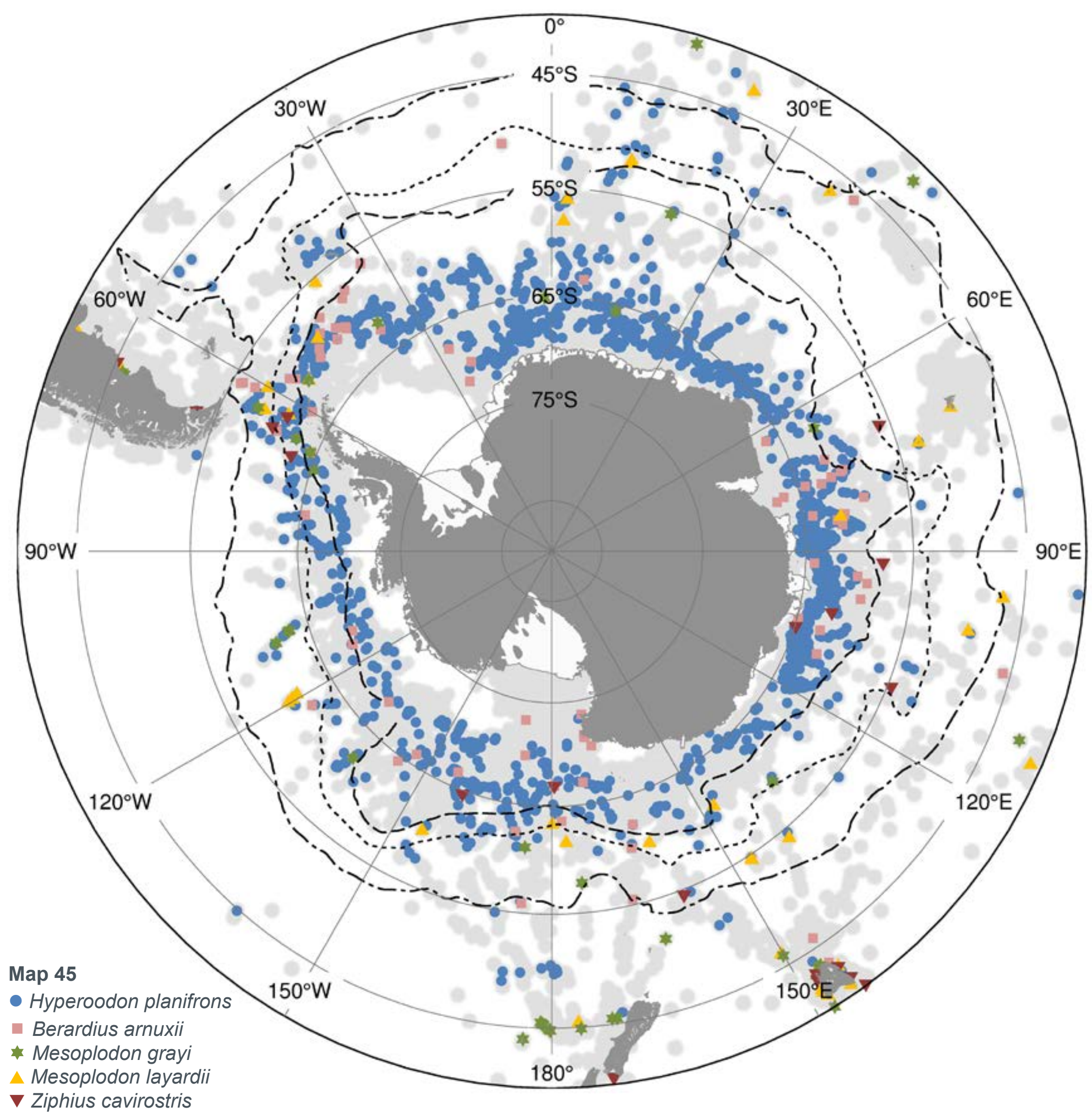
Wienecke, B., Robertson, G., 1997. Foraging space of emperor penguins *Aptenodytes forsteri* in Antarctic shelf waters in winter. *Marine Ecology-Progress Series*, 159, 249–263. doi:10.3354/meps08629.

Wienecke, B., Robertson, G., 2002. Foraging areas of king penguins from Macquarie Island in relation to a Marine Protected Area. *Environmental Management*, **29**, 662–672. doi:10.1007/s00267-0015-1.

Wynen, L.P., Goldsworthy, S.D., Guinet, C., Bester, M.N., Boyd, I.L., Gjertz, I., Hofmeyr, G.J.G., White, R.W.G., Slade, R., 2000. Postsealing genetic variation and population structure of two species of fur seal (*Arctocephalus gazella* and *A. tropicalis*). *Molecular Ecology*, **9**, 299–314.

Zimmer, I., Wilson, R.P., Gilbert, C., Beaulieu, M., Ancel, A., Plötz, J., 2008. Foraging movements of emperor penguins at Pointe Géologie, Antarctica. *Polar Biology*, **31**, 229–243. doi:10.1007/s00300-007-0352-5.





Whales and Dolphins Maps 44–45 Map 44. Commerson's Dolphin: *Cephalorhynchus commersonii*, Southern Right Whale Dolphin: *Lissodelphis peronii*, Spectacled Porpoise: *Phocoena dioptrica*. Map 45. Southern Bottlenose Whale: *Hyperoodon planifrons*, Giant Beaked Whale: *Berardius arnuxii*, Gray's Beaked Whale: *Mesoplodon grayi*, Strap-toothed Whale: *Mesoplodon layardii*, Cuvier's Beaked Whale: *Ziphius cavirostris*.

THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

Scope

Biogeographic information is of fundamental importance for discovering marine biodiversity hotspots, detecting and understanding impacts of environmental changes, predicting future distributions, monitoring biodiversity, or supporting conservation and sustainable management strategies.

The recent extensive exploration and assessment of biodiversity by the Census of Antarctic Marine Life (CAML), and the intense compilation and validation efforts of Southern Ocean biogeographic data by the SCAR Marine Biodiversity Information Network (SCAR-MarBIN / OBIS) provided a unique opportunity to assess and synthesise the current knowledge on Southern Ocean biogeography.

The scope of the Biogeographic Atlas of the Southern Ocean is to present a concise synopsis of the present state of knowledge of the distributional patterns of the major benthic and pelagic taxa and of the key communities, in the light of biotic and abiotic factors operating within an evolutionary framework. Each chapter has been written by the most pertinent experts in their field, relying on vastly improved occurrence datasets from recent decades, as well as on new insights provided by molecular and phylogeographic approaches, and new methods of analysis, visualisation, modelling and prediction of biogeographic distributions.

A dynamic online version of the Biogeographic Atlas will be hosted on www.biodiversity.aq.

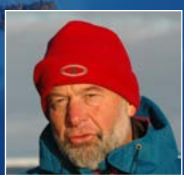
The Census of Antarctic Marine Life (CAML)

CAML (www.caml.aq) was a 5-year project that aimed at assessing the nature, distribution and abundance of all living organisms of the Southern Ocean. In this time of environmental change, CAML provided a comprehensive baseline information on the Antarctic marine biodiversity as a sound benchmark against which future change can reliably be assessed. CAML was initiated in 2005 as the regional Antarctic project of the worldwide programme Census of Marine Life (2000-2010) and was the most important biology project of the International Polar Year 2007-2009.

The SCAR Marine Biodiversity Information Network (SCAR-MarBIN)

In close connection with CAML, SCAR-MarBIN (www.scarmarbin.be, integrated into www.biodiversity.aq) compiled and managed the historic, current and new information (i.a. generated by CAML) on Antarctic marine biodiversity by establishing and supporting a distributed system of interoperable databases, forming the Antarctic regional node of the Ocean Biogeographic Information System (OBIS, www.iobis.org), under the aegis of SCAR (Scientific Committee on Antarctic Research, www.scar.org). SCAR-MarBIN established a comprehensive register of Antarctic marine species and, with biodiversity.aq provided free access to more than 2.9 million Antarctic georeferenced biodiversity data, which allowed more than 60 million downloads.

The Editorial Team



Claude DE BROYER is a marine biologist at the Royal Belgian Institute of Natural Sciences in Brussels. His research interests cover structural and ecofunctional biodiversity and biogeography of crustaceans, and polar and deep sea benthic ecology. Active promoter of CAML and ANDEEP, he is the initiator of the SCAR Marine Biodiversity Information Network (SCAR-MarBIN). He took part to 19 polar expeditions.

Huw GRIFFITHS is a marine Biogeographer at the British Antarctic Survey. He created and manages SOMBASE, the Southern Ocean Mollusc Database. His interests include large-scale biogeographic and ecological patterns in space and time. His focus has been on molluscs, bryozoans, sponges and pycnogonids as model groups to investigate trends at high southern latitudes.

Cédric d'UDEKEM d'ACOZ is a research scientist at the Royal Belgian Institute of Natural Sciences, Brussels. His main research interests are systematics of amphipod crustaceans, especially of polar species and taxonomy of decapod crustaceans. He took part to 2 scientific expeditions to Antarctica on board of the *Polarstern* and to several sampling campaigns in Norway and Svalbard.

Bruno DANIS is an Associate Professor at the Université Libre de Bruxelles, where his research focuses on polar biodiversity. Former coordinator of the scarmarbin.be and antabif.be projects, he is a leading member of several international committees, such as OBIS or the SCAR Expert Group on Antarctic Biodiversity Informatics. He has published papers in various fields, including ecotoxicology, physiology, biodiversity informatics, polar biodiversity or information science.

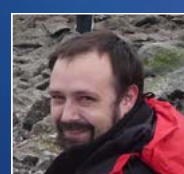
Susie GRANT is a marine biogeographer at the British Antarctic Survey. Her work is focused on the design and implementation of marine protected areas, particularly through the use of biogeographic information in systematic conservation planning.

Christoph HELD is a Senior Research Scientist at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven. He is a specialist in molecular systematics and phylogeography of Antarctic crustaceans, especially isopods.

Falk HUETTMANN is a 'digital naturalist' he works on three poles (Arctic, Antarctic and Hindu-Kush Himalaya) and elsewhere (marine, terrestrial and atmosphere). He is based with the university of Alaska-Fairbank (UAF) and focuses primarily on effective conservation questions engaging predictions and open access data.

Philippe KOUBBI is professor at the University Pierre et Marie Curie (Paris, France) and a specialist in Antarctic fish ecology and biogeography. He is the Principal Investigator of projects supported by IPEV, the French Polar Institute. As a French representative to the CCAMLR Scientific Committee, his main input is on the proposal of Marine Protected Areas. His other field of research is on the ecoregionalisation of the high seas.

Ben RAYMOND is a computational ecologist and exploratory data analyst, working across a variety of Southern Ocean, Antarctic, and wider research projects. His areas of interest include ecosystem modelling, regionalisation and marine protected area selection, risk assessment, animal tracking, seabird ecology, complex systems, and remote sensed data analyses.



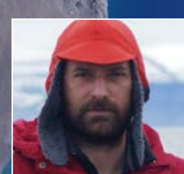
Anton VAN DE PUTTE works at the Royal Belgian Institute for Natural Sciences (Brussels, Belgium). He is an expert in the ecology and evolution of Antarctic fish and is currently the Science Officer for the Antarctic Biodiveristy Portal www.biodiversity.aq. This portal provides free and open access to Antarctic Marine and terrestrial biodiversity of the Antarctic and the Southern Ocean.

Bruno DAVID is CNRS director of research at the laboratory BIOGÉOSCIENCES, University of Burgundy. His works focus on evolution of living forms, with and more specifically on sea urchins. He authored a book and edited an extensive database on Antarctic echinoids. He is currently President of the scientific council of the Muséum National d'Histoire Naturelle (Paris), and Deputy Director at the CNRS Institute for Ecology and Environment.

Julian GUTT is a marine ecologist at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, and professor at the Oldenburg University, Germany. He participated in 13 scientific expeditions to the Antarctic and was twice chief scientist on board Polarstern. He is member of the SCAR committees ACCE and AnT-ERA (as chief officer). Main focii of his work are: biodiversity, ecosystem functioning and services, response of marine systems to climate change, non-invasive technologies, and outreach.

Graham HOSIE is Principal Research Scientist in zooplankton ecology at the Australian Antarctic Division. He founded the SCAR Southern Ocean Continuous Plankton Recorder Survey and is the Chief Officer of the SCAR Life Sciences Standing Scientific Group. His research interests include the ecology and biogeography of plankton species and communities, notably their response to environmental changes. He has participated in 17 marine science voyages to Antarctica.

Alexandra POST is a marine geoscientist, with expertise in benthic habitat mapping, sedimentology and geomorphic characterisation of the seafloor. She has worked at Geoscience Australia since 2002, with a primary focus on understanding seafloor processes and habitats on the East Antarctic margin. Most recently she has led work to understand the biophysical environment beneath the Amery Ice Shelf, and to characterise the habitats on the George V Shelf and slope following the successful CAML voyages in that region.



Yan ROPERT COUDERT spent 10 years at the Japanese National Institute of Polar Research, where he graduated as a Doctor in Polar Sciences in 2001. Since 2007, he is a permanent researcher at the CNRS in France and the director of a polar research programme (since 2011) that examines the ecological response of Adélie penguins to environmental changes. He is also the secretary of the Expert Group on Birds and Marine Mammals and of the Life Science Group of the Scientific Committee on Antarctic Research.