ANTARCTIC OCEAN ALLIANCE

PROTECTING THE WILD SOUTH

ANTARCTIC OCEAN LEGACY: PROTECTION FOR THE EAST ANTARCTIC COASTAL REGION

EXECUTIVE SUMMARY

In October 2011, the Antarctic Ocean Alliance (AOA) proposed the creation of a network of marine protected areas (MPAs) and marine reserves in 19 specific areas in the Southern Ocean around Antarctica[1]. This report, **Antarctic Ocean Legacy: Protection for the East Antarctic Coastal Region**, outlines a vision for marine protection in the East Antarctic, one of the key regions previously identified by the AOA.

Currently, only approximately 1% of the world's oceans are protected from human interference, yet international agreements on marine protection suggest that this number should be far higher[2 3 4].

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body that manages the marine living resources of the Southern Ocean (with the exception of whales and seals), has set a target date of 2012 for establishing the initial areas in a network of Antarctic MPAs.

One of the key places for which the AOA seeks protection is the East Antarctic coastal region. This remote area, while vastly understudied, is home to a significant proportion of the Southern Ocean's penguins seals and whales. The East Antarctic coastal region also contains large seafloor and oceanographic features found nowhere else on the planet.

The AOA offers this report to assist in designating marine reserves and MPAs in the East Antarctic coastal region. This is the third in a series of "Antarctic Ocean Legacy" proposals from the AOA[5 6].

This report describes the geography, oceanography and ecology of this area. The AOA acknowledges the scientists and governments that have studied the region and welcomes and gives support to the proposal that has been submitted for marine protection in the East Antarctic by Australia, France and the EU, but cautions that constant vigilance and additional marine reserves will be required to ensure that the conservation values of the proposal are not compromised in the future.

The AOA proposes that in addition to the seven areas referenced by Australia, France and the EU, four additional areas also be considered for protection in the coming years. A network MPAs and marine reserves encompassing these additional areas and those proposed by Australia, France and the EU would span approximately 2,550,000 square kilometres.

AOA indicative map of a representative network of marine protected areas and marine reserves in the Southern Ocean.

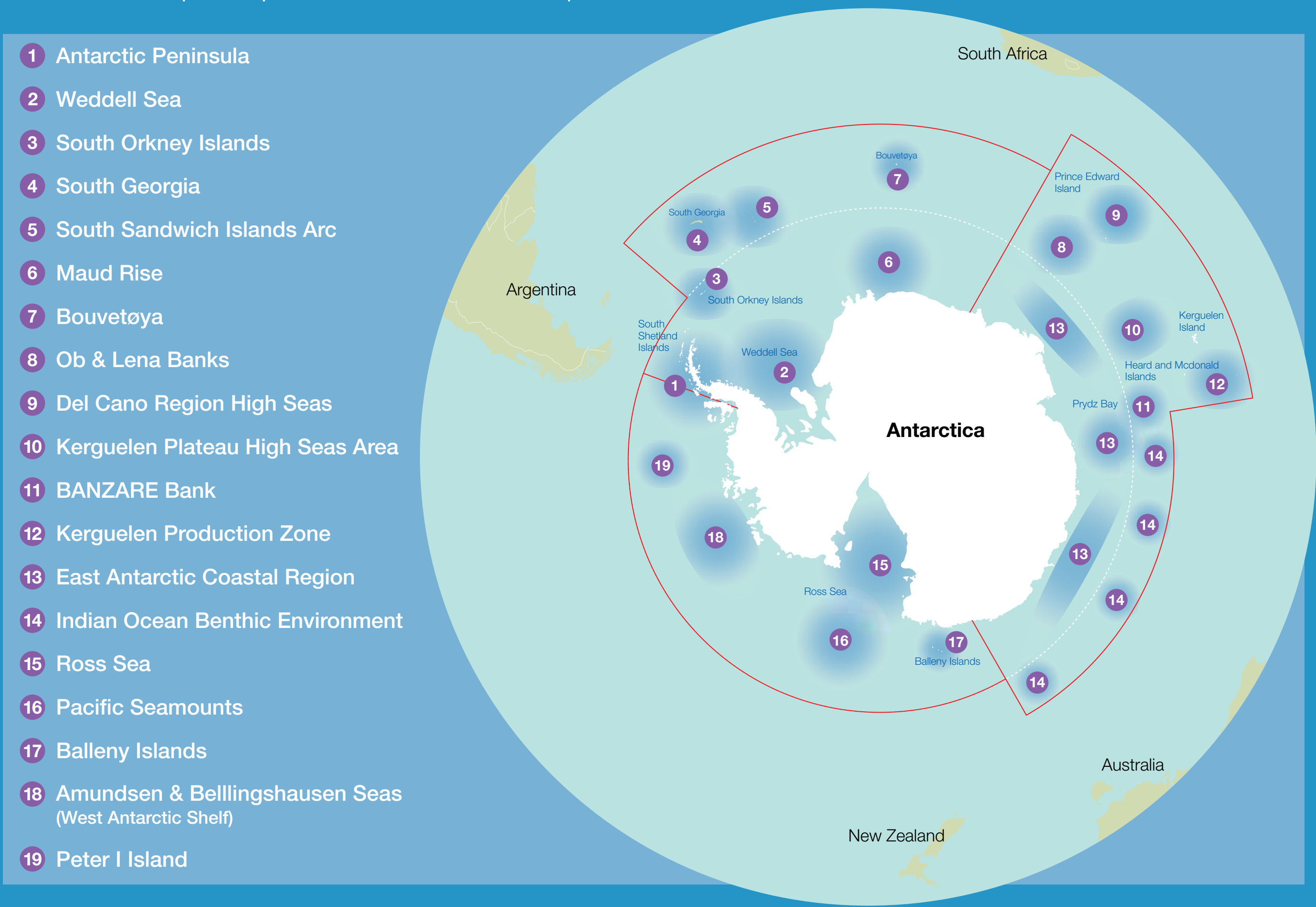

Image by John B. Weller.

Because the East Antarctic coastal region is "data-poor", the AOA plan is based on the application of the precautionary approach, one of the core concepts at the centre of CCAMLR's mandate.

This proposal includes:

1. A representative sample of biological features at the species, habitat and ecosystem scale to ensure broad scale protection.
2. Areas of protection large enough to encompass broad foraging areas for whales, seals, penguins and other seabirds.
3. Protection of many of the region's polynyas, which are sources of food for many species.
4. Protection of unique geomorphic features, including the Gunnerus Ridge, Bruce Rise, a trough mouth fan off Prydz Bay, various seamounts and representative areas of shelf, slope and abyssal ecoregions.
5. Full protection of Prydz Bay, an area that supports large numbers of seabirds and mammals as well as likely nursery grounds for krill and toothfish.
6. Protecting areas of scientific importance that may serve as climate reference areas.

Currently, only approximately 1% of the world's oceans are protected from human interference, yet international agreements on marine protection suggest that this number should be far higher.

The designation of a network of large-scale MPAs and marine reserves in the East Antarctic coastal region would be an important and inspirational step for marine protection in the Southern Ocean. CCAMLR Members have an unprecedented opportunity to establish a network of marine reserves and MPAs an order of magnitude greater than anything accomplished before. With such a network in place, key Southern Ocean habitats and wildlife, including those unique to the East Antarctic coastal region, would be protected from the impacts of human activities.

The AOA submits that with visionary political leadership, CCAMLR can grasp this opportunity and take meaningful steps to protect critical elements of the world's oceans that are essential for the lasting health of the planet.

ABOUT THE ANTARCTIC OCEAN ALLIANCE

The **Antarctic Ocean Alliance** is an international coalition of leading environmental and conservation organisations and philanthropists from around the world including the Antarctic and Southern Ocean Coalition (ASOC), Blue Marine Foundation (UK), Deepwave (Germany), ECO (NZ), Forest and Bird (NZ), Greenovation Hub (China), Greenpeace, Humane Society International, International Fund for Animal Welfare (IFAW), International Polar Foundation, International Programme on the State of the Ocean (IPSO), Korean Federation for Environmental Movement (KFEM), The Last Ocean, Mission Blue (US), Oceans 5 (US), Whale and Dolphin Conservation Society (WDCS) and WWF. Associate partners include Oceana, Natural Resources Defense Council (NRDC) and other groups worldwide.

ANTARCTIC OCEAN ALLIANCE
PROTECTING THE WILD SOUTH

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Image © Greenpeace / Jiri Rezac.

Adélie penguins on ice.
Image © Greenpeace / Roger Grace.

INTRODUCTION

Image © Greenpeace / Jiri Rezac.

THE EAST ANTARCTIC COASTAL REGION

The East Antarctic coastal region comprises an ecosystem that has been shaped by grand features and processes. The Eastern Antarctic Ice Sheet flows off the Antarctic continent into the Southern Ocean, an icy surface abruptly giving way to the marine environment. Coastal currents, like the Prydz Bay Gyre, mingle with the expansive fronts of the Antarctic Circumpolar Current, a clockwise current that circulates the continent. Coastal polynyas, areas of open water amidst the sea ice, form up and down the coast of East Antarctica. Further offshore is the Cosmonaut Polynya, one of only two major open ocean polynyas currently in the Southern Ocean.

Millennia of glacial streams have carved deep canyons into the continental shelf and slope all along the East Antarctic coastal region. In the eastern stretches of the region, the Gunnerus Ridge rises from the depths, with a seamount off its northern end. In the central region of the East Antarctic, the Bruce Rise forms one of only two marginal plateaus in the Southern Ocean. Off the continental shelf of Prydz Bay, a large trough mouth fan and a myriad of associated canyons form a unique habitat.

Along the shores of the East Antarctic, millions of seals and seabirds make their home, feeding mostly on Antarctic and crystal krill as well as silverfish. The East Antarctic supports many colonies of Adélie and emperor penguins, the latter of which have been rapidly decreasing in recent years[7]. Leopard and crabeater seals pup on the pack ice just offshore. Other birds, seals and whales come to feed in the region's waters, especially Prydz Bay. The bay also supports nursery grounds for krill and Antarctic toothfish, the top piscine predator in the Southern Ocean[8, 9].

The region's unique oceanographic and seafloor features coupled with its biological value to seabirds, seals and other animals make the East Antarctic coastal region a prime area for protection.

Crabeater seal. *Image by Cassandra Brooks.*

East Antarctica is a large region and while some areas and features have been well studied, others remain enveloped in mystery. Scientists are still trying to understand the dynamics between the oceanography and the seafloor environment and define the species that live there. Because of the overall lack of information about the East Antarctic coastal region, scientists and managers consider it a "data-poor" region. Nonetheless, the region's unique oceanographic and seafloor features coupled with its biological value to seabirds, seals and other animals make the East Antarctic coastal region a prime area for protection.

CANDIDATE FOR MARINE PROTECTION

The marine life of the East Antarctic coastal region is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)[10]. The Commission and the Convention that established it comprise a key marine-focused component of the Antarctic Treaty System. CCAMLR's objective is the conservation of marine living resources. Setting aside regions as MPAs and marine reserves is a key component of CCAMLR's management toolbox[11]. In a region as large as the East Antarctic, a group of multiple marine reserves and MPAs is appropriate, and should be included in the larger Southern Ocean network of MPAs.

In this report, "MPA" is used to describe areas where certain activities are limited or prohibited to meet specific conservation, habitat protection, or fisheries management objectives. A marine reserve refers specifically to a highly protected area that is off limits to all extractive uses, including fishing. Marine reserves provide the highest level of protection to all elements of the ocean ecosystem.

To be effective, MPAs and marine reserves must be large enough to encompass and protect key ecological processes and the life cycle of the species living there[12]. A group of large MPAs and reserves that connect ocean processes across space and over time in the East Antarctic is the most effective and powerful tool to ensure long-term resiliency of the region. Unique seafloor and pelagic features such as the Cosmonaut Polynya and Bruce Rise should be included, as well as known foraging grounds for seabirds and mammals. Reference areas that act as baselines for long-term climate research studies should also be included.

While some areas and features of the East Antarctic coastal region and have been well studied, others remain enveloped in mystery.

Because the East Antarctic coastal region is data-poor, it is appropriate for CCAMLR to employ the precautionary approach when designating protected areas. Areas that are less well known may be equally or even more ecologically important and should be included in the network. In areas where less biological data is available, seafloor and pelagic habitats can be used as proxies for biological diversity[13]. Including replicate features and habitats within the network of MPAs and marine reserves can help ensure that the region's biodiversity is conserved.

Penguins on the fast ice, Antarctica.
Image by John B. Weller.

DEFINITION OF THE EAST ANTARCTIC COASTAL REGION

Image © Greenpeace / Jorge Gutman.

The East Antarctic coastal region spans the coast along the Eastern Antarctic Ice Sheet from Enderby Land to Terre Adélie – from 30°E to 150ºE and from the coast out to 60ºS – and is contained within the Eastern Antarctic planning domain adopted at CCAMLR in 2011. The western boundary extends to the eastern margins of the Weddell Gyre and encompasses most of the South Indian Ocean out to the east towards the western edge of the Ross Sea region planning domain. The East Antarctic coastal region can be divided into west, central and eastern regions of the South Indian Ocean based on ecological barriers likely caused by the influences of the Weddell and Ross Sea Gyres coupled with variations in wind and sea ice[14 15].

In this report, these regions will be further referred to as Dronning Maud (West Indian; from 0ºE to 55ºE), Central Indian (from 55ºE to 137ºE) and Oates (East Indian; from 137ºE to 170ºE). Moving from west to east, the Central Indian province can further be divided into the West Kerguelen subregion (from 55ºE to 68ºE), Prydz Bay subregion (from 68ºE to 82ºE), East Kerguelen subregion (from 82ºE to 110ºE) and the Wilkes subregion (from 110ºE to 137ºE)[16]. For the purposes of this report, the East Antarctic coastal region does not include BANZARE Bank, the Kerguelen Plateau or any of the related islands.

Key attributes of the East Antarctic coastal region include important climate change reference areas, particularly in the Oates region, and significant Adélie and emperor penguin colonies.

Emperor penguin chick. *Image by John B. Weller.*

Key attributes of the East Antarctic coastal region include:

- Important climate change reference areas, particularly in the Oates region;
- Significant Adélie and emperor penguin colonies;
- Breeding and foraging grounds for many other seabird, seal and whale species;
- Nursery grounds for krill, toothfish and other fish species;
- One of the Southern Ocean's largest trough mouth fans, a unique benthic feature;
- Bruce Rise, one of only two marginal plateaus in the Southern Ocean;
- Cosmonaut Polynya, one of only two major open ocean polynyas in the Southern Ocean.

BIRDS AND MAMMALS OF THE EAST ANTARCTIC COASTAL REGION

Image by John B. Weller.

Though much of the icy East Antarctic coastal region is difficult for humans to access, it is heavily populated with marine mammals and birds that breed and feed there, including seals, whales, penguins and albatross. Several species of whale, including blue, fin, humpback and minke have all been recorded in the East Antarctic[17], with minkes and humpbacks being the most abundant[18].

Four species of seals breed in the region: crabeater, Weddell, Ross and leopard. Crabeater seals are by far the most numerous with about one million estimated to breed in the East Antarctic coastal region[19]. Ross seals, which are designated a “Specially Protected Species” under the Environment Protocol to the Antarctic Treaty, are distributed throughout the region, with an estimated population of approximately between 41,300 and 55,900[20], or as much as 42% of the total population[21]. At least 7,300 to 12,000 leopard seals are also found in the region[22]. Weddell seals are the only seals that breed on the fast ice of the Eastern Antarctic shelf, but often move to the pack ice after the breeding season. Their exact population estimates remain unknown. Additionally, elephant seals from sub-Antarctic islands visit the East Antarctic coastal region’s rich waters to forage[23].

Ross seal. *Image by Elliott Neep.*

Significant numbers of emperor and Adélie penguins breed throughout the Eastern Antarctic, with an estimated 50,000 pairs of emperor penguins[24] and about 750,000 pairs of Adélie penguins distributed over more than 25 colonies[25]. These represent approximately 17% and 27% of the world populations of emperors and Adélies, respectively. Emperors and Adélies forage over great distances, with emperors at times travelling up to 900 km from their colonies and Adélies more than 480 km[26 27].

Ross seals, which are designated a “Specially Protected Species” under the Environment Protocol to the Antarctic Treaty, are distributed throughout the region, with an estimated population of approximately between 41,300 and 55,900, or as much as 42% of the total population.

The East Antarctic coastal region is home to a host of other seabirds as well. Like Adélies and emperors, snow petrels breed on the Antarctic continent, with roughly 50 colonies located in the Eastern Antarctic[28]. Prydz Bay alone harbours at least one million breeding pairs of snow petrels[29]. Southern giant petrels, southern fulmars, cape petrels, Antarctic petrels, Wilson's storm petrels and south polar skuas also breed in the Prydz Bay region[30]. An even more impressive array of seabirds forage in the vicinity, including subantarctic skuas, Antarctic terns, Arctic terns, wandering albatross, black-browed albatross, grey-headed albatross, light-mantled sooty albatross, northern giant petrels, white-headed petrels, mottled petrels, Kerguelen petrels, blue petrels, a variety of prion species, white-chinned petrels, dark shearwaters and black-bellied storm petrels[31].

Significant numbers of emperor and Adélie penguins breed throughout the Eastern Antarctic, with an estimated 50,000 pairs of emperor penguins and about 750,000 pairs of Adélie penguins distributed over more than 25 colonies.

Humpback whale in Southern Ocean. *Image © Greenpeace / Jiri Rezac.*

During the initial years of Patagonian toothfish fishing in the Southern Ocean, large numbers of white-chinned petrels were caught as bycatch by both legal and illegal toothfish longliners. Although mitigation measures have essentially eliminated seabird bycatch by legal fishers operating within the CCAMLR area, illegal, unreported and unregulated (IUU) fishing continues to be a problem. White-chinned petrels are still listed as vulnerable on the IUCN Red List[32]. These petrels forage across a vast area of the Eastern Antarctic from Enderby Land to Queen Mary Land, including the coastal areas out to beyond 50°S. Wandering and black-browed albatrosses have also been listed as vulnerable and endangered on the IUCN Red List[33]. These species are still at significant risk of being caught and killed by fishing vessels when they range outside of the CCAMLR area.

Overall, there is still much to learn about the East Antarctic's birds and mammals. Locations and sizes of penguin colonies are fairly well known for the entire region, though they may be underestimated[34]. Information on other seabirds, seals and whales is less extensive and there is still a great deal of uncertainty about the size of their populations.

Snow petrel with icebergs. *Image by John B. Weller.*

DRONNING MAUD (WEST INDIAN) REGION

Image © Greenpeace / Jiri Rezac.

The Dronning Maud (West Indian) region encompasses the marine areas adjacent to the eastern portion of Dronning Maud Land and the western part of Enderby Land, intersecting the East Antarctic planning domain from 30°E to 55°E. The Weddell Gyre influences circulation between 30°E and 40°E, bringing in cooler and fresher water[35]. Two major features of the West Indian sector are the Gunnerus Ridge, a unique continental margin ridge, and the Cosmonaut Polynya.

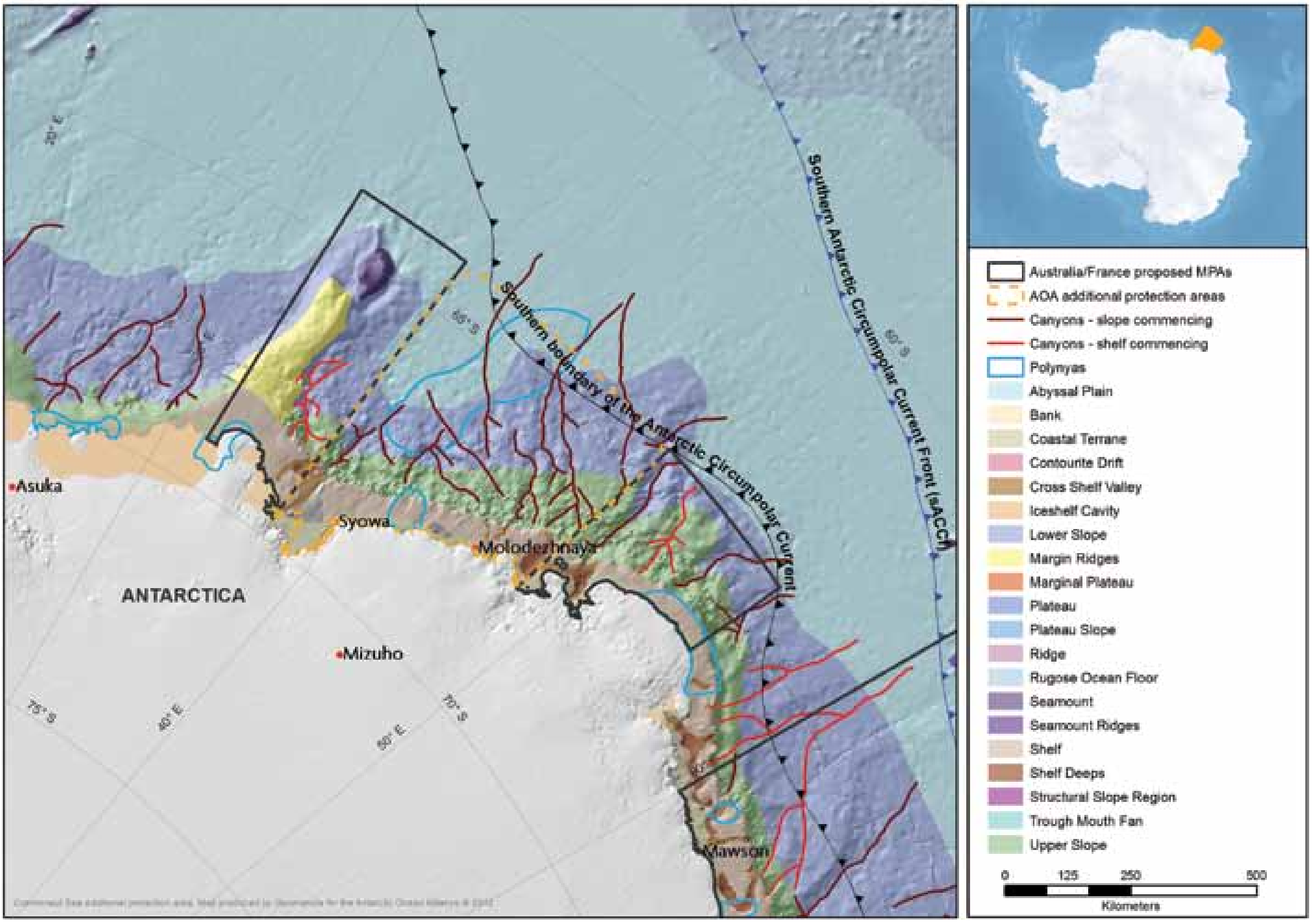
The Gunnerus Ridge is a prominent marginal ridge rising in the eastern reaches of this region. The ridge rises from the continental slope to about 1,200 m depth, shallow enough to interfere with circulation[36] and cause upwelling which then enhances local primary productivity[37]. The ridge is a unique feature, one of only two in the East Antarctic coastal region and by far the larger of the two. Just north of the ridge is a large seamount.

Pack ice in the East Antarctic coastal region. *Image by John B. Weller.*

While little is known about the Gunnerus ridge or its associated seamount, these features are generally isolated habitats that have evolved slowly over millions of years.

While little is known about the ridge or its associated seamount, these features are generally isolated habitats that have evolved slowly over millions of years[38]. Throughout the world's oceans, seamounts support diverse and unique species assemblages[39 40 41]. As shallow uprisings in otherwise deep areas, seamounts can act as stopovers or connection grounds for species in disparate locations tens of hundreds of kilometres away from each other[42 43]. They may also serve as a source population for neighbouring environments[44]. Seamounts tend to have remarkably high levels of biomass when compared to surrounding waters[45]. The Southern Ocean has relatively few and scattered seamounts, each of which likely has its own unique scientific value[46].

To the east of the Gunnerus Ridge, in the coastal areas adjacent to Enderby Land, the seafloor regions share some characteristics with the Gunnerus region, but also some unique seafloor habitats, including an extensive continental slope with a variety of canyons. The waters off Enderby Land also appear to have a distinct population of molluscs and have been identified as a "hotspot" of mollusc diversity[47].



The Cosmonaut Polynya, located in the Cosmonaut Sea, at roughly 65ºS and 45ºE off Enderby Land and near Cape Ann, is one of only two major, regularly recurring open-ocean polynyas currently in the Southern Ocean. Forming over depths of 3,000-4,000 m, the Cosmonaut Polynya is one of the most persistent polynyas in the Southern Ocean and has been observed every year since 1972 when scientists began collecting satellite data[48]. The formation is at times more of an embayment than a distinct polynya[49], while other years it is actually two polynyas, the East and West Cosmonaut Polynya, which often merge over the winter season[50]. During many years these are then joined by an eastward extending chain of polynyas that extends as far as 90ºE[51]. The polynya opens and closes throughout the winter season, sometimes growing as large as 137,700 km^2 and persisting for days to weeks at a time[52 53]. Like their coastal counterparts, open-ocean polynyas are highly productive. Krill aggregations have been found in correlation with upwellings associated with the Cosmonaut Polynya[54].

Antarctic krill.
Image by Stephen W. Brookes, Australian Antarctic Division.

Much remains unknown about the ecology of this area. A few emperor penguin colonies have been documented and a variety of other seabirds have also been observed in the area, including Adélie penguins, Antarctic petrels, snow petrels, Wilson's storm petrels, light-mantled sooty albatrosses, prions, Southern giant petrels and Arctic terns[55]. The upper ocean layers of the region appear to have substantial krill densities, however not nearly as significant as those found off the Antarctic Peninsula[56]. Limited acoustic sampling has revealed the presence of sperm, fin, sei and humpback whales in the region[57].

CENTRAL INDIAN REGION

Image © Greenpeace / Jiri Rezac.

The Central Indian region constitutes a large swath of the East Antarctic coastal region and covers a wide range of habitats and geomorphologic features. Stretching from MacRobertson Land to Wilkes Land (approximately 55°E -137°E), this region has a variety of seafloor habitats and is a rich feeding ground for marine birds and mammals. On the basis of seafloor features, the area can be roughly divided into four subregions – West Kerguelen, Prydz Bay, East Kerguelen and Wilkes[58].

WEST KERGUELEN SUBREGION

The West Kerguelen subregion lies off the coast of MacRobertson Land, between 55ºE to 68ºE. Above the narrow continental shelf, coastal polynyas form, driving local productivity. Deep underwater, canyons cut through the shelf and slope, while further offshore seamounts rise from the deep abyssal plains.

The region is important for mammals and seabirds. Emperor and Adélie penguins have several colonies in the region. The Adélie population is particularly large, with about 100,000 penguins aggregated into three colonies[59]. One of these colonies is the site of long-term monitoring under the CCAMLR Ecosystem Monitoring Program (CEMP) and is one of two active CEMP monitoring sites in MacRobertson Land[60]. A recent at-sea survey of seabirds indicates that the area is dominated by Antarctic petrels, prions, blue petrels, white-chinned petrels, Kerguelen petrels and light-mantled sooty albatrosses, among others[61].

The West Kerguelen region is important for mammals and seabirds... The Adélie population is particularly large, with about 100,000 penguins aggregated into three colonies.

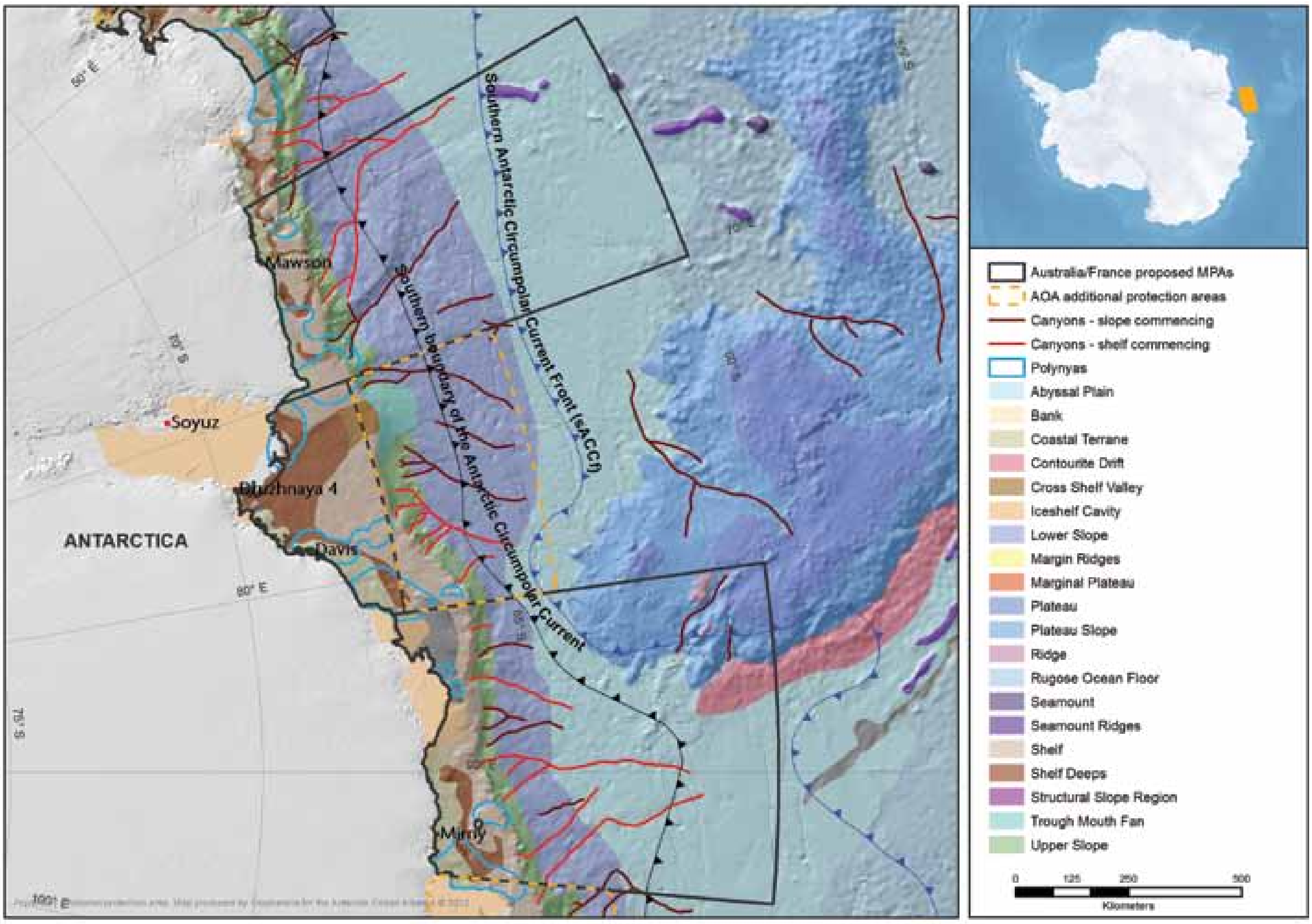
PRYDZ BAY SUBREGION

Prydz Bay, located roughly between 68ºE to 82ºE in the Cooperation Sea, is an incredible hotspot for marine life in the East Antarctic coastal region. The bay contains the largest area of high primary productivity of the entire East Antarctic region[62]. There are several coastal polynyas in Prydz Bay, including one of the most productive polynyas in the Antarctic[63] and north of the bay is the Prydz Gyre.

Elephant seal. *Image © Greenpeace / Robin Culley.*

At the head of Prydz Bay, the Amery Ice Shelf and Lambert Glacier form the largest glacial system in East Antarctica, draining roughly 16% of the East Antarctic Ice Sheet. As a result, they release large volumes of subglacial sediment, which flow down the Prydz Bay continental slope forming a large trough mouth fan that has been measured at 150 km wide and extending out over 90 km. This trough mouth fan is an unusual feature and one of the largest in the Southern Ocean[64]. Large troughs and their associated canyons modify currents, potentially upwelling cold, nutrient rich waters to the sea surface[65 66]. This mixing can enhance local primary productivity and provide rich foraging grounds for birds and mammals[67].

Prydz Bay



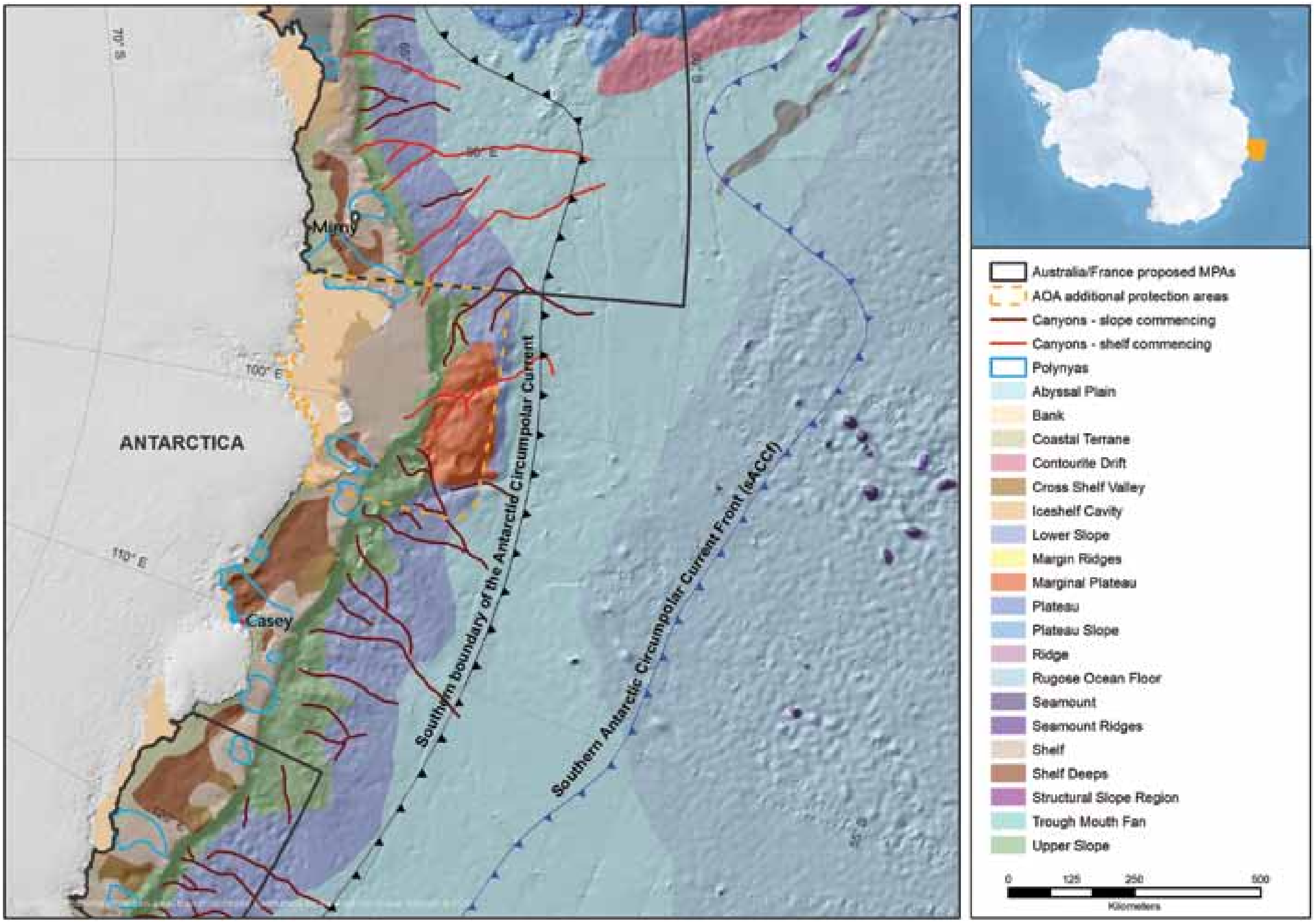
South polar skua. *Image by Elliot Neep.*

These oceanographic features combined with unique bathymetry provide excellent foraging grounds for birds and mammals. All East Antarctic seals forage in Prydz Bay and the surrounding waters. Within Prydz Bay, nine seabirds breed, including emperor and Adélie penguins. Adélie penguins in the East Antarctic are highly dependent on the region's coastal polynyas with the size of the polynyas having a direct relationship to the size of Adélie colonies[68]. Southern giant petrels, southern fulmars, cape petrels, Antarctic petrels, snow petrels, Wilson's storm petrels and south polar skuas also breed in the area[69]. At least 16 additional bird species visit the area, presumably to forage. These birds include the subantarctic skua, Antarctic tern, Arctic tern, wandering albatross, black-browed albatross, grey-headed albatross, light-mantled sooty albatross, northern giant petrel, white-headed petrel, mottled petrel, Kerguelen petrel, blue petrel, prion species, white-chinned petrel, dark shearwater and black-bellied storm petrel[70].

This region also provides foraging grounds for elephant, leopard and crabeater seals[71]. Sperm whale calls have been detected in the region as well but numbers are unknown[72].

Moreover, Prydz Bay serves as a likely nursery ground for krill[73], perhaps due to the presence of coastal polynyas, which can facilitate early season phytoplankton growth[74]. Their life cycle appears tightly linked to the circulation of the Prydz Gyre, with mature adult krill found in the outer regions of the gyre and less mature krill found towards the centre[75]. Overall, Prydz Bay has some of the highest densities of adult krill in the East Antarctic, perhaps providing a source for krill for the greater region[76].

Bruce Rise



Weddell seal with Antarctic toothfish. *Image by Jessica Meir.*

Increasing evidence suggests that the Indian Ocean sector supports a unique population of Antarctic toothfish, which inhabit large expanses of the region throughout their life cycle[77 78]. Data collected aboard fishing vessels in the East Antarctic indicate that small juvenile toothfish are often caught in the Prydz Bay and the West Kerguelen subregion[79]. Meanwhile, large fish are found off the deeper continental slopes in the West Indian Region and Wilkes subregion. Further, almost exclusively large maturing fish are caught around the northern adjacent BANZARE Bank[80 81]. These data suggest that Prydz Bay and adjacent waters might be the primary nursery grounds for this population of Antarctic toothfish. Other common fish species include Antarctic silverfish, Antarctic jonasfish, Antarctic lanternfish, while the most abundant squid is a species of glass squid[82].

EAST KERGUELEN SUBREGION

The East Kerguelen subregion encompasses the area east of Prydz Bay, from 82ºE to 110ºE. Small polynyas litter the coast, forming over a narrow continental shelf and slope cut with canyons. This region, along with Prydz Bay, encompasses the southernmost reaches of BANZARE Bank. It also includes a portion of the Southern Ocean's only contourite drift, an expansive mound of mud that is highly influenced by currents coming off the slope out into the abyssal plain region. These distinctive features likely host unique seafloor communities[83].

Further east in the region, off the coast of Queen Mary Land and the expansive Shackleton Ice Shelf, lies the Bruce Rise. This underwater feature is one of only two marginal plateaus in the Southern Ocean[84]. The rise, which extends from the continental margin, encompasses 1,100 km^2 at depths around 1,000 m[85]. Similar to other elevated underwater features, marginal plateaus often influence local oceanography. The Maud Rise, the only other Antarctic marginal plateau, has a complex system of localized currents, jets and eddies which drive local upwelling. This upwelling then drives pelagic primary productivity, leading to high densities of krill, which can in turn support large numbers of predators[86]. The seafloor below the Maud Rise is rich with invertebrates, such as molluscs, sponges and worms, many of which are unique to the Maud Rise[87].

Light sea sponge.
Image by Michael Zupanc, Australian Antarctic Division.

East Kerguelen, including the area around Bruce Rice, has Adélie and emperor penguin colonies, which forage in the surrounding waters[88]. In the areas adjacent to Prydz Bay, leopard, crabeater, Weddell and Ross seals forage[89].

WILKES SUBREGION

The Wilkes subregion encompasses the area off Wilkes Land, from 110ºE to 137ºE[90] and has largely been studied for its geological value. A hundred million years ago, the marine edge of Wilkes Land was joined to what is now Southern Australia as part of the supercontinent Gondwana[91]. But by 30 million years ago, they fully separated and have been slowly spreading: Antarctica to the south and Australia to the north. The Wilkes Land continental edge and adjacent seafloor has lent tremendous insight into the geological history of Antarctica[92], including a record of the initial opening between Australia and Antarctica[93].

The Wilkes region has also proved an ideal site for studying historic, modern and future glacial conditions. It is the only place in the Antarctic where the onset of glaciation can be traced from the shelf to the abyssal plain. This allows researchers to better reconstruct the East Antarctic Ice Sheet's (EAIS) icy history, including how long ago it formed and providing insight for future predications in a changing climate[94]. The EAIS, which is the largest ice sheet in the world, is typically grounded to the land above sea level. However, along the eastern continent-ocean margin of Wilkes Land the EAIS is grounded below sea level, which has made it more sensitive to climate change in the past and perhaps in the future[95].

Wilkes Land continental edge and adjacent seafloor has lent tremendous insight into the geological history of Antarctica, including a record of the initial opening between Australia and Antarctica.

As the location of a tremendous geological rift, the seafloor of the Wilkes region has very distinct habitats. The narrow continental shelf breaks into a slope riddled with an intricate network of submarine canyons and shallow valleys, all likely formed by historic glacial rivers. These canyons and valleys help transport sediment down the slope, forming a myriad of fan-shaped deposits over the continental rise[96 97]. The area also has coastal polynyas.

While much is known about the geology of the Wilkes region, for the most part biological data is sparse. Some seals forage in the region, particularly elephant, crabeater and Ross seals[98]. Just inside the western edge of Wilkes region is an emperor penguin colony[99] and there are Adélie colonies nearby at the Windmill Islands[100].

OATES (EAST INDIAN) REGION

Image by Darci Lombard.

The Oates or East Indian region intersects the East Antarctic planning domain between 137 E and 150 E within the bounds of the D'Urville Sea, is the best-studied area of the East Antarctic coastal region. This area is incredibly important for its role in generating Antarctic Bottom Water (AABW), cold dense water that drives global ocean circulation[101]. Coastal polynyas drive productivity in the region, particularly the Mertz Glacier Polynya, a major and consistent polynya that persists from year to year[102]. The coastal region has a narrow continental shelf and slope heavily carved with canyons. Multiple vulnerable marine ecosystems have been identified on this slope[103]. In the west, a shallow slope region capped by a unique ridge rises from the abyssal plains, while to the east the seafloor reveals a cluster of seamounts, called the d'Urville Sea-Mertz Seamounts. This region is also where the immense Mertz Glacier Tongue recently calved. Many birds and mammals live here and the region also has important nursery grounds for many fish species.

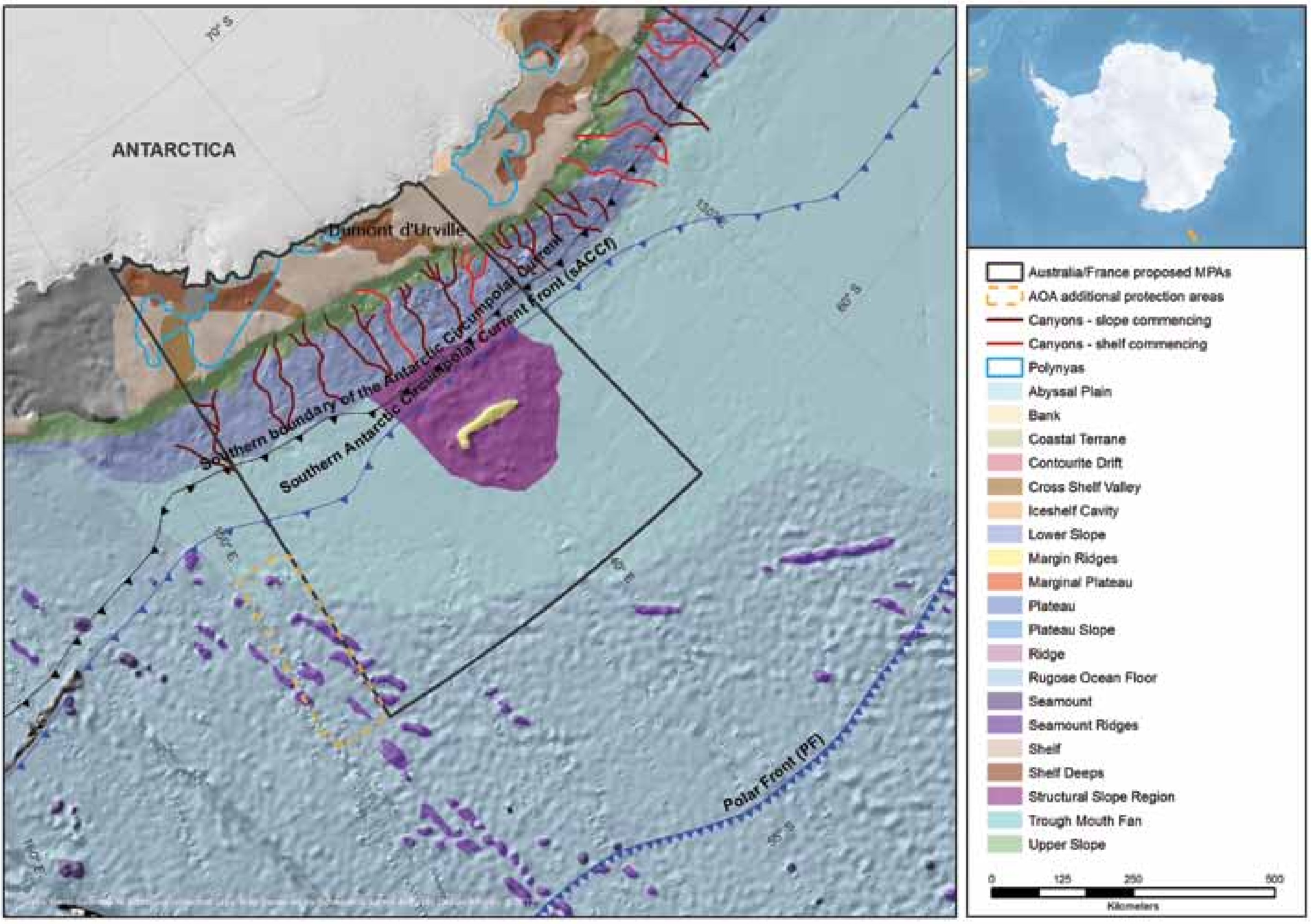
Larval icefish. *Image by Uwe Kils / Wikimedia Commons.*

A recent detailed study of the area by Australia, France and Japan (conducted as part of the worldwide Census of Marine Life) collected a significant amount of new information that will assist in developing an ecoregionalization of the area[104 105]. The voyage, known as CEAMARC, or the Collaborative East Antarctic Marine Census, collected information on many aspects of the ecosystem, including benthic species and habitats, fish species, plankton and oceanography[106]. Within this relatively small area, several distinct types of benthic communities were discovered. The distribution of these communities varies according to the different seafloor habitats, which are driven by seafloor geomorphology as well as currents and iceberg scour[107].

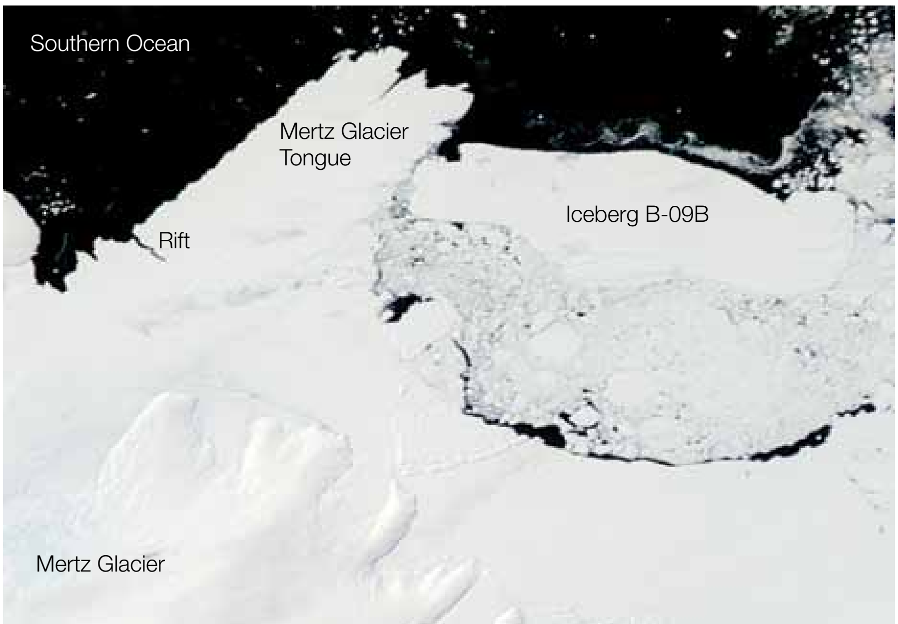
The East Indian region... is the best-studied area of the East Antarctic coastal region. This area is incredibly important for its role in generating Antarctic Bottom Water (AABW), cold dense water that drives global ocean circulation.

Numerous birds and mammals make their home in the East Indian region, likely feeding on swarms of crystal krill or groups of Antarctic silverfish[108 109]. Ten seabird species breed here including Adélie and emperor penguins, snow and Antarctic petrels and Antarctic fulmars[110 111]. Adélie penguins have the largest population with more than 100,000 breeding pairs[112 113]. The area also has a long-term monitoring program for marine mammals and birds[114]. Other studies confirmed that the area between Adélie Land and Mertz Glacier Tongue provides nursery grounds for many fish species, including Antarctic silverfish, the dusky notothen, crocodile icefish, Hunter's icefish and others[115].

Seamounts



Given the depth of knowledge about this region and its importance in the formation of AABW, it is a prime reference area for monitoring the impacts of climate change on ocean processes[116]. For example, the recently calved Mertz Glacier, which released a 2,500 km^2 iceberg[117], provides a unique opportunity to study the seafloor and oceanographic changes that follow this type of disturbance. The break up and subsequent glacial melting may be freshening the water in the area, changing the salinity and potentially slowing down the rate of AABW formation[118], which could have global oceanographic consequences[119].



The Mertz Glacier Tongue. *Satellite image courtesy of NASA.*

THREATS

Image by Cassandra Brooks.

COMMERCIAL EXPLOITATION

Historic Mammal Harvesting

In line with the history of much of the Southern Ocean, 20th century whalers targeted the waters off the East Antarctic, particularly for blue and humpback whales[120]. More than 10,000 humpback whales were taken between 1947 and 1973 with an unknown number taken in the years prior[121]. Despite a steady recovery of most humpback populations, they have yet to reach pre-exploitation levels[122]. Blue whales were also heavily targeted in the East Antarctic between the years of 1930 – 1963[123]. Their current Southern Ocean population remains small, but appears to be increasing over the past few years, although still only a fraction of the original size[124 125].

Most industrial sealing occurred off the Kerguelen, Heard and McDonald Islands, to the north of the East Antarctic[126]. These operations ceased in the late 19th century and seal populations have since been recovering.

Old whaling ship, Antarctica.
Image by JD Andrews / earthxplorer.com.

Antarctic krill. *Image by Lara Asato.*

Krill Fishery

The East Antarctic coastal region supports significant Antarctic krill populations, which are estimated to be almost 39 million tonnes, though this is likely to be an underestimate[127 128 129]. Krill fisheries began during the 1970s off the East Antarctic and peaked in the mid-1980s before declining and finally ceasing in the 1994/95 season[130 131]. A total of 750,000 tonnes of krill have been harvested from this area[132].

The current krill catch limit is 892,000 tonnes for the East Antarctic[133] but at present krill fishers prefer to target the waters off the Antarctic Peninsula and the Scotia Sea rather than making the extended journey to the East Antarctic.

As demand for krill products increases, new countries are taking an interest in the fishery. Advances in harvesting technology have also increased the efficacy of fishing[134]. Because krill is among the last of the global fisheries not exploited at full capacity, it has potential for expansion in the future[135 136], which could increase pressure on Southern Ocean ecosystems. Currently unexploited areas with large krill populations, like the East Antarctic coastal region, could soon be worth the voyage for increasingly motivated distant water fishing fleets.

Fin-Fishing History

Fin-fishing in the East Antarctic began in the area around the Kerguelen Islands as early as the late 1950s[137], but did not reach the coastal areas until 1982[138]. A few fish species were harvested, including Antarctic silverfish, spiny icefish and rays, but catches were low and ceased by the late 1980s[139 140].

Ten years later, an experimental trawl fishery targeting multiple species, including Antarctic toothfish, was initiated in the western area of the East Antarctic (CCAMLR Area 58.4.2). By the 2001/02 season the fishery was changed to an exploratory longline fishery[141]. In 2003/04 a longline fishery also commenced in the eastern region of the East Antarctic (CCAMLR Area 58.4.1)[142].

Multiple countries sporadically participated in the fishery. Catch rates in the west remained low, only filling a fraction of the 780 tonne catch limit. In the east, catch rates were more reliable, with vessels achieving the 600 tonne catch limit. Meanwhile IUU fishing vessels ravaged the area, at times accounting for an estimated 74% of the catch in the East Antarctic (including the nearby BANZARE Bank)[143]. Moreover, the regional tag-recapture program was proving unreliable at obtaining adequate data for a toothfish stock assessment. Fisheries managers still do not have estimates of population dynamics, stock structure, productivity, recruitment or spawning for Antarctic toothfish in the East Antarctic[144 145].

Catch data suggest that these Antarctic toothfish are likely part of the BANZARE Bank population[146] and that collectively this stock is not highly productive. The combined catch quotas and excessive IUU fishing led to concerns that the East Antarctic populations had been over harvested[147]. By the 2008/09 season these concerns led CCAMLR to cut catch rates to 70 tonnes in the west and 210 tonnes in the east.

Antarctic toothfish with diver. *Image by Rob Robbins.*

Indiscriminate Illegal Gillnets

Significant progress has been made in reducing the level of IUU catch through the cooperation of CCAMLR, its Member nations and legal fishers. However, a number of IUU fishers still operate primarily in the South Indian Ocean and directly off the East Antarctic coastal region. The conservative catch limits remain in place today, as IUU fishing remains a problem and is unlikely to further decline[148 149].

In recent years, IUU fishers have increasingly used deepwater gillnets in the area, making IUU estimates nearly impossible to calculate[150 151 152]. Gillnets are banned by CCAMLR because they pose a significant environmental threat due to their high levels of bycatch and the risk of "ghost fishing," which refers to nets that have been cut loose or lost in the ocean and continue catching marine life for years[153]. The amount of toothfish caught in IUU gillnets remains unknown, but is likely substantial. For example, gillnets found by Australian officials in 2009 spanned 130 km and had ensnared 29 tonnes of Antarctic toothfish[154].

IUU fishing and the uncertainty associated with toothfish populations severely compromise fisheries management and has led to the rapid decline of some toothfish stocks[155 156]. Moreover, like many deep dwelling fish, toothfish live a long time, grow slowly as adults and mature late in life, all characteristics that make them vulnerable to overfishing[157]. Local depletions of toothfish may easily occur, as has happened over BANZARE Bank[158 159]. Scientists have yet to understand the Antarctic toothfish's life history in the East Antarctic, which further compromises management.

CLIMATE CHANGE AND OCEAN ACIDIFICATION

Rapid, human induced climate change, mainly from increased carbon dioxide (CO_2) and other greenhouse gas emissions, is affecting all parts of the Earth[160], and regions of the ice-dominated Antarctic are some of the most rapidly changing on the planet[161 162]. However, the impacts of climate change are not uniform across the region. Wintertime warming along the western Antarctic Peninsula has increased 1.01°C per decade from 1950-2011[163], the most rapid rise in annual observed temperature anywhere on the planet. Yet other parts of the continent show little change or even a slight cooling[164]. There is also strong evidence that the persistent seasonal ozone hole over Antarctica (which was first discovered in the early 1980s) may exacerbate the impacts of climate change, mainly by increasing the strength of the westerly winds that surround the continent[165].

In the East Antarctic, the climate trend is not clear. No major warming or cooling has taken place[166 167], yet changes in sea ice have been significant[168]. Since the 1950s, sea ice extent has declined[169], but conversely, as of the 1970s, the sea ice season has increased by more than 40 days[170]. These changes have had dramatic effects on the animals that live there, most notably seabirds.

Warming waters and reductions in sea ice could be especially detrimental to emperor penguins off the East Antarctic. Over the past 50 years, Adélie Land emperor colonies have declined by 50%[171]. This current decline has been caused by extensive penguin mortality during an especially warm period over the 1970s. The associated reductions in sea ice likely reduced krill habitat, affecting the food web and leaving emperors with less food to eat[172]. Conversely, during years when the sea ice season was longer, emperor adults survived. But because of extended distances between the colonies and feeding grounds, many of their nests failed[173]. Future projections paint an even grimmer picture for Adélie Land's emperors: their populations will likely decline by 81% or more by 2100[174].

Rapid, human induced climate change, mainly from increased carbon dioxide (CO_2) and other greenhouse gas emissions, is affecting all parts of the Earth, and regions of the ice-dominated Antarctic are some of the most rapidly changing on the planet.

Southern giant petrel. *Image by Lara Asato.*

Other seabirds are also feeling the effects of these sea ice changes. Nine types of seabirds, including emperor penguins, Adélies, southern fulmars, south polar skuas and five petrel species, are arriving to their colonies an average of 9.1 days later and laying their eggs 2.1 days later since the 1950s[175]. The longer sea ice season may be the culprit since it can delay the birds' access to their colonies and to food resources[176].

Scientists are only beginning to unravel the contrasting effects of climate change in the East Antarctic. Protecting the foraging ranges of emperor penguins and other seabirds in a marine reserve will help scientists study the impacts of climate change without the interference of other stressors. In doing so, perhaps they can devise solutions.

Sea Ice

Every year sea ice forms around Antarctica, effectively doubling the size of the continent. The annual advance and retreat drives ecosystem processes, including primary productivity and provides habitat for a variety of species throughout their life history[177]. The presence of ice is essential for the life history of krill, particularly for larval krill, which feed on microorganisms under the ice[178]. A reduction in krill could have cascading effects throughout the ecosystem since krill are a critical part of the diet of many whales, seals, penguins and fish. Reductions in sea ice may also impact many marine animals, especially those, such as crabeater seals, which critically depend on sea ice during various stages in their life cycle[179 180].

Ocean Acidification

The world's oceans continuously absorb CO_2 from the atmosphere. There is, however, a cost to this natural carbon mitigation. Between 1751 and 2004, as CO_2 emissions increased, surface ocean pH decreased[181], resulting in a 30% increase in ocean acidity[182]. As CO_2 dissolves in seawater it forms a weak (carbonic) acid, driving a decrease in ocean pH in a process known as ocean acidification. This change in pH has the potential to greatly affect many important marine biological and biogeochemical processes, including decreasing the amount of calcium carbonate in the ocean – a key building block for shell building animals[183].

The cold waters of the Southern Ocean are naturally lower in calcium carbonate than warmer waters and thus closer to the tipping points at which organisms will begin to suffer deleterious effects[184]. Scientists predict that within the next two decades key planktonic species, such as pteropods (small marine snails), will no longer be able to build robust shells[185]. In time, they may not be able to build shells at all. Krill embryos and larvae may also be at risk[186]. If pteropods, krill and other shell-building animals perish, it will have adverse ramifications that will cascade throughout the Southern Ocean ecosystem.

Between 1751 and 2004, as CO_2 emissions increased, surface ocean pH decreased, resulting in a 30% increase in ocean acidity.

OPPORTUNITY AT CCAMLR

Image by John B. Weller.

A growing body of scientific research has demonstrated that MPAs and marine reserves are effective tools for increasing the health and resilience of ocean ecosystems[187]. In recognition of this, at the 2002 WSSD, countries around the world made commitments to establish representative networks of MPAs across the world's oceans by 2012[188]. CCAMLR, the body responsible for the conservation and management of marine living resources in the Southern Ocean has responded to this call and committed to meeting the WSSD goal by designating a network of protected areas in the Southern Ocean, including in the East Antarctic[189].

CCAMLR applies a precautionary, ecosystem-based approach to managing marine life in the Southern Ocean. The application of these principles has made CCAMLR more progressive amongst bodies responsible for managing fishing in areas beyond national jurisdiction. Through its MPA process thus far, CCAMLR has shown that it has the capacity for leadership by setting a target date to create a network and designating the South Orkney Islands Southern Shelf as a marine reserve in 2010.

CCAMLR headquarters, Hobart, Australia. *Image by Richard Williams.*

There has been a concerted effort from a number of CCAMLR Members to advance work on other concrete MPA proposals, and a number of scientific workshops have been organised to analyse the best available science to identify additional areas for protection. CCAMLR's efforts are guided by several criteria for MPAs and marine reserves:

1. Protection of representative examples of marine ecosystems, biodiversity and habitats at an appropriate scale to maintain their viability and integrity in the long term;
2. Protection of key ecosystem processes, habitats and species, including populations and life-history stages;
3. Establishment of scientific reference areas for monitoring natural variability and long-term change or for monitoring the effects of harvesting and other human activities on Antarctic marine living resources and on the ecosystems of which they form part;
4. Protection of areas vulnerable to impact by human activities, including unique, rare or highly biodiverse habitats and features;
5. Protection of features critical to the function of local ecosystems;
6. Protection of areas to maintain resilience or the ability to adapt to the effects of climate change[190].

Members of CCAMLR have a major opportunity to ensure that a Southern Ocean network of marine reserves and MPAs meets these criteria, thus safeguarding these ecosystems for future generations. The East Antarctic coastal region is one of incredible biodiversity and will form a key part of the network. The AOA urges CCAMLR to fulfill all of these criteria in providing comprehensive protection for the remarkable East Antarctic coastal region.

PROPOSALS FOR MARINE PROTECTION

Image by John B. Weller.

CURRENT PROPOSALS

Australia, France and the EU have submitted a proposal for a network of seven MPAs in the East Antarctic coastal region[191]. Some of these MPAs would protect only the seafloor environment while the others would encompass both seafloor and water column environments. From west to east, their proposed group of MPAs includes:

- the Gunnerus Ridge and associated seamount (seafloor only);
- an area off Enderby Land in the West Indian Region (seafloor only);
- a large marine reserve from the coast out to 60°S off eastern Enderby Land – west of Prydz Bay;
- the southernmost region of Prydz Bay;
- a large marine reserve east of Prydz Bay from the coast out to 60°S;
- the coast off Wilkes Land (seafloor only); and
- A large marine reserve from the coast out to 60°S off George V Land in the western Dumont D'Urville Sea in the East Indian Region.

Their proposal identifies MPAs that would encompass many of the different seafloor bioregions that have been identified thus far. It also includes foraging grounds for birds and mammals as well as potential nursery grounds for toothfish, krill and other species of icefish. The Australian, French and EU proposal is also designed to protect large areas encompassing ecosystem processes in order to act as reference areas to study the effects of fisheries and of environmental change such as the impacts of climate change and ocean acidification.

However no specific marine reserves have been included in the proposal and this will be an issue for future deliberation. The AOA urges that large scale marine reserves need to be included in the management plan to ensure that the conservation objectives of the MPAs are not compromised.

THE AOA PROPOSAL FOR MARINE PROTECTION IN THE EAST ANTARCTIC COASTAL REGION

The AOA welcomes Australia, France and the EU's proposal for a representative system of marine protected areas in the East Antarctic, but has identified four marine reserves that should be considered for inclusion in this network in coming years in order to be fully precautionary, increasing the levels of protection afforded large scale ecosystems process and key habitats. The AOA recommends that these should encompass key environments and ecosystems processes, including both pelagic and seafloor features.

No marine reserves have been included in the current proposal. This will be a major issue for future negotiations. The AOA urges that large scale marine reserves are included in the management plan of the current proposal to ensure that the conservation objectives of the MPAs are not compromised.

In the Dronning Maud (West Indian) region, the AOA proposes a large marine reserve from the coast out to 64°S that connects the MPAs over the Gunnerus Ridge and the seafloor habitats off Enderby Land proposed by Australia, France and the EU. This marine reserve would protect the Cosmonaut Polynya and its associated foraging grounds for seabirds, seals and whales and important seafloor habitats including a complex series of slope commencing canyons. The AOA further encourages that the level of protection afforded by the MPAs proposed by Australia, France and the EU over the Gunnerus Ridge and off Enderby Land be increased to that of full marine reserves to protect both habitats in the water column and the seafloor.

In the Central Indian region north of Prydz, the AOA proposes a marine reserve in the area from the coast out to 64°S. This would include extending the boundary of the marine reserve proposed by Australia, France and the EU in the Prydz Bay region further north, increasing protection of unique pelagic and seafloor features, such as the Prydz Gyre and one of the largest trough mouth fans. It will further protect foraging grounds for birds and seals and nursery grounds for krill and toothfish.

A further additional marine reserve is proposed by AOA to include the area north of the Shackleton Ice Shelf encompassing Bruce Rise. Protection should extend from the coast out to 63°S to include productivity and foraging associated with the Rise.

The AOA advocates that the MPA off Wilkes Land in the Central Indian region proposed by Australia, France and the EU should be designated as a full marine reserve.

In the Oates (East Indian) region, the AOA proposes protection over seamounts in the waters adjacent to the large marine reserve north of George V Land proposed by Australia, France and the EU.

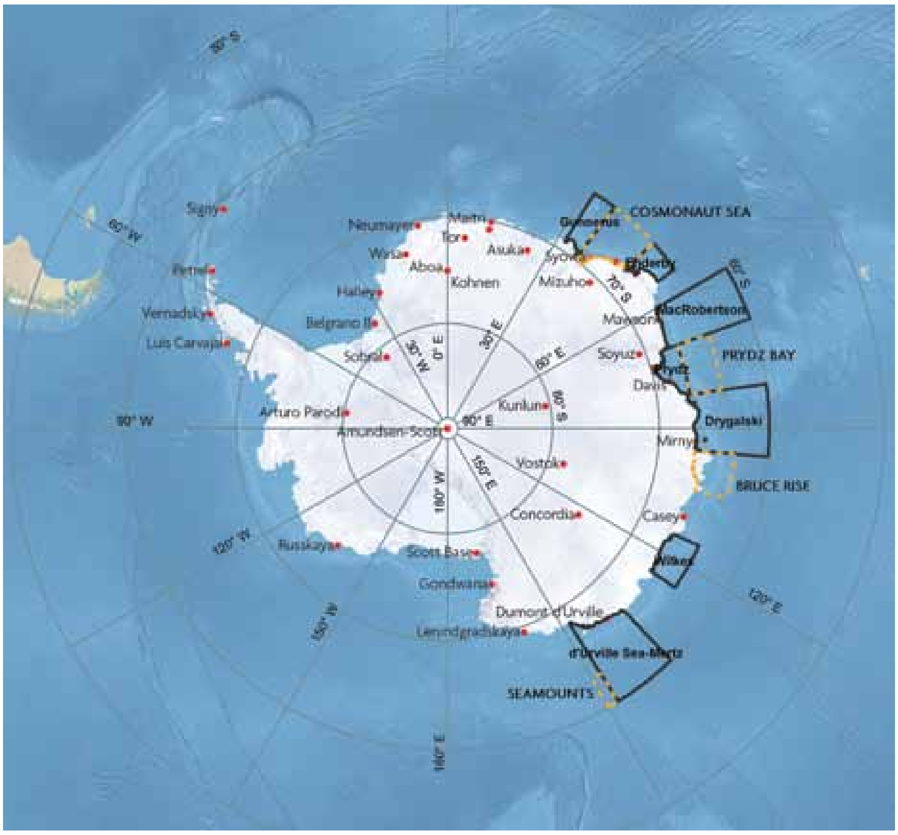
Marine Reserves as Precautionary Management

In regions of high uncertainty, marine reserves provide the greatest protection for marine life and ecosystems[192 193 194 195]. A marine reserve protects biodiversity, including the ecological structure and function at the genetic, species, habitat and ecosystem level[196]. These reserves protect against the potentially negative impacts of human activity, conserving ecological integrity[197]. They also provide control sites to help scientists understand ecological changes as well as the impacts of fishing elsewhere[198], and they can serve as important areas for long-term scientific research.

Marine reserves need to be large enough to avoid fragmenting the ecosystem, particularly in cases of high uncertainty[199]. Species assemblages in the East Antarctic coastal region remain poorly understood, and scientists do not know how connected or restricted these communities are. For example, in other regions of the Antarctic, species assemblages may be unique according to depth or to a specific canyon or individual seamount, while in other areas these assemblages may be connected over grand scales[200 201 202]. The group of marine reserves in the East Antarctic coastal region should include all known habitat types and replication of these habitats.

In the East Antarctic coastal region, some marine reserves, particularly in Prydz Bay, should extend north to fully accommodate ecosystem processes. In doing so, the foraging range of penguins will largely be protected as well as foraging ranges for other seabirds and seals. Because of its incredible productivity, Prydz Bay may be the region most important for fully protecting ecosystem processes. Within the bay alone, nine seabirds breed, including emperor and Adélie penguins, as well as petrels, fulmars and skuas[203].

Current Antarctic MPAs Proposed



At least 16 additional bird species forage in the area[204]. Penguins and other seabirds forage to at least 60°S and potentially even further north[205 206]. White-chinned petrels, a species classified as vulnerable on the IUCN Red List, forage extensively in areas immediately north of Prydz Bay[207].

In regions of high uncertainty, marine reserves provide the greatest protection for marine life and ecosystems.

In data poor regions, large areas should remain free from exploitation until more knowledge is gained about the function and dynamics of the ecological system[208]. Juvenile Antarctic toothfish originating in Prydz Bay are likely part of a larger South Indian Ocean population. Protecting them, and making other areas off limits to fishing, will help supply the areas that are open to fishing[209]. Currently, the East Antarctic only supports a minor Antarctic toothfish fishery. While there is currently no krill fishing in the region, CCAMLR continues to set a quota for the East Antarctic in anticipation of a future fishery.

The East Antarctic coastal region is an essential part of a network of Southern Ocean marine protected areas. The region contains foraging hotspots for birds and mammals, nursery grounds for krill and fish and rich seafloor communities, many of which have yet to be described. The East Antarctic coastal region also contains unique features, including the Cosmonaut Polynya, Bruce Rise and the d'Urville Sea-Mertz Seamounts. The AOA welcomes Australia, France and the EU's proposal for a representative system of marine protected areas in the East Antarctic, but has identified additional marine reserves that should be considered for inclusion in this network in coming years. Given the fragile and unique nature of the ecosystem, and the uncertain future of the Antarctic, the AOA urges CCAMLR members to support fuller protection of the East Antarctic coastal region, including the areas identified in this report.

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Two Emperor penguins. *Image by John B. Weller.*

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