ANTARCTIC OCEAN ALLIANCE
PROTECTING THE WILD SOUTH

ANTARCTIC OCEAN LEGACY: TOWARDS PROTECTION OF THE WEDDELL SEA REGION




EXECUTIVE SUMMARY

A circumpolar network of marine reserves (MRs) and marine protected areas

In 2011 the Antarctic Ocean Alliance (AOA) proposed a representative system of marine protected areas (MPAs) and marine reserves be put in place across 19 regions around Antarctica. The proposed system aims to preserve areas that collectively capture a wide and representative range of species, habitats and ecosystems across all major ocean basins from the top of the water column to the seafloor, and include key biodiversity hotspots.

Antarctic Ocean Legacy: towards protection of the Weddell Sea Region, is the initial AOA report on the Weddell Sea and seeks to contribute to scientific and policy work critical to the creation of a full vision for marine protection for two of the key regions previously identified by the AOA – the Weddell Sea and the Maud Rise.

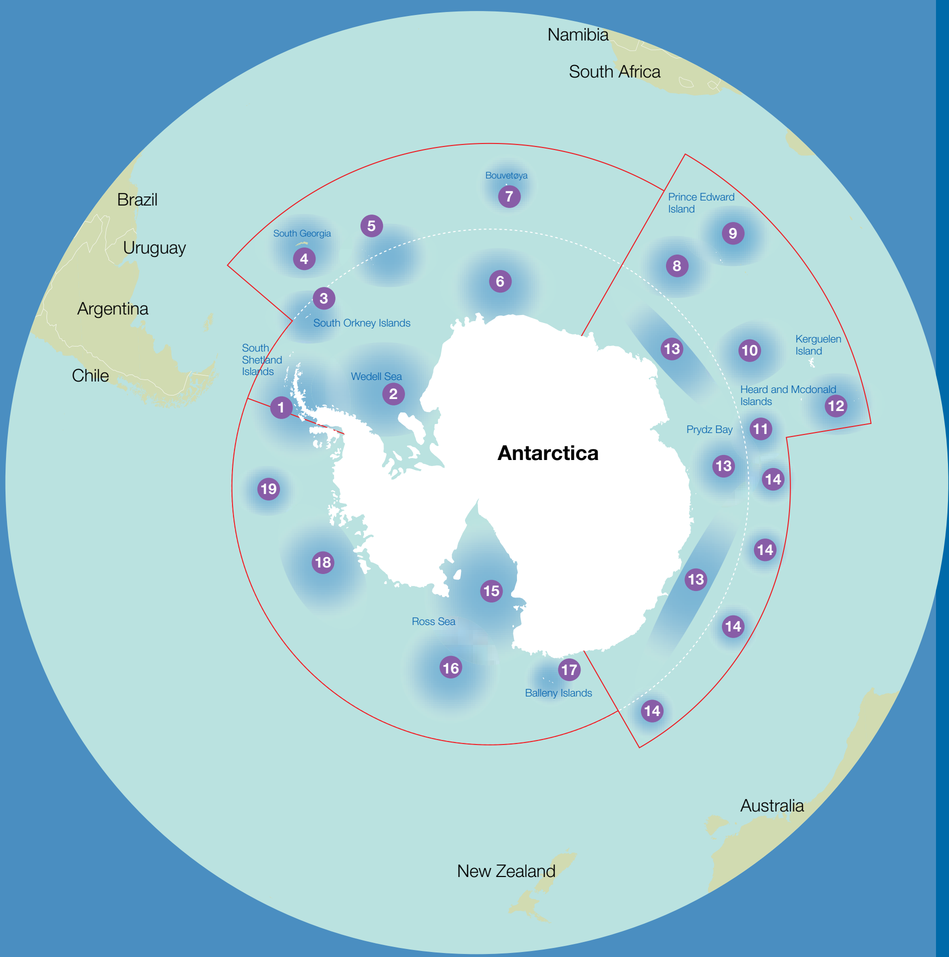
In 2009 the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) agreed to create a representative system of marine protected areas (MPAs) by 2012.[1] Although the deadline has passed, the South Orkneys MPA has been created and mature proposals for the Ross Sea and East Antarctic regions are close to designation.

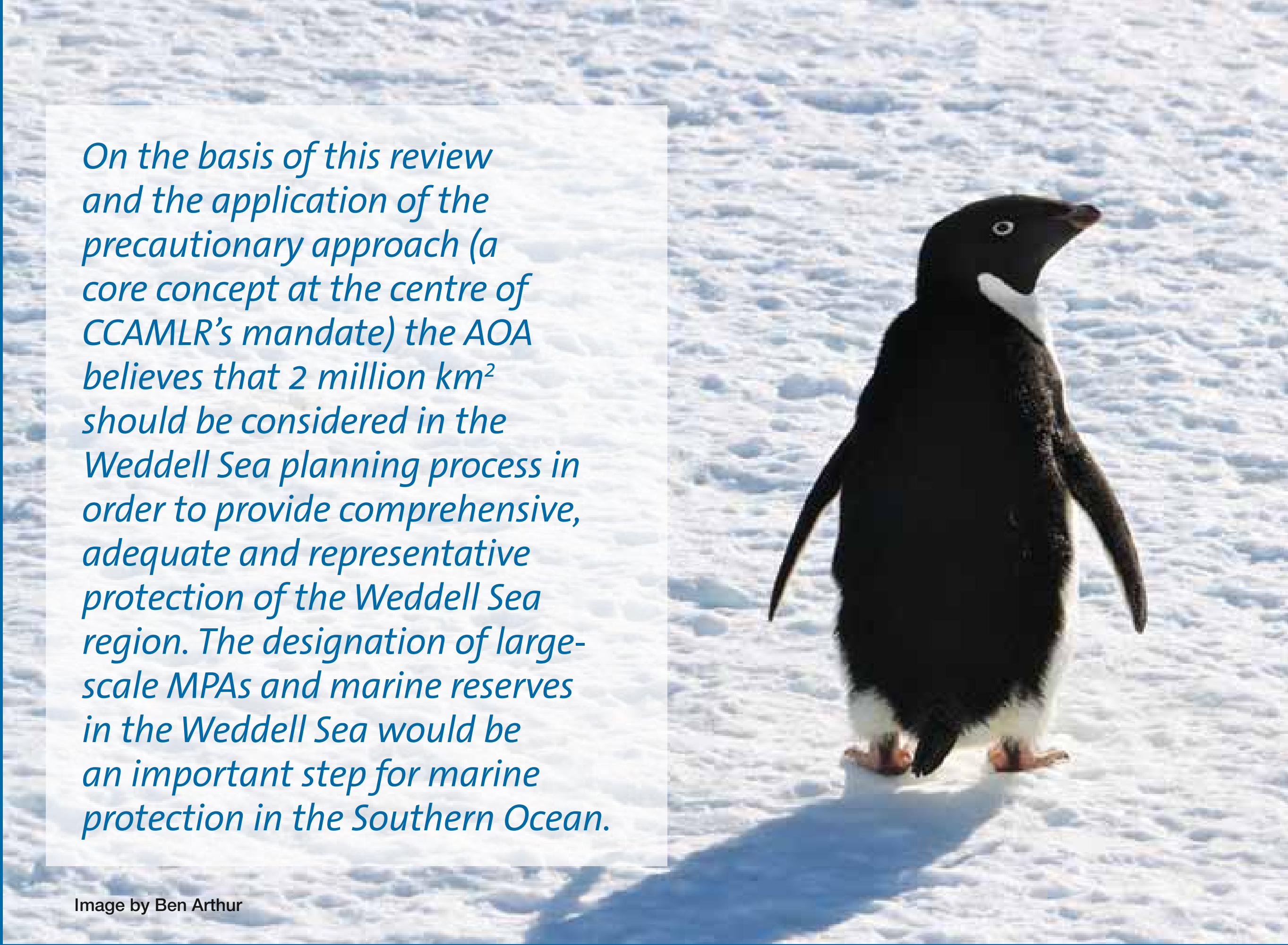
AOA's proposed 19 areas include ecosystems critical to the life-history stages of endemic species including the toothfish – the region's top predatory fish. They contain the breeding and foraging grounds for animals high in the food web, such as penguins, seals and whales. Furthermore regions such the Ross Sea, East Antarctica and the Weddell Sea can serve as valuable climate reference areas and critical climate refugia for ice-dependent species.

Currently, only 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.

AOA is proposing marine protected areas and marine reserves in 19 areas to protect the ecosystems and wildlife of the Southern Ocean.

1. Antarctic Peninsula
2. Weddell Sea
3. South Orkney Islands
4. South Georgia
5. South Sandwich Islands Arc
6. Maud Rise
7. Bouvetøya
8. Ob & Lena Banks
9. Del Cano Region High Seas
10. Kerguelen Plateau High Seas Area
11. BANZARE Bank
12. Kerguelen Production Zone
13. East Antarctic Coastal Region
14. Indian Ocean Benthic Environment
15. Ross Sea
16. Pacific Seamounts
17. Balleny Islands
18. Amundsen & Belllingshausen Seas (West Antarctic Shelf)
19. Peter I Island





On the basis of this review and the application of the precautionary approach (a core concept at the centre of CCAMLR's mandate) the AOA believes that 2 million km^2 should be considered in the Weddell Sea planning process in order to provide comprehensive, adequate and representative protection of the Weddell Sea region. The designation of large-scale MPAs and marine reserves in the Weddell Sea would be an important step for marine protection in the Southern Ocean.

Image by Ben Arthur

In this report, the Antarctic Ocean Alliance collates research on the biodiversity, oceanography, geomorphology and ecosystems of the Weddell Sea and has identified three regions centred on the Western Weddell Shelf, Eastern Weddell Shelf, and the Queen Maud Land – Lazarev Sea Coastal Zone totalling more than 2 million km^2 that encompass the diverse ecological values within the Weddell Sea MPA planning region and warrant further investigation.

CCAMLR has before it a significant opportunity to create a representative system of MPAs and marine reserves with pending designations in East Antarctica and the Ross Sea in 2014. CCAMLR's previous innovative approaches to addressing important environmental issues, including combating Illegal, Unreported and Unregulated (IUU) fishing, protecting vulnerable seafloor habitats and mitigating seabird by-catch have earned it a significant international reputation.[2] If the MPA commitment is fulfilled, CCAMLR will once again demonstrate that it is a leader in ocean conservation.

Building on the work of Members, and the research summarised in this report, CCAMLR could also designate MPAs in the Weddell Sea region in the near future, taking meaningful steps to protect critical elements of the world's oceans that are essential for the lasting health of the planet.

ANTARCTIC OCEAN ALLIANCE

The Antarctic Ocean Alliance is a coalition of leading environmental groups, and high-profile individuals from around the world. These include The Pew Charitable Trusts, WWF, Greenpeace, Humane Society International, the Antarctic and Southern Ocean Coalition (ASOC), the Blue Marine Foundation (UK), Mission Blue (US), Oceans 5 (US), Deep Wave (Germany), The Last Ocean, the Korean Federation for Environmental Movement (KFEM), Greenovation Hub (China), Forest & Bird (NZ), ECO (NZ), Friends of the Earth (Japan), Whale and Dolphin Conservation and associate partners the Natural Resources Defense Council (NRDC), Oceana, the International Fund for Animal Welfare (IFAW), BLOOM Association (FR), the International Polar Foundation, Terra Mar, the Marine Conservation Institute, the International Program on the State of the Ocean (UK), Eco Sys Action, Plant a Fish, Ocean Care (CH) and Ocean Planet (Australia). We are supported by individuals such as actor Leonardo DiCaprio, actor and UN Biodiversity Ambassador Edward Norton, oceanographer Dr. Sylvia Earle, actors Sam Neill and Yoo Jie-Tae, and entrepreneurs Wang Jing and Sir Richard Branson.

ANTARCTIC OCEAN ALLIANCE
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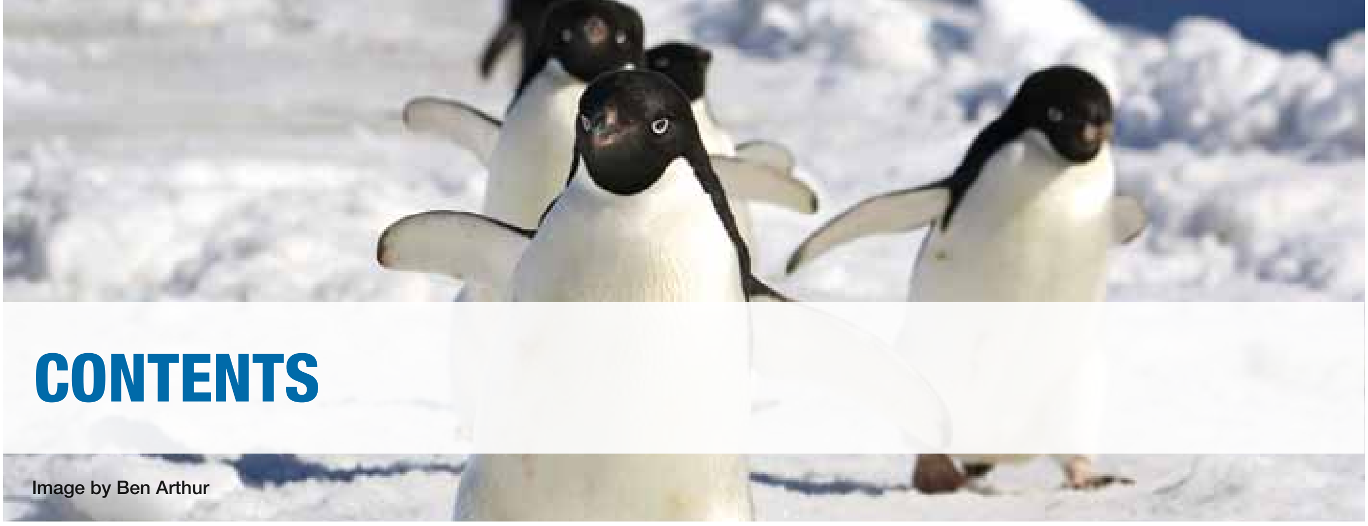

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Image by Ben Arthur

Adélie penguins at ice edge.
Image by David Neilson.

INTRODUCTION

Image by Ben Arthur

Ice-bound, wild and remote, the Weddell Sea is a large, deep embayment nestled between the Antarctic Peninsula and Cape Norvegia. Lying south of the Atlantic Ocean, it is one of the most intact ecosystems in the world.[3] At its widest, it is 2,000 km across, with the whole region encompassing 3.4 million km^2. The Weddell Sea has often been inaccessible to humans, but as research has increased over the past few decades, a picture has emerged of a vibrant marine ecosystem sustained by a combination of currents, seafloor features and ice.

This research has revealed incredible biodiversity, particularly on the seafloor, with dozens of new species discovered on recent sampling expeditions. There are many more species yet to be discovered. Several species of whales and dolphins and six species of seals are found in the Weddell Sea, as well as a diversity of fish and seabirds. Even at depths of 6,000 metres, life has been found, underscoring the incredible diversity of life in the region.

Nutrient rich currents interact with seafloor features, sea ice and ice shelves in a complex system that results in hotspots of plankton growth on the surface, supporting life from the surface to the ocean depths. The complexity of the Weddell Sea's region's undersea landscape enhances the diversity of life under the waves and ice by creating varied habitats for different undersea animals.[4]

Several species of whales and dolphins and six species of seals are found in the Weddell Sea, as well as a diversity of fish and seabirds.

Weddell seals underwater. *Image by changehali.*

The enormous richness of life generated by these interactions supports many seabird and mammal species including emperor penguins, Weddell, crab eater, and elephant seals as well as minke, humpback, blue, and fin whales. These animals come to feed on krill and silverfish, found in the many areas of high phytoplankton production (also known as "primary productivity") throughout the region. Yet climate change is having major impacts on the region with disruption to the icy environment (as will be detailed later in this report). Changes in sea ice could be devastating for many species whose life cycle depends on pack ice.

Protecting the unique, ecologically intact, and diverse deep-water regions of the Weddell Sea in a system of large-scale marine reserves and MPAs would ensure that its rich benthic biodiversity, krill populations, and large predators (including whales) continue to thrive.

DEFINITION OF THE WEDDELL SEA REGION

Image by Ben Arthur

For the purposes of this report, we consider the Weddell Sea region to include the area proposed by the Weddell Sea MPA project group[5] (see map opposite page). The Antarctic Peninsula and the Antarctic continental margin are the western and southern boundaries, respectively. The northern boundary extends from just under the tip of the Antarctic Peninsula to 20°E, above the coast of Queen Maud Land. This area covering approximately 3.4 million km^2 (excluding ice shelves) roughly corresponds to the extent of the Weddell Gyre, a large, clockwise current. Through the Gyre's circulation, features off the Queen Maud Land – Lazarev Sea Coastal Zone in the east, including the Astrid Ridge, Astrid Plateau, Maud Rise and their associated seamounts, are connected to the Weddell Sea in the west.

The project group concluded that because this area "covers a specific oceanographic and ecological entity", it is logical to use it as the basis for MPA planning.[6]

The area covered by the Weddell Sea MPA planning region encapsulates almost all types of geomorphic features of the Southern Ocean seafloor.

WEDDELL SEA MPA PLANNING REGION GEOMORPHOLOGY

The area covered by the Weddell Sea MPA planning region encapsulates almost all types of geomorphic features of the Southern Ocean seafloor. Most striking is the broad and relatively deep shelf of the Weddell Sea, the Maud Rise and the Astrid Ridge and associated plateau. The broad Weddell continental shelf contrasts with the narrow continental shelf common to most of the Antarctic continental margin such as that found along the Queen Maud Land – Lazarev Sea Coastal Zone. Other important features include the shelf-commencing Filchner Trough with the Crary Fan at its mouth, shelf-commencing canyons, banks, seamounts, shelf deeps, ice shelf cavities and cross-shelf valleys. A number of these types of features are known to commonly support vulnerable marine ecosystems.[7,8]

Adélie penguins diving. *Image by David Neilson.*

UNIQUE OCEANOGRAPHY – THE WEDDELL GYRE

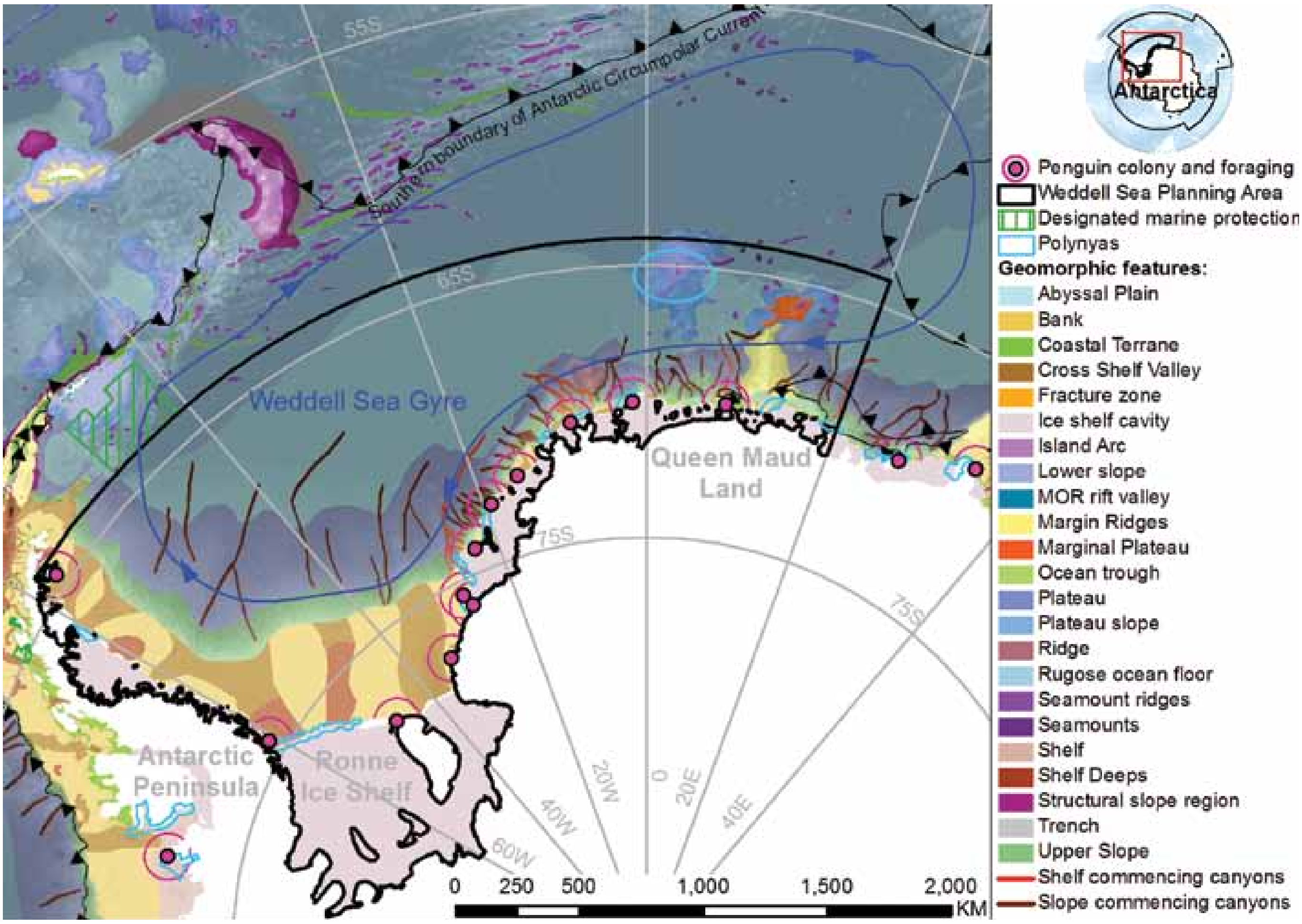
The Weddell Gyre is a huge clockwise circulating gyre that dominates the dynamics of the southern portion of the Atlantic sector of the Southern Ocean. It is bounded by the Antarctic Peninsula in the West, the Filchner – Ronne ice shelf/Queen Maud land to the south and the southern boundary of the Antarctic Circumpolar Current to the north and east. Representing the largest gyre system in the Southern Ocean, its coverage and therefore its influence extend over many of the region's important features including the Weddell Shelf, Maud Rise, Astrid Ridge and Astrid Plateau. Further, the Weddell Gyre's influence extends globally as it is one of few places in the world where deep and bottom water formation occur, driving global thermohaline[9] circulation.[10,11]

At the surface, water mass movement is primarily influenced by wind. Current velocities increase with depth (~1,000 metres) with large volumes circulating around a pronounced and persistent double cell structure, with one cell in the western Weddell basin and the other over a deeper basin northeast of the Maud Rise. Exchange of waters between the Weddell Gyre and other water masses occurs through eddies generated at the gyre's fringes, but it is possible for waters in the middle of the gyre to spend extended periods within the system.[12]

Shallow areas just to the north of the Filchner-Ronne Ice Shelf are primary locations for the production of Antarctic bottom water.[13] Other areas along the Weddell shelf close to the Larsen Ice shelves also contribute to the formation of bottom water.[14] Where bottom water forms, the denser, nutrient-laden water subsequently flows down the continental slope. Elephant seals have been observed spending extended amounts of time in these areas, providing further evidence that these nutrients stimulate local biodiversity.[15]

At the eastern boundary of the Weddell Gyre, where it deflects south along with the Antarctic Circumpolar current, a region of high primary productivity has recently been identified. This area is approximately 600,000 km^2, with an extension of 600 km from north to south between 56° and 62.5° south and 1,000 km east to west. It corresponds to areas of high abundance of humpback whales according to historical whaling records.[16]

The Weddell Sea Region



SEA ICE DYNAMICS

Although pelagic phytoplankton production, geological formations and ocean processes deep in the Weddell Sea drive many ecosystem processes, sea ice on the surface also plays a significant role. As sea ice forms and melts, it exerts an enormous influence over Antarctic hydrography and Antarctic species at all levels of the food web, from algae to penguins to whales. The types of plant species present in the phytoplankton of different areas varies depending on the proximity to sea ice, where the ice can cause changes to the water column, thus inducing changes to the local habitat.[17] Small crustaceans called copepods likewise spend different parts of their life cycles in different areas, sometimes near the ice, sometimes in open water.[18] At higher levels of the food web, species whose prey are affected by the presence or absence of sea ice will therefore be indirectly influenced by sea ice. Sometimes these impacts are not straightforward. For example, increased sea ice extent (SIE) in winter results in fewer breeding pairs of snow petrels the following spring, but those that do breed have higher breeding success and healthier chicks.[19] Greater SIE in winter can make it more difficult for petrels to forage, but seems to result in better krill recruitment, increasing the food supply available to petrel parents during breeding.[20]

As climate change takes effect and temperatures warm resulting in less stability of ice shelves, it is expected that iceberg scour will increase with negative impacts on seafloor biodiversity.

Humpback whale in the Southern Ocean. *Image by Jeri Rezac, Greenpeace.*

ICE SCOURING

Iceberg scouring, the scraping of an iceberg along the seafloor, has a significant influence on the distribution, development and local abundance of seafloor biodiversity. Surveys in the south eastern Weddell Sea reveal that both diversity and overall biomass are highest in undisturbed areas and progressively decreases from areas of older disturbance to areas of the most recent disturbance.[21] Iceberg scour is believed to contribute to an overall increase in biodiversity since each scour event opens up areas to be opportunistically and progressively colonised. In addition, areas of previous scour events will be at different stages of complexity with colonisation from species that are potentially new to the area. After iceberg scouring, some areas were barren or had only low concentrations of suspension feeders (bryozoans, colonial ascidians, certain sponges), while others had very dense assemblages of mature suspension feeders that sift their food from the water currents around them.[22] As climate change takes effect and temperatures warm resulting in less stability of ice shelves (fast ice), it is expected that iceberg scour will increase with negative impacts on seafloor biodiversity.[23]

A Southern Giant Petrel *Macronectes giganteus* soars past an iceberg at the edge of the sea ice. *Image by Ben Arthur, Institute for Marine and Antarctic Studies.*

LIFE IN THE WEDDELL SEA REGION

Image by Ben Arthur

PLANKTON AVAILABILITY AND PRODUCTIVITY

Most marine ecosystems depend on abundant plant plankton, or phytoplankton, for energy. The amount of phytoplankton production in an ecosystem often influences the abundance of animal species. The Weddell Sea region supports thriving populations of many species even though most of its open ocean regions have low average productivity.[24] Plankton blooms, or areas where there is a sudden burst of phytoplankton growth, occur throughout the Weddell Sea planning domain, including open ocean areas like the Maud Rise, creating hotspots of high productivity. For example, some "superblooms" in the Weddell Sea can span tens of thousands of square kilometres.[25]

These blooms are influenced by the Weddell Sea's geomorphology and unique oceanographic features, which can generate the conditions needed for enhanced productivity and hot spots. At the eastern boundary of the Weddell Gyre, glaciers and large amounts of sea ice suddenly come into contact with warmer waters, resulting in significant amounts of melting.[26] This melting adds nutrients to the surrounding waters, facilitating a dense plankton superbloom.[27] Additionally, the formation and upwelling of deep water brings nutrients to the surface in several spots throughout the Weddell Sea, enhancing the productivity of those areas and attracting predators. As this comes into contact with the Maud Rise, nutrients are brought to the surface and drive productivity in the polynya[28] (an area of persistent open water amongst sea ice). In another hotspot, the Filchner Trough, nutrient-rich water mixes with the southern region of the Weddell Gyre. This area attracts southern elephant seals,[29] indicating that the mixing results in increased plankton production. The edge of the ice shelves near the Antarctic Peninsula in the Weddell Sea is also a highly productive region.[30] There are highly productive areas throughout the Southern Ocean and some in the Weddell Sea are particularly productive. In fact, a quarter of the annual ice-edge plankton production of the Southern Ocean occurs in the Weddell Sea.[31]

ANTARCTIC KRILL AND OTHER ZOOPLANKTON

Antarctic krill, considered one of the most important species in the Antarctic food web, plays the same critical ecosystem role as elsewhere in the Southern Ocean by linking primary production to higher levels of the food web.[32] The northernmost region of the planning domain, which is closest to the southern boundary of the Antarctic Circumpolar Current has the greatest concentration of krill, while areas further south have comparatively fewer krill.[33] Additionally, data for krill in a large swath of the Weddell Sea (60°W to 30°W, south of approximately 67°S) do not exist, presumably because ice in that region makes surveying difficult.[34]

Antarctic krill. *Image by Lara Asato.*

Other important macrozooplankton include salps, free-floating invertebrates related to sea squirts. The salp species *Salpa thompsoni* and Antarctic krill species *Euphausia superba* together make up 50% of the total biomass of the animals on the lower end of the Antarctic food chain.[35] Krill populations may be very large as research suggests the presence of many birds that feed on krill-eating fish.[36] Current predictions of warming in the Weddell Sea indicate that even under scenarios in which carbon emissions decrease below recent levels, krill populations are likely to decline.[37,38] As this occurs, salp populations may increase,[39] with unknown but likely negative consequences for the ecosystem, particularly higher trophic levels due to salps lower food value compared to krill.[40]

WEDDELL SEA REGION SEAFLOOR COMMUNITIES

Despite being a harsh environment, the Weddell Sea seafloor hosts many diverse habitats. It is home to many hundreds of invertebrate species such as

- Crustaceans such as isopods, amphipods; and to a lesser extent decapods
- Molluscs, including snails and slugs (gastropods), chitons, and bivalves;
- Polychaete Worms that contribute significantly to species abundance and overall biomass in the Weddell Sea;[41]
- Sponges, including seven species of stone corals (Scleractinians).[42]

Two hundred and thirty different species of amphipods can be found on the eastern Weddell Sea continental shelf alone.[43] Sponges contribute up to 96% of the biomass in undisturbed areas of the eastern Weddell Sea continental shelf[44] and are represented by hundreds of different species.[45]

Other benthic organisms of note in the Weddell Sea region include echinoderms, such as sea urchins, sand dollars, sea cucumbers, sea stars, anemones, tunicates, bryozoa and corals.

It has been reported that polychaete richness is even higher on the Weddell Sea continental shelf than on that of the Ross Sea.[48]

Sea-floor images from ROV transects during POLARSTERN cruise ANT-XIII/3 to the Weddell Sea, Antarctica. *Image by Julian Gutt.*

Eastern Weddell continental shelf seafloor creatures are some of the most intensely studied in Antarctica.[46] Seafloor species numbers and diversity in areas of the Weddell Sea and along the coast of the Lazarev Sea are considered high in comparison with other Southern Ocean areas. Particularly complex assemblages of species can be found off Kapp Norvegia on the eastern Weddell Sea continental shelf.[47]

Seafloor creatures in the Weddell Sea MPA planning region are distributed in a patchy manner, rather than evenly spread across the seafloor.[49] This patchiness is the result of the complex influence of a number of factors including depth, water temperature and salinity, iceberg scour, current speed and direction, substrate and sediment composition, and ice cover.

More sponges are known from the Weddell Sea than any other location of the Southern Ocean. Communities of habitat forming suspension feeding animals, in particular large sponges (>10 cm) are associated with a higher diversity of species and overall abundance of animals as they often form hosting habitat for other species in their earlier stages of life.[50] These communities containing sponges, bryozoans, cnidarians, and ascidians are found in abundance along the shelf of the south-eastern Weddell Sea and Lazarev Sea along the Queen Maud Land – Lazarev Sea Coastal Zone.[51] Echinoderms (sea stars and sea urchins) are some of the most common animals found on the Weddell Sea continental shelf.[52] The presence of sponges (and echinoderms) can also prevent the colonization of some animals that are less present when these filter feeders dominate.[53] For example, higher numbers of deposit feeders occur in less diverse areas with lower concentrations of animals.[54]

Sea Spider. *Image by John B. Weller.*

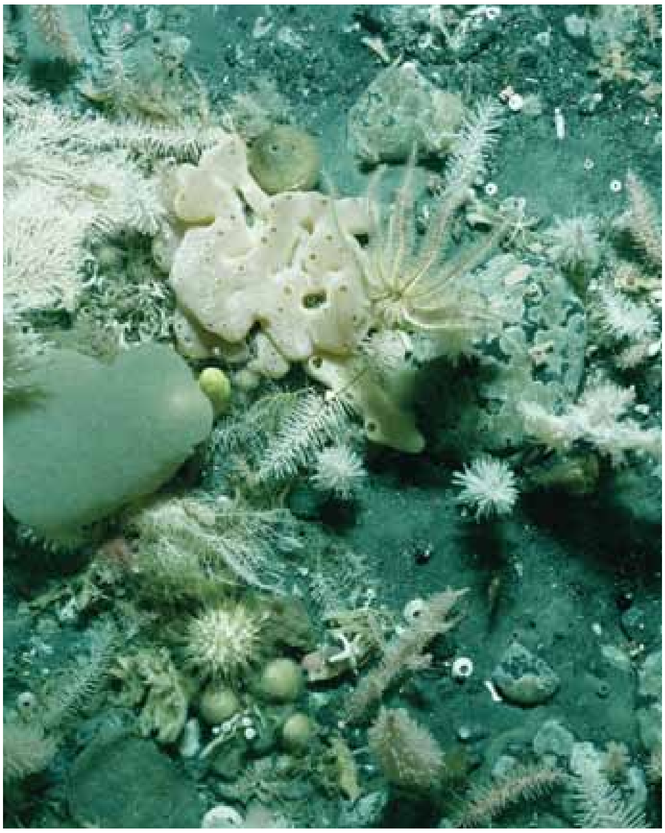
There are 87 species of sea spiders (pycnogonids) found in the Weddell Sea. Many are believed to be circumpolar in distribution resulting from the Antarctic Coastal Current. Depth is believed to be a strong influence on the distribution of sea spiders with species changing with depth and far more sea spider species living on the shelf above the shelf break to depths of 900 to 1,000 metres.[55]

Less was known about the deeper seafloor environments of the Southern Ocean, however recent exploration in the Weddell Sea deep has identified significant levels of biodiversity. Efforts such as the ANDEEP programme have focused attention on the deeper environments of the Weddell Sea. This survey, which took place from 2002 to 2005, documented significant levels of biodiversity and a large percentage of species sampled were new to science. Levels of diversity for some organisms including isopods (crustaceans like woodlice or pill bugs), bivalves and gastropods were found to be comparable to tropical and temperate regions.[56]

It is now apparent that with each new survey, significant numbers of new species will be discovered, underscoring the incredible richness of Weddell Sea seafloor communities.

While species and communities tend to differ between shallow and deep environments, there are also links between deep water and shelf species of the Weddell Sea. These links are thought to be facilitated by the relatively deep shelf of Antarctica and repeated periods of glaciation that covered shallower environments in ice forcing shelf species to adapt through migrations between deep and shallow environments and vice versa.[57] One result of this is that many species, such as isopods, can exist at a range of different depths.[58] A species of foraminifera (a single celled protozoan), which inhabits the shallow waters of McMurdo Sound in the Ross Sea (< 30m) is also found in depths greater than 1,000m in the Weddell Sea.

While the Antarctic Circumpolar Current segregates Southern Ocean shallow water seafloor dwelling animals from other ocean basins, no such limitation exists for deep dwelling creatures. Some species are found only in the Southern Ocean while others are found in other ocean basins as well.[59] With the Weddell Sea region being a major engine of global thermohaline circulation and source of deep water for the world's oceans, there are connections between species in the Weddell Sea basin and other ocean basins, the Atlantic in particular. These connections however extend only to species with characteristics that allow them to disperse widely, such as foraminifera.[60]



Sea-floor images from ROV transects during POLARSTERN cruise ANT-XIII/3 to the Weddell Sea, Antarctica. *Image by Julian Gutt.*

FISH

The fish of the Weddell Sea region are remarkably diverse and show a distinction between the species found on the shelf and in deeper waters. Like the rest of the Southern Ocean, the shelf and upper slope are dominated by species from the suborder Notothenioidei. The major notothenioid families of the region are icefish, dragonfish, plunderfish and notothens, which include the Patagonian and Antarctic toothfish.[61,62] Although any species that can survive in harsh polar oceans is impressive, many notothenioids have attracted particular scientific interest due to the presence of antifreeze proteins that keep their blood from freezing. In shallower waters, the Antarctic silverfish is the most abundant fish and an important prey species, making up 60% of the diets of Weddell and crabeater seals.[63]

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

The dominant demersal (bottom) fish species in the Weddell Sea include the crowned rockcod, the slender scalyhead, the blunt scalyhead, the plunderfish and Myers' icefish.[64] The open waters of the Weddell Sea are home to a number of small species of fish (up to about 30 centimetres in length) that are the main krill predators in the region, surpassing birds, seals and whales in terms of their biomass.[65] The most abundant of these fish are bristlemouths, deepsea smelts, barracudinas and lanternfish.[66] They live at depths down to 1,000 metres, but travel up closer to the surface at night to feed. Other species in the Weddell Sea include grenadiers, which are also important prey fish, eels and skates.[67] The latter include the McCain's skate, an IUCN near threatened species with a vulnerable life history due to its slow growth and late maturity.[68]

A Snow Petrel *Pagodroma nivea*.
Image by Ben Arthur, Institute for Marine and Antarctic Studies.

SEABIRDS

The Weddell Sea region is home to many different species of birds with penguin populations far outnumbering flying seabirds. Chinstrap[69] and Adélie[70] penguins are the most abundant and can be found on icebergs and pack ice respectively.[71,72] Emperor penguins are less common and live on pack ice.[73,74] Other common birds are the cape petrel, the Antarctic fulmar, the snow petrel, southern giant petrel and the Antarctic petrel.

The birds of the Weddell Sea region are often found in varying abundances and locations throughout the year as their life cycle is tightly linked to the ice and the breeding or hunting grounds it provides.[75,76,77] For example, Antarctic petrels, snow petrels and chinstrap penguins are the most abundant birds in the marginal sea ice zone, a transitional zone characterized by "concentrated fields of pancake ice interspersed with small ice floes",[78] and the two species of petrels are also found on the pack ice. In the summer, birds are especially abundant at the interface between open water and pack ice.[79]

Emperor penguins. *Image by David Neilson.*

MAMMALS

The seal species living in the Weddell Sea region are crabeater seals, leopard seals, Antarctic fur seals, Weddell seals and Ross seals.[80] Elephant seals have been observed to travel the enormous distance from King George Island to the Weddell Sea. A possible explanation for this behaviour is that they are foraging on the locally abundant Antarctic silverfish, a key prey item.[81]

Antarctic silverfish are also the primary prey for other seals including the Weddell seal whose diving patterns follow the movement of the fish throughout the day. The seals can stay under water for more than an hour and can dive to depths of 450m. They hunt mainly at night, when fish migrate up into warmer waters, thus preserving energy.[82] Similar foraging behaviour has been observed for other seals in the Weddell Sea, although they do not seem to come close to the Weddell seal's depth records of more than 600m.[83,84,85]

A newborn Southern Elephant Seal *Mirounga leonine* pup only several days old. *Image by Ben Arthur, Institute for Marine and Antarctic Studies.*

A Crabeater Seal *Lobdon carcinophaga* resting on an ice floe. *Image by Ben Arthur, Institute for Marine and Antarctic Studies.*

Crabeater seals tend to stay in shallower waters, which might be due to their preference for feeding on krill under the ice.[86] Seal diving behaviour is not only related to following prey, but also diving to greater depths – and away from floating sea ice which creates a lot of noise – which may enable them to hear vocal cues of other seals. Crabeater seals especially have been found to be quite social and to swim in groups of up to 20 animals[87] (by contrast, leopard seals are solitary and only rarely interact while hunting).[88] Crabeater seals prefer extensive ice cover and in the spring are found in pairs or pairs and a pup.[89] Their distribution varies by season and correlates with krill aggregations within phytoplankton blooms at the pack ice edge in the summer.[90]

Cetaceans (whales and dolphins) can be found in large numbers near pack-ice in the Weddell Sea region, where the ice provides high krill productivity.[91] Cetaceans of the Weddell Sea region range from large baleen whales (minke, fin, humpback and blue) to toothed whales such as sperm whales, orcas, pilot whales and hourglass dolphins. Even a Burmeister's porpoise has been sighted.[92] Some whales species are listed as vulnerable (sperm), or endangered (blue and fin). Protection of feeding grounds provides support for cetacean species under pressure.

A relationship between the abundance of Antarctic krill and increased numbers of minke whales has been observed.[93] Whales have been observed in high numbers at the ocean front of the Weddell Gyre.[94,95]

Cetaceans of the Weddell Sea region range from large baleen whales (minke, fin and humpback) to toothed whales such as sperm whales, orcas, pilot whales and hourglass dolphins.

WEST WEDDELL SHELF

Image by David Neilson

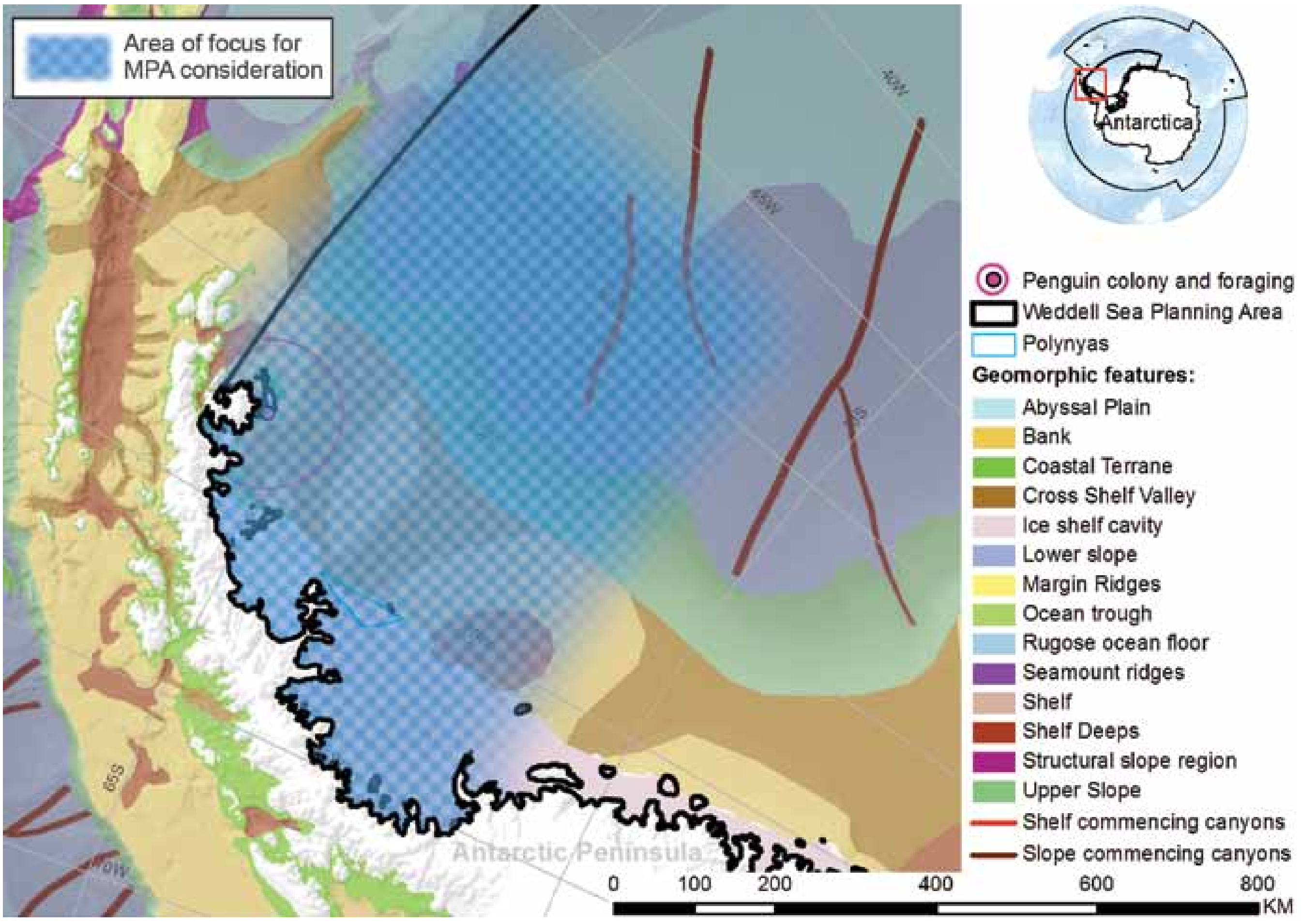
The west Weddell shelf contains critical areas and features that will come under consideration for future marine protection including the Weddell continental shelf itself, the Belgrano and Berkner banks and wildlife associated with the Larsen Ice Shelf.

THE WEDDELL CONTINENTAL SHELF

The Weddell continental shelf spans from the west side to the east, but key features from the western side will be considered here.

The Weddell Sea continental shelf, like most of the Antarctic continental shelf is deep, reaching depths of approximately 900-1,000 metres at the shelf break along the Eastern Weddell Sea.[96] However, it is not uniform in depth, encompassing a number of cross-shelf valleys, most notably the Filchner Trough, banks such as the Belgrano and Berkner Banks, and even deeper depressions called shelf deeps.

West Weddell Shelf



Overall, the majority of the shelf, in particular the shelf deeps, is considered to have low currents and therefore fine sediments, which can support mobile deposit feeding creatures such as crustaceans and those living within the sediments such as worms.[97] Shelf deeps occur in front of the Larsen Ice Shelf along the eastern Antarctic Peninsula and where the Peninsula intersects with the Ronne Ice Shelf. Other features include the Belgrano and Berkner Banks. These banks are exposed to stronger currents and are thus able to support suspension feeding communities, however they will also likely be impacted by iceberg scouring events.[98]

The areas of the continental shelf in front of the major ice shelves, Larson, Ronne and Filchner and the south east coast of the shelf represent some of the most productive, or phytoplankton-rich, areas within the Weddell Sea.[102] This high productivity supports large numbers of phytoplankton eating species such as krill, which in turn attract large numbers of predators from fish to whales.

Whales in the Southern Ocean. *Image by John B. Weller.*

The southern portion of the Weddell continental shelf is overlain by the Filchner – Ronne Ice Shelf. Since the ice shelf prevents sunlight from inducing primary production, the large cavity occurring below the ice shelf can only support biodiversity through organic material transported by currents that flow underneath. There is evidence that in the second half of the 20th century warmer water from the Antarctic coastal current has penetrated under the Filchner Ice Shelf[99] and thus may have contributed to the development of communities beneath the ice shelf. In addition to water masses moving under the ice shelf there is evidence of exchange in the reverse direction. Water modified through cooling and freshening from the melting of ice shelves is believed to contribute significantly to deep and bottom water formation along the continental slope by flowing down the Filcher Trough and over the shelf break to the deeper waters of the Weddell Sea abyss.[100,101]

An Antarctic Fur Seal *Arctocephalus gazella* pup.
Image by Ben Arthur, Institute for Marine and Antarctic Studies.

EAST WEDDELL SHELF

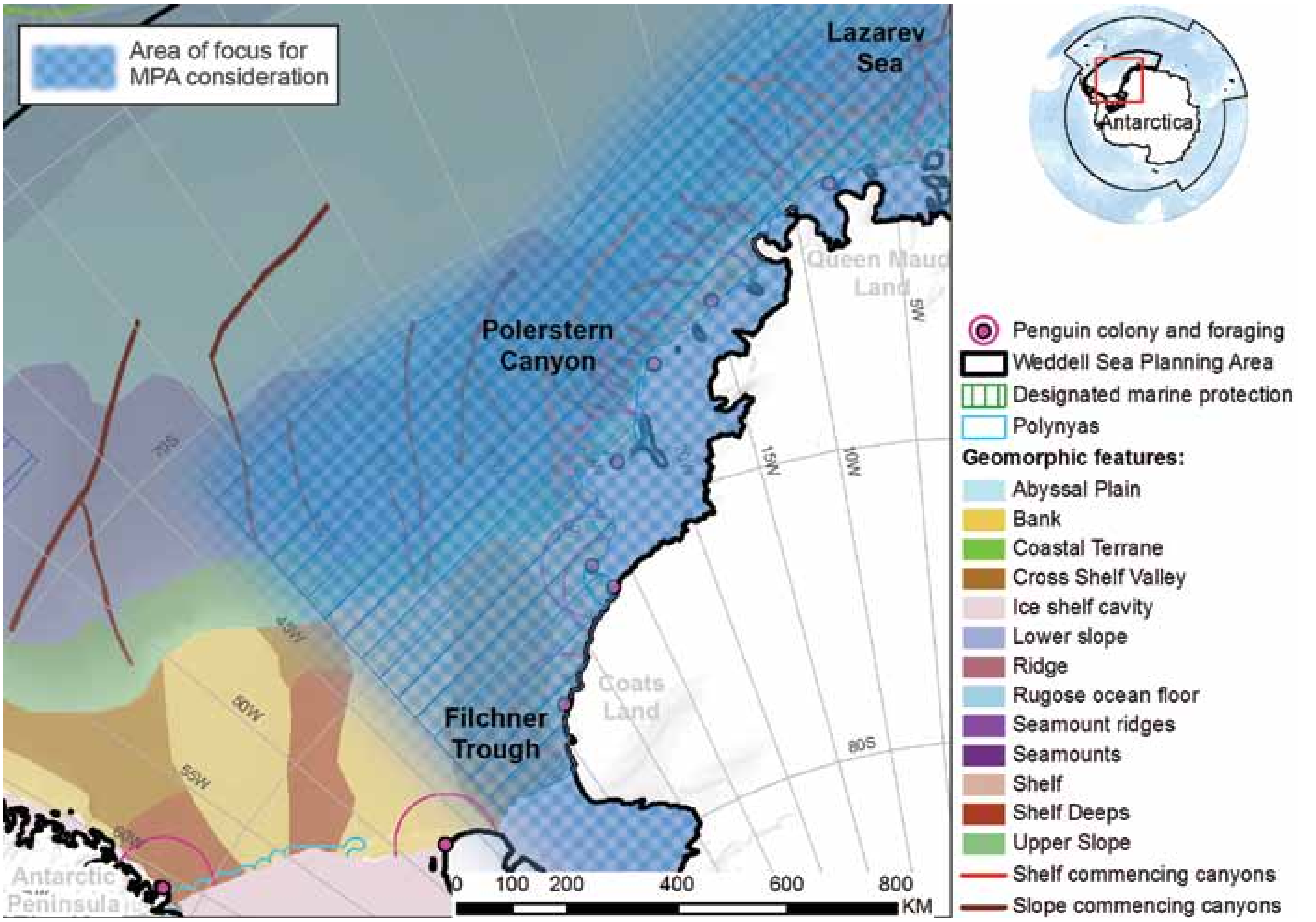
Image by Wendy Pyper

The east Weddell shelf contains critical areas and features that will come under consideration for future marine protection including the Filchner Trough, the Crary Fan and the Polarstern Canyon.

THE FILCHNER TROUGH

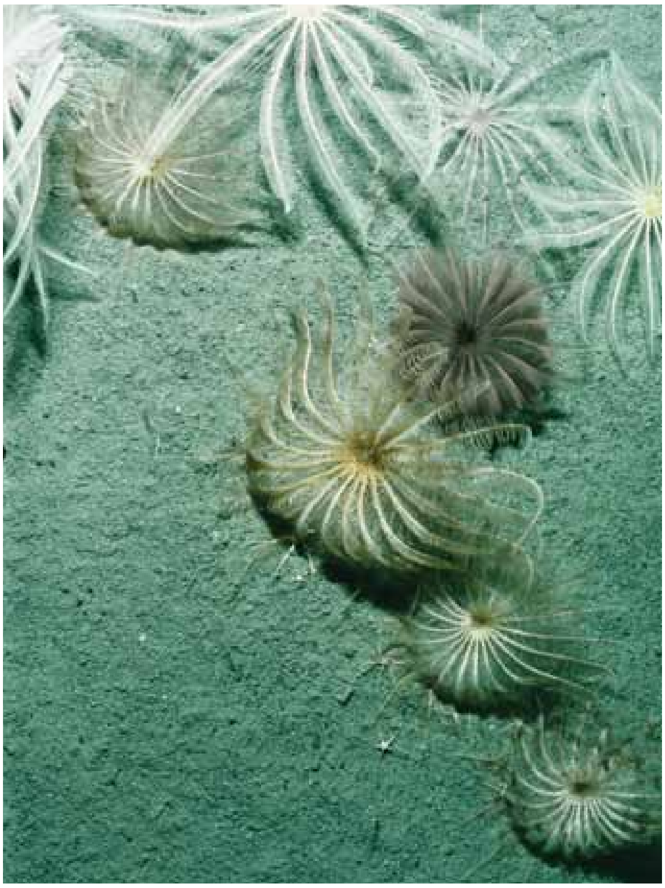
The Filchner Trough, the deepest region of the Weddell Sea continental shelf, provides a topographical conduit from which shelf water is transported north to deeper areas. This process, where cold shelf water is channelled through the trough over the shelf break is important for the formation of Antarctic bottom water (ABW), helping to drive the global ocean conveyor belt and supplying oxygen and nutrient rich water to the world's oceans.[103] The Filchner Trough may be the most important or even only place in the Weddell Sea where shelf water consistently flows over the shelf break, driving bottom water formation.[104]

East Weddell Shelf



The waters above the trough are also one of the primary areas of sea ice production, with dense nutrient-laden brine adding to the movement of water masses down the trough, over the shelf break and down the continental slope. The bathymetry and resulting outflow from the Filchner Trough combine with the meeting of the southern branch of Weddell Gyre, resulting in a high degree of mixing of water masses. Southern elephant seals have been found to spend extended periods in areas where this mixing occurs, suggesting strong links between top predators and physical features and processes.[105] A large, diverse range of seafloor communities also benefit from nutrients brought by the flowing water masses, with species that live on or near the seafloor and within its sediments being found in the trough.[106]

Elephant seals. *Image by David Neilson.*



Sea-floor images from ROV transects during POLARSTERN cruise ANT-XIII/3 to the Weddell Sea, Antarctica. *Image by Julian Gutt.*

THE CRARY FAN

Beyond the shelf break of the Filchner Trough, the largest trough mouth fan in the Southern Ocean, the Crary Fan, is situated on the continental slope. Such fans are broad aprons of smooth sediment deposited when ice streams extend across troughs or cross-shelf valleys. These sediment formations can extend to water depths of 2,500 to 3,000 metres. Due to the flow of water depositing sediments the Crary Fan likely contains a mix of opportunistic suspension feeders, animals within the sediments and mobile deposit feeders.

THE POLARSTERN CANYON

The Weddell Sea MPA planning region contains a number of shelf-commencing canyons and an even greater number of continental slope-commencing canyons. In one case, along the Dronning Maud Land coast a particularly complex Polarstern shelf-commencing canyon occurs coincident with a recurrent coastal polynya. In this area there is a high level of nutrient transfer from areas of high pelagic productivity associated with the polynya on the shallow shelf to deeper environments via the canyon complex.

This nutrient transfer is likely to support a diverse set of species assemblages as one descends down the canyon complex.[107]

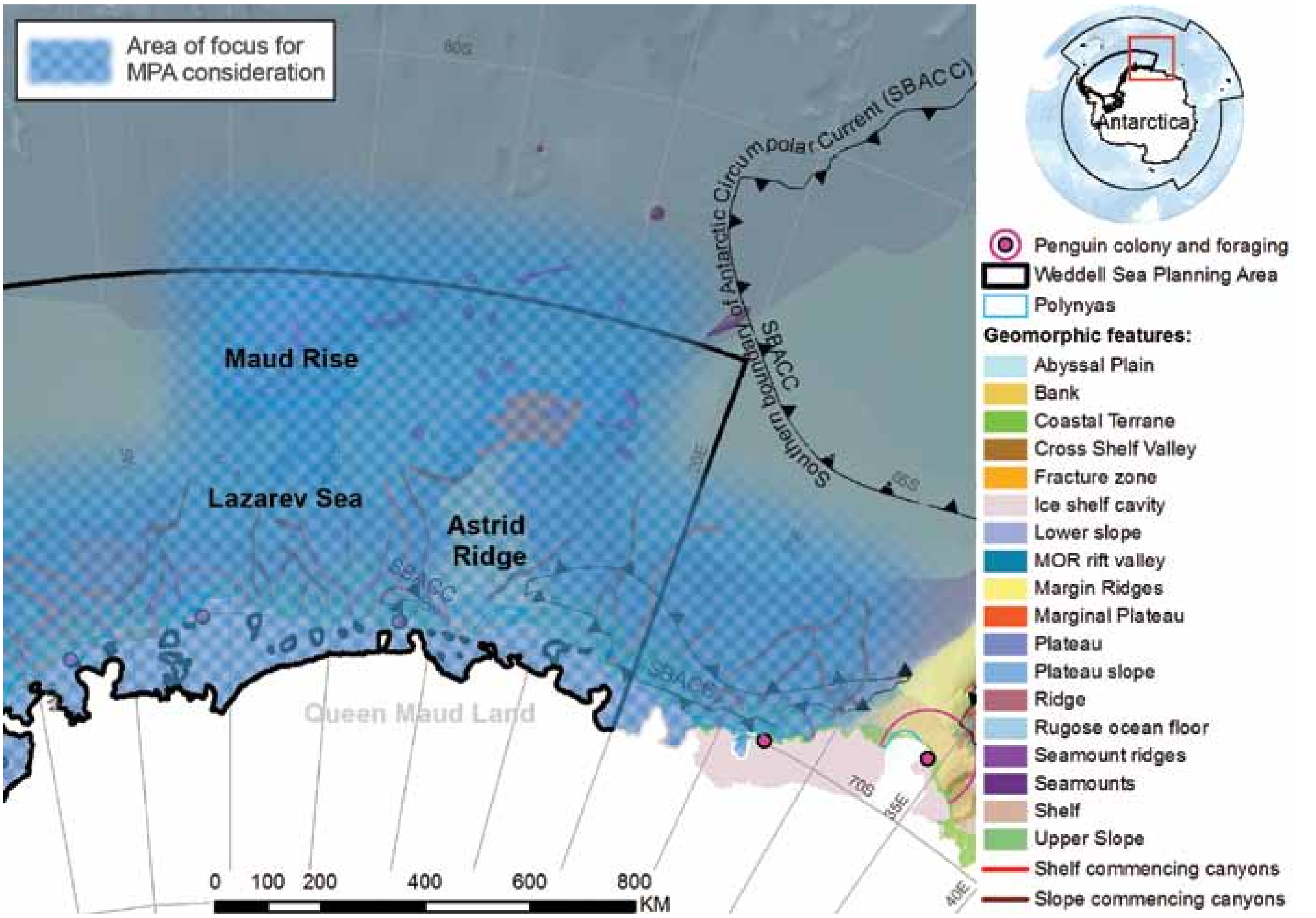
THE QUEEN MAUD LAND – LAZAREV SEA COASTAL ZONE

Image by David Neilson

The Queen Maud Land – Lazarev Sea Coastal Zone includes some critical areas and features that will come under consideration for marine protection, including the Maud Rise, the Lazarev Sea and the Astrid Ridge and Plateau.

The seas north of the Princess Martha and Astrid coasts of Queen Maud Land (between 15° W and 15° E) have a unique oceanography influenced by the interactions of currents (especially the Weddell Gyre and associated eddies) with the bathymetry of the Maud Rise, Astrid Ridge and other features.[108] The Astrid Ridge and Plateau protrude from the continental shelf while numerous canyons carve into the depths. These underwater physical features modify local currents, enhancing productivity, while the canyons likely help bring nutrient rich waters to and through the area.[109] This complex system causes localised currents, jets and eddies which drive local upwelling.

The Queen Maud Land – Lazarev Sea Coastal Zone



Upwelling brings nutrients to the surface driving pelagic primary production, which in turn can support concentrations of top predators.[110] This complex local oceanography and associated upwelling likely causes low annual sea ice densities and the periodic formation of a persistent open ocean polynya over the Maud Rise. The existence of this polynya supports primary productivity driven by upwelled nutrients.

THE MAUD RISE

The Maud Rise is a dramatic mid-ocean plateau that rises from depths of 3,000m to 1,000m at the southern reaches of the Atlantic sector of the Southern Ocean. The interaction of the rise with the Weddell Gyre results in upwelling of deep water. This upwelling contributes to lower concentrations of sea ice and the formation of a polynya over the rise making the area around the Maud Rise distinct from other adjacent areas of the Southern Ocean. While most Southern Ocean polynyas occur adjacent to the Antarctic continent, the waters overlying the Maud Rise represent one of only two recurring open ocean polynyas in the Southern Ocean. The upwelling includes nutrient transfer resulting in an area of significant primary productivity.[111]

The productivity and diverse species assemblage at Maud Rise extends from the seafloor up through the water column to the surface over the Maud Rise.[112] This dynamic sea ice environment supports a high density of zooplankton,[113] including substantial krill aggregations directly over the rise as well as in the coastal area to the south.[114] The local abundance of krill brings high concentrations of crabeater seals, minke whales, Adélie penguins, Antarctic petrels and snow petrels.[115] The seafloor below is rich with sponges, molluscs, crustaceans and worms, including tube-dwelling suspension feeders. Many of these species are unique to the Maud Rise.[116] Research to date has determined that interactions between oceanographic features, underwater topography and sea ice separate the region, and its ecosystem, from surrounding areas of the Southern Ocean.

Krill from the Lazarev Sea (including over the Maud Rise) play a key role in supporting fish, birds and mammals across the Atlantic basin of the Southern Ocean including the Scotia Sea.

Snow Petrel. *Image by David Neilson.*

Some scientists believe that the Maud Rise krill populations may be connected to a larger krill metapopulation that spans the area from the Western Antarctic Peninsula and Scotia Sea to the Lazarev Sea.[117] The westward flow of the Weddell Gyre potentially spreads krill from the Lazarev and Weddell Sea into the Scotia Sea where the main krill fishery operates. If this hypothesis is true, then krill from the Lazarev Sea (including over the Maud Rise) play a key role in supporting fish, birds and mammals across the Atlantic basin of the Southern Ocean including the Scotia Sea. Moreover, impacts to krill populations from climate change or other stressors could reverberate across the entire Atlantic sector of the Southern Ocean.

During the winter, when primary plankton productivity under the sea ice is lowest, the Maud Rise becomes an important hotspot for krill predators. The relatively warm, upwelling water of this oceanographic feature melts sea ice, which encourages the growth of microalgae on which krill come to feed. Krill predators such as Adélie penguins, Antarctic and snow petrels, crabeater seals and minke whales congregate in this area to forage.[118]

Adélie penguin. *Image by Ben Arthur, Institute for Marine and Antarctic Studies*

East of the Weddell Sea, the continental shelf reduces to the narrow shelf common to most of the Antarctic coastal margin. However, the Maud Rise and Astrid Ridge and Plateau along with shelf- and slope-commencing canyons occur generating a range of habitats, both on the seafloor and in the upper water column.

THE ASTRID RIDGE AND PLATEAU

The Astrid Ridge is one of only five margin ridges extending out from the Antarctic continent into the Southern Ocean. At the northernmost extent of the Astrid Ridge is the Astrid Plateau, one of only two plateaus located along the continental margin of Antarctica.[119] Both features are likely shallow enough to modify the eastward flowing coastal current or east wind drift,[120,121] with evidence of upwelling and nutrient transfer, along with observations of increased chlorophyll, indicating that plankton productions and therefore local biodiversity are enhanced.[122]

QUEEN MAUD LAND SEAMOUNTS

The two deepest seamounts in the Southern Ocean are found in the northeastern portion of the Weddell Sea MPA planning area, one along the northern boundary and one on the eastern boundary.[123] Seamounts are commonly known to host unique highly biodiverse assemblages of species[124] and are often strong candidates for protection.

Weddell seal. *Image by David Neilson.*

HUMAN IMPACTS AND THREATS

Image by Ben Arthur

FISHING HISTORY

Harsh sea ice conditions had previously made fishing difficult in much of the region in the 1970s, when many other Southern Ocean fish populations were beginning to be exploited.[125] Fishing in the Weddell Sea MPA planning region occurs in the CCAMLR statistical subdivisions 48.5 and 48.6. Longline fishing began in the region off the Queen Maud Land – Lazarev Sea Coastal Zone in sub-area 48.6 in 1997, but has occurred only recently in the Weddell Sea in sub-area 48.5 since the start of the 2012-13 fishing season. Overall, the region is considered "data-poor" by CCAMLR.

Originally classed as a new fishery, the fishery north of the Queen Maud Land – Lazarev Sea Coastal Zone was reclassified as an exploratory fishery in 1999 due to recognised high levels of Illegal, Unreported and Unregulated (IUU) fishing. Catches initially focused on Patagonian toothfish well to the north of the MPA planning region, but over time effort moved in the southern area of sub-area 48.6 with increasing catches of Antarctic toothfish. Current catch limits for the exploratory toothfish fishery in the seas north of Queen Maud Land, but south of 60° south in sub area 48.6 are for 210 tonnes.

Scientific research fishing in the western sector of the planning domain in the Weddell Sea began in the 2012/13 fishing season with a catch of approximately 60.6 tonnes.[126]

CLIMATE CHANGE

Over the past few decades, the Weddell Sea region has played a highly visible role in the global discussion of climate change due to the dramatic disintegration of parts of the Larsen Ice Shelf in 1995 and 2002. Located in the western Weddell Sea adjacent to the Antarctic Peninsula, two of the three segments of the ice shelf (Larsen A and B) have completely disintegrated thus far, resulting in the accelerated flow of glaciers from land into the sea,[127] a phenomenon predicted by many climate change scientists. Reductions of the ice sheet and the resultant acceleration of glacier flow into the ocean contributes to sea level rise. In the years to come, the Weddell Sea will be a focal point for studies of global and regional climate change impacts.

Iceberg. *Image by David Neilson.*

The current picture of climate change impacts in the Weddell Sea shows a sharp contrast between the western and eastern sectors. The western sector is adjacent to the West Antarctic Peninsula, one of the fastest warming areas on the planet, and is experiencing both warming conditions and decreasing sea ice.[128] The eastern sector, however, has been experiencing growing sea ice over the past few decades and contributes significantly to the general increase in Southern Ocean sea ice extent.[129] One model predicts that these trends could be interrupted relatively suddenly by increasing sea ice in the western Weddell Seas starting in about 2030.[130] Changes in ice are also likely to have local consequences on important processes such as carbon sequestration and primary productivity of plankton, since melting sea ice and icebergs contribute nutrients that allow the development of phytoplankton blooms.[131] Although there is uncertainty about the local effects of climate change, it seems likely that the Weddell Sea will undergo significant changes, some of which will take place on short timescales.

Changes in temperature, ice sheet mass, sea ice extent and glaciers will impact polar species, many of which are long-lived and slow-growing – characteristics that tend to inhibit rapid adaptation to changing conditions. Many Antarctic benthic organisms are particularly affected by any significant changes to ice.[132] Some species appear to have benefited temporarily from the Larsen A and B collapses, but other species with life cycles closely linked to current conditions may fare poorly.[133] For example, sea squirts were thriving following the Larsen collapses, but as filter feeders they may be negatively impacted if decreasing sea ice causes a surplus of food particles in the water column.[134] Predicting the overall impact of climate change on seafloor ecosystems is difficult given the number of overlapping and reinforcing environmental factors that play a role in shaping their habitats. Increases in primary plankton productivity driven by declines in sea ice may enable growth for some species but overall diversity could decrease.[135] Without a better understanding of seafloor communities, although it is certain that global warming will reshape and remake them, it is unclear exactly what changes will take place.

Rising temperatures can also have an adverse effect on bird habitats. Forty seven colonies of emperor penguins have been counted in Antarctica, and twelve of them are located at the Weddell Sea MPA planning region.[136] A medium-sized emperor penguin breeding colony is located on the Larson C Ice Shelf on the east of the Antarctic Peninsula. While most breeding colonies are located on sea ice,[137] this colony is one among a number of colonies that have been found on the ice-shelf. This behaviour might be an adaptation to sea ice loss in the rapidly warming region.[138,139] The life cycle of emperor penguins is linked to the condition of sea ice and variations of sea ice concentration have a negative effect on the population size and reproductive success of the penguins.

Climate change is predicted to have disastrous effects on emperor penguins, with projected population decreases in some areas of as much as 81% by 2100.[140,141]

Emperor penguins. *Image by Wendy Pyper.*

Although the life cycle and reproductive strategy of snow petrels differ in many aspects from the emperor penguin's they are also dependent on sea ice and affected by changes in its availability and extent. Snow petrels will not attempt to breed in years when conditions are unfavourable or the parent's survival through the breeding season is unlikely owing to the increased strain it causes on the birds. It has been found that fewer snow petrels attempt to breed when sea ice concentrations are lower in the fall before the mating season. The same is true for emperor penguins. This behaviour might be due to the decreased availability of food resources such as krill resulting from lower sea ice cover. If less krill can be found, the birds might be unable to store the energy needed for surviving the mating season.[142] As is the case with other krill predators, Antarctic mammals are also projected to be affected by changes in krill abundance due to rising temperatures and changes in ocean acidity.[143,144,145]

OCEAN ACIDIFICATION

Ocean acidification is one of the effects of excessive carbon dioxide emissions. As humans release CO_2 into the atmosphere from burning fossil fuels, the oceans absorb some of this CO_2, which lowers the water pH, making it more acidic. Over the last 200 years, the oceans have become 30% more acidic. If this trend continues, calcifying organisms will suffer deleterious effects.[146] The increased acidity can dissolve their shells and skeletons, while the influx of CO_2 decreases the availability of carbonate ions. This further hinders their ability to build shells and skeletons.

The cold waters of the Southern Ocean are naturally lower in calcium carbonate than warmer waters and are thus closer to the tipping point at which organisms will begin to suffer deleterious effects.[147] 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.[148] In time, they may not be able to build shells at all. If pteropods, or other shell-building animals perish, it will have adverse ramifications that will cascade throughout the Southern Ocean ecosystem.

OPPORTUNITY FOR CCAMLR

Image by Ben Arthur

CCAMLR was established as part of the Antarctic Treaty System to conserve the species and ecosystems of the Southern Ocean. Entering into force in 1982, CCAMLR's central objective is to conserve Antarctic marine life while managing the rational use of marine resources in accordance with three principles of conservation:

1. Prevent any harvested population from decreasing so low that it is unable to maintain itself;
2. Maintain and where necessary restore the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources;
3. Prevent or minimise the risk of change to the marine ecosystem based on best available science.

The CAMLR Convention establishes that the Commission can implement spatial and temporal protection which can include marine protected areas and marine reserves.

With Members' commitments to conservation and the written principles that underpin its central conservation objective, CCAMLR stands out from other organisations with oversight of areas beyond national jurisdiction in its approach to conserve and manage biodiversity. This is reflected in a major work stream of CCAMLR to identify and protect areas of the Southern Ocean. In 2008 an initial suite of eleven priority areas was developed to focus work on developing and implementing marine protected areas in the Southern Ocean. In 2011 these areas were refined to nine planning domains. Furthermore CCAMLR agreed on criteria for marine protected areas and no-take marine reserves and adopted a process for considering proposals for protection through Conservation Measure 91-04.

The South Orkneys MPA was created in 2009. Two more proposals are close to designation; a system of marine protected areas in East Antarctica proposed by Australia, the European Union and France, and a Ross Sea marine protected area proposed by New Zealand and the United States. In addition, Germany and Russia have initiated a process towards protecting biological diversity in the Weddell Sea. The initial workshop held in Germany in April 2014 to review the available science and determine the values requiring protection in the Weddell Sea is an important step in this process.

Protection of the Weddell Sea as part of a Southern Ocean network of MPAs and no-take marine reserves will safeguard an area of enormous biological diversity, including many species of whales, seals and seabirds. It will also conserve the rich benthos, and the species yet to be discovered in the western Weddell Sea, a region that remains largely unexplored.

CCAMLR committed to deliver a system of marine protected areas by 2012 but failed to meet this deadline. After protection of the Ross Sea and East Antarctica, protection of the Weddell Sea would be a powerful demonstration to the international community of CCAMLR Member States' appropriate stewardship of the Southern Ocean. This is essential for CCAMLR to remain a respected marine governance body.

Protection of the Weddell Sea will be particularly important as the waters off the Western Antarctic Peninsula continue to warm, stressing the myriad of animals living on the continental shelf and in the depths of the Weddell Sea. Protection must include both pelagic and benthic areas because the rich diversity of life in the Weddell Sea region ranges from the pack ice to the seafloor.

In this report, the Antarctic Ocean Alliance has collated research on the biodiversity, oceanography, geomorphology and ecosystems of the Weddell Sea region and has identified three regions centred on the Eastern Weddell Shelf, Western Weddell Shelf, and the Queen Maud Land – Lazarev Sea Coastal Zone totalling more than 2 million km^2 than encompass the diverse ecological values within the Weddell Sea MPA planning region. These areas deserve strong consideration as candidates for protection in an upcoming MPA.

CCAMLR Members must seize the opportunity that protection of the Weddell Sea offers to create a global legacy for humanity in our changing world.

CASE FOR MARINE PROTECTION

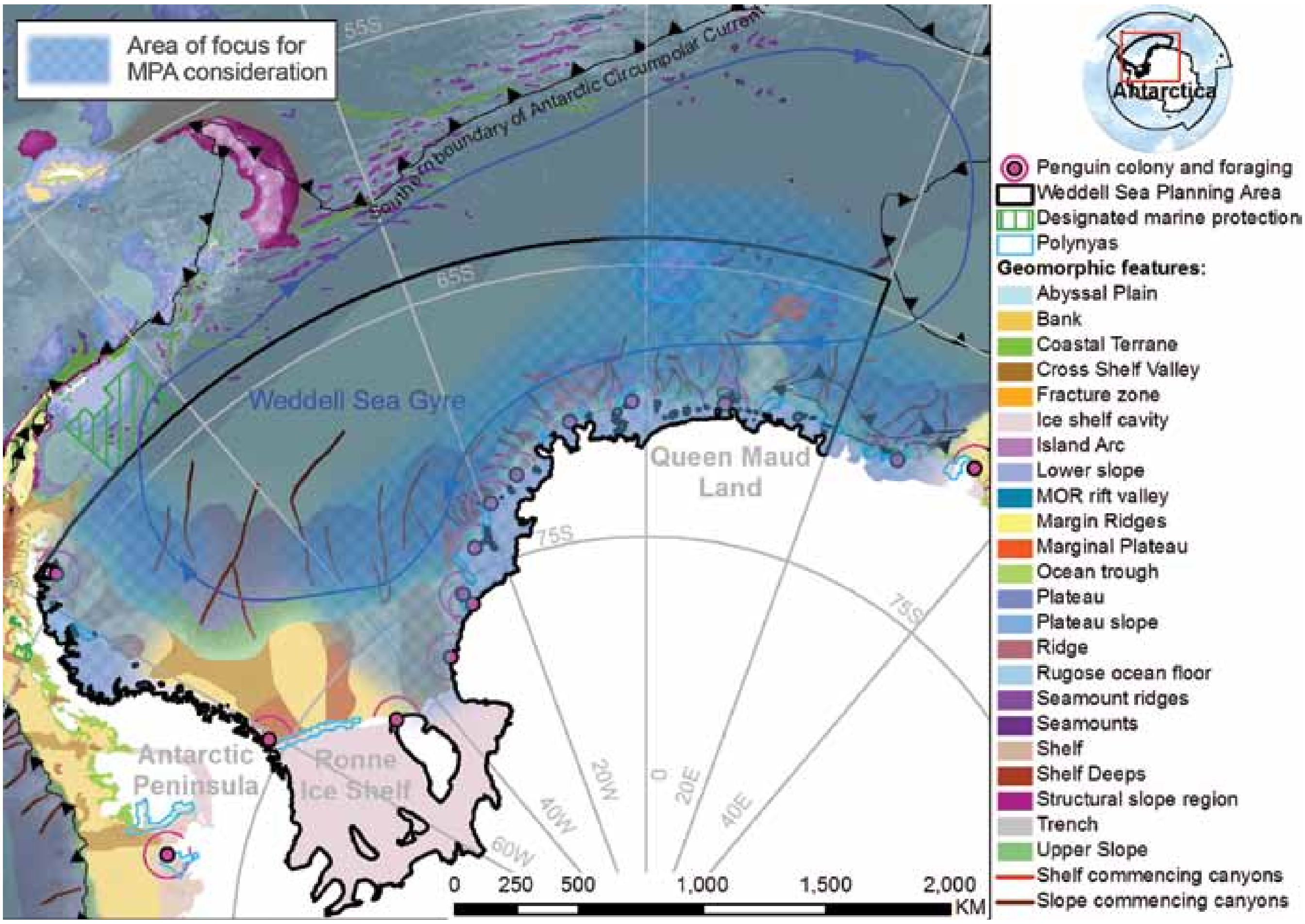
Image by David Neilson

AOA submits that significant parts of the Weddell Sea and the Lazarev Sea-Queen Maud Land Coastal Zone, encompassed by the Weddell Sea MPA planning region, warrant protection under the objectives CCAMLR set out in its Conservation Measure CM 91-04.

On the basis of this review and the application of the precautionary approach (a core concept at the centre of CCAMLR's mandate) the AOA believes that 2 million km^2 should be considered in the Weddell Sea planning process in order to provide comprehensive, adequate and representative protection of the Weddell Sea region. The designation of large-scale MPAs and marine reserves in the Weddell Sea would be an important step for marine protection in the Southern Ocean.

An extensive array of representative examples of marine ecosystems, biodiversity and habitats are to be found across the Weddell Sea MPA planning region. For example, the interaction of water masses with geomorphic features at the Maud Rise and resultant low sea ice concentrations leading to the formation of a recurrent open ocean polynya create

Area of focus for MPA consideration in the Weddell Sea Region



a rare highly productive open ocean environment with large aggregations of top predators. These systems and their associated habitats and biodiversity need to be protected at a sufficient scale and duration to protect their viability and integrity over the long term.

A wealth of studies across the Weddell Sea MPA planning region have demonstrated a high level of biological diversity spread across distinct seafloor faunal communities. Every new scientific effort dramatically increases the number of known species suggesting a high prevalence of vulnerable marine ecosystems.

There are opportunities for unique scientific reference areas for monitoring natural variability and long-term change in relation to changes in sea ice dynamics and resultant impacts on biodiversity.

Southern Giant Petrel *Macronectes giganteus*. *Image by Ben Arthur, Institute for Marine and Antarctic Studies.*

Weddell seal. *Image by David Neilson.*

Other areas of the open ocean also provide key ecosystem processes and habitats important to the life-history stages of phyto- and zooplankton productivity that in turn support foraging grounds of top predators such as humpback whales.

There are opportunities for unique scientific reference areas for monitoring natural variability and long-term change in relation to changes in sea ice dynamics and resultant impacts on biodiversity. This is particularly important given the currently undiscovered state of biodiversity in parts of the Weddell Sea region, including the north-western Weddell Sea, and the changes from ice shelf collapse that are occurring in the region as a result of climate change.

The Weddell Sea is also a prime location to study the impacts and re-colonisation process that occurs as a result of frequent iceberg scour, in particular since scour events are predicted to increase in occurrence in response to changes from a warming climate.

This is a region that is particularly vulnerable to the effects of climate change and ocean acidification and change is already occurring. Protection of the key features, ecosystems and natural processes of the Weddell Sea and Maud Rise will help the region remain resilient in the face of change.

CCAMLR Conservation Measure 91-04 Clause	Weddell Sea Features Warranting Protection
The protection of representative examples of marine ecosystems, biodiversity and habitats at an appropriate scale to maintain their viability and integrity in the long term.	Protection of representative examples of: • Seafloor habitat, particularly along the south-eastern Weddell Sea and the Lazarev Sea coasts • Areas of high productivity off the western Weddell Sea Coast, north of the Filchner-Ronne Ice Shelf, along the south-eastern Weddell and Lazarev Sea Coasts and in the open ocean above the Maud Rise and at the eastern edge of the Weddell Gyre • The sea ice zone as feeding and breeding habitat for higher predators
The protection of key ecosystem processes, habitats and species, including populations and life-history stages.	• Areas of high productivity including: a) a documented humpback whale foraging area at the eastern edge of the Weddell Gyre; b) waters over the Maud Rise; c) waters overlying the Filchner Trough; and d) off the western Weddell shelf • Protection of habitat forming communities of seafloor creatures such as sponges that are important to early life-history stages of other species • Areas with suitable ice conditions for emperor penguin breeding colonies
The 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.	• Protection of areas along the western Weddell Sea coast adjacent to the Antarctic Peninsula to study the effects of ice shelf collapse on biodiversity in particular changes in species composition and colonisation of areas formerly covered by ice shelves • Protection of areas prone to iceberg scour to study the colonisation of areas that have undergone previous scouring events, especially given iceberg scour events are expected to increase as climate change accelerates • Protection of areas of high productivity in the sea ice zone to study how changes in sea ice distribution as a result of the impacts of climate change affect productivity and biodiversity
The protection of areas vulnerable to impact by human activities, including unique, rare or highly biodiverse habitats and features.	• Benthic biodiversity, in particular dense but fragile sponge communities along the south-eastern Weddell and Lazarev Sea shelves • Geomorphic features such as seamounts, ridges and plateaus that are vulnerable to bottom fishing and can host complex seafloor communities • Shelf-commencing canyons, the Polarstern Canyon in particular
The protection of features critical to the function of local ecosystems.	• Protection of habitat forming communities of seafloor creatures such as sponges important to the juvenile stages of other species • Protection of areas of high productivity, in particular over the Maud Rise and at the outlet of the Filchner Trough
The protection of areas to maintain resilience or the ability to adapt to the effects of climate change.	• Protection of areas with current and projected areas of suitable ice conditions for emperor penguin breeding habitat • Protection of a seafloor habitats at a range of latitudes and depths to facilitate the resilience of calcifying seafloor creatures to the impacts of climate change and ocean acidification • Protection of areas where sea ice is expected to be persistent in the long term as areas of higher productivity to support the primary production upon which higher predators depend

ACKNOWLEDGEMENTS

The Antarctic Ocean Alliance acknowledges the many contributors to this report.

AOA Authors: Claire Christian, Geoff Keey, Rob Nicoll and Paula Senff.

Reference Group: Steve Campbell, Mark Epstein, Andrea Kavanagh, Richard Page, Rodolfo Werner and Bob Zuur.

Reviewers: Dr. Amanda T. Lombard, University of Cape Town, Cassandra Brooks, Post Graduate at Stanford University, and Dr. Joseph T. Eastman, Ohio University.

Editors: Stephen Campbell, Dae Levine.

Design: Metro Graphics Group.

Maps: Geomancia and Centre for Conservation Geography.

Data and Analysis: The AOA respectfully acknowledges the work of the many scientists referred to in this report and the contributions of many CCAMLR member governments.

Photos: AOA is grateful for the photographic contributions from Ben Arthur, Lara Asato, Cassandra Brooks, Julian Gutt, Nisha Harris, David Neilson, Wendy Pyper, Jeri Rezac and John B. Weller.

Cover photographs by: Ben Arthur, Cassandra Brooks, Nisha Harris.

This report was printed on recycled paper.

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